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INTERNATIONAL YEAR OF ASTRONOMY 2009

The Mysteries of our UNIVERSE

AWARD

Serge Haroche
Recipient of the
2009 CNRS Gold Medal

cnrs advancing the frontiers

contents

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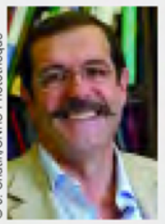
AWARDS IN PHYSICS...

Alain Aspect and Thomas Ebbesen are the 2009 winners of the prestigious Senior Researcher Prizes in Quantum Electronics and Optics of the European Physical Society.

Awarded every two years, these prizes recognize major achievements in fundamental and applied research, respectively.



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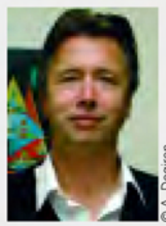
Alain Aspect, CNRS senior researcher and also CNRS Gold Medal winner in 2005, has been awarded this prize for his work on the fundamental aspects of quantum electronics and optics, which has paved the way for the modern revolution in quantum information processing, cryptography, and computing.

Thomas Ebbesen, professor at Strasbourg University and director of ISIS,[1] received the award for his research on the optical properties of nanostructured metals, at the interface of nanoscience and photonics.



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1. Institut de science et d'ingénierie supramoléculaire (CNRS / Université Strasbourg-I).

...AND IN MATHEMATICS

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The 2009 Clay Research Award was attributed to **Jean-Loup Waldspurger** from the Institut de mathématiques de Jussieu[1] for his work in p-adic harmonic analysis, particularly his contributions to the transfer conjecture and the fundamental lemma. This work, combined with that of others, has made it possible to finally resolve important, long-standing parts of the Langlands program. This prize is awarded each year by the Clay Mathematics Institute (Cambridge, MA, US) to recognize major breakthroughs in mathematical research.

1. CNRS / Universités Paris-VI and -VII.

→ **AWARDS**

Serge Haroche, CNRS Gold Medal for 2009

Serge Haroche, physicist at the Kastler Brossel laboratory (LKB)[1] and professor at the Collège de France, has been awarded the 2009 CNRS Gold Medal, the highest distinction in French scientific research. This specialist in atomic physics and quantum optics joins a long list of eminent physicists who received this award, notably Alfred Kastler and Jean Brossel (in 1964 and 1984), who gave their names to Haroche's laboratory, as well as Claude Cohen-Tannoudji (in 1996), who also received the Nobel Prize in 1997 and was his thesis supervisor. The recipient of 14 national and international scientific awards and author of more than 180 publications, Haroche confided that he was "very honored by this award and the opportunity CNRS has given him to promote fundamental research." He also emphasized the fact that his work "was the result of efforts by an entire team." Haroche has specifically developed a new field, that of cavity quantum electrodynamics, which consists in studying interactions between a single atom and a few photons in a "box," or cavity. The physics of this microscopic system fly in the face of intuition and can only be understood in the context of quantum theory. Indeed, already during his thesis, Haroche was studying the concept of "dressed" atoms, describing how an atom interacting with a cloud of photons sees its properties markedly affected by this coupling. "These subjects have been important throughout my career," he explains, adding that "in my more recent research, the atom has been 'dressed' much more lightly than it was at the start. A single photon, and even an empty cavity are enough to profoundly affect its behavior." Haroche's work has enabled the experimental verification of postulates in quantum physics, inspired by the thought experiments of Albert Einstein and Niels Bohr, and made possible by recent technological advances. His research may be of importance in the new science of quantum information processing. According to Bertrand Girard, scientific director of CNRS' Institute of Physics, Haroche is a "world-renowned scientist with an extraordinary depth of thought and an exceptional understanding of extremely complex phenomena." The Gold Medal will be awarded during a special ceremony this December in Paris.

C.Z.

1. Laboratoire Kastler Brossel (CNRS / ENS / Université Paris-VI).

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editorial

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Dominique Le Quéau,
Director of the National Institute for Earth Sciences and Astronomy (INSU).

Universal **Research**

CNRS International Magazine has chosen to celebrate the International Year of Astronomy with a wide-sweeping investigation of past, current, and future astronomical research, as well as a survey of new challenges faced by scientists in their never-ending and awe-inspiring quest to unravel the secrets of our universe.

International, but especially European astronomy is today at a watershed, after 30 years of modernization which has profoundly altered its structure and de facto governance. In retrospect, this will no doubt be seen as a key moment in the history of science. The instruments currently being put into operation, whether on the ground or in space, will for the first time give us access to first-hand information about our origins. More generally, it is the entire history of the universe–its own origins, as well as those of the planets and of life–that can henceforth be directly investigated by newly-built and designed observation instruments, some of which are already gathering and transmitting data.

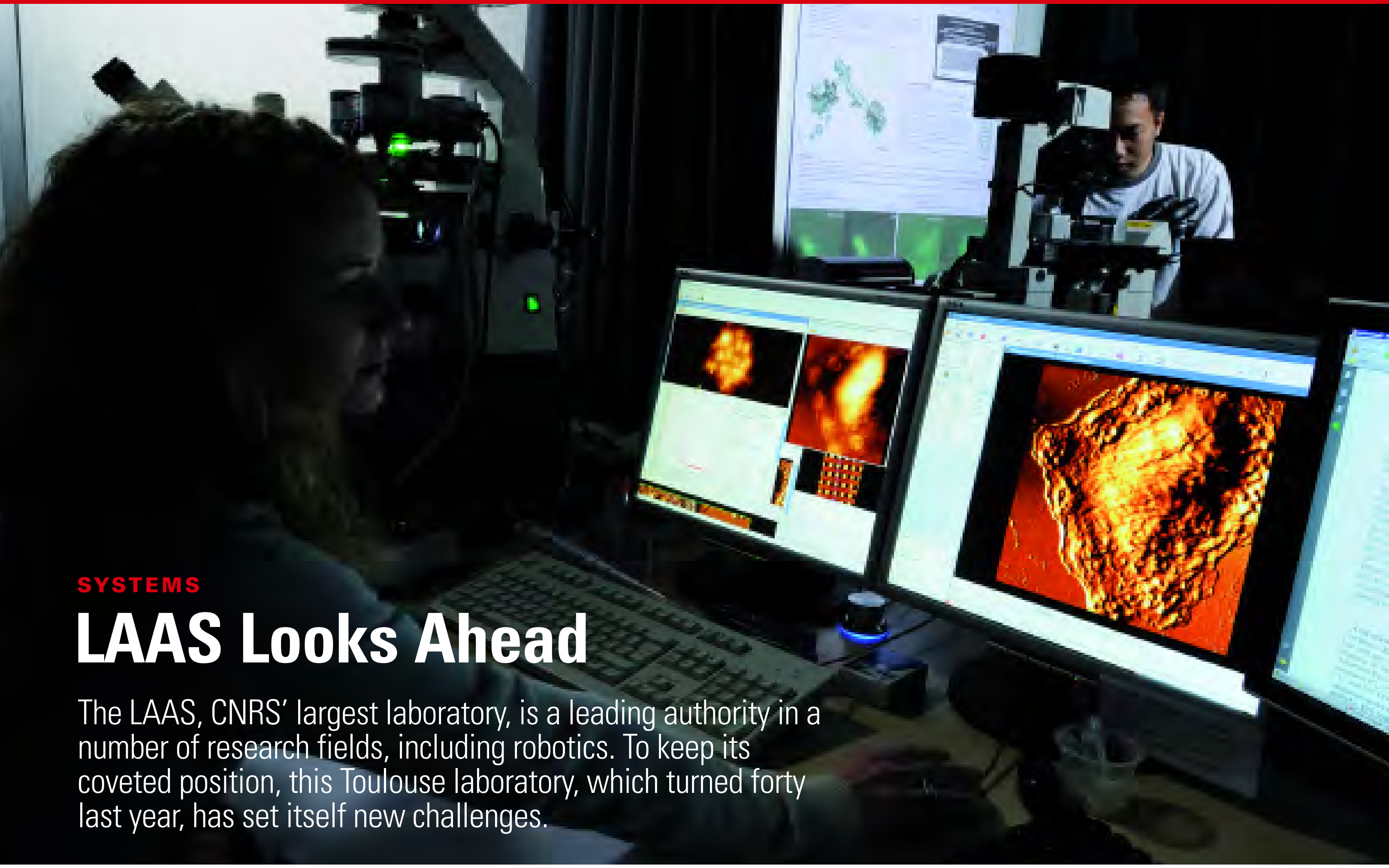
On May 14th, 2009, the Planck and Herschel space missions were launched from the Kourou Space Center in French Guiana, and were both heading to their final orbit destination, some 1.5 million kilometers from Earth. By using imaging and polarimetry to measure fluctuations in the cosmic microwave background, Planck will be able to observe the origins of the primordial universe–beyond the cosmological horizon–and constrain the physics of its very first moments. Hershel, on the other hand, will aim its instruments towards the first structures to have emerged from these first, almost completely uniform, phases of the universe, which eventually gave rise to our familiar galaxies.

Together with giant ground-based telescopes operating both at visible wavelengths (the Very Large Telescope, and the future European Extremely Large Telescope) and at submillimeter wavelengths (IRAM and soon the ALMA radio telescope), these instruments will enable astronomers to access the entire past history of the matter and energy–perhaps more accurately "matters" and "energies"–that make up our universe. Although COROT, a space-telescope launched by CNES at the end of 2006, has already detected extrasolar planets, only the ground-based very large telescopes will be able to observe them directly, defining the characteristics of the environments in which they were born and probing their atmospheres, which could lead to the discovery of traces of living processes, or even life itself.

The challenges that astronomy currently faces require instruments that are both large and expensive. These can only be designed and produced within a context of broad international and European collaborations such as the European Southern Observatory and the European Space Agency, as well as scientific and technical forecasting exercises carried out on a global scale. For instance, the ALMA radio telescope, currently being built in the Atacama desert in Northern Chile, is the result of the integration of three initially independent projects, from Europe, the US, and Japan, with joint governance and management. While collaboration and cooperation must be the guiding principles for building and operating these very large instruments, it is competition between teams that will guarantee the excellence of their results, both upstream when it comes to choosing the best instrument design and technologies, and downstream when selecting the best observation programs.

It is only in this way that we will be able to shed light objectively, and perhaps definitively, on some points in the "program" outlined as early as 1686 by Bernard le Bouyer de Fontenelle, the first of the Enlightenment philosophers, in his *Conversations on the Plurality of Worlds*:[1] "Our Sun has planets which it lights; why shouldn't every fixed star have some which it lights too?"

1. Bernard Le Bouyer de Fontenelle, *Entretiens sur la pluralité des mondes* (Paris: Janet et Cotelle, 1820).



SYSTEMS

LAAS Looks Ahead

The LAAS, CNRS' largest laboratory, is a leading authority in a number of research fields, including robotics. To keep its coveted position, this Toulouse laboratory, which turned forty last year, has set itself new challenges.

LAAS scientists focus on interactions between miniaturized technologies and microelements in living organisms. Shown here, the topography of a human macrophage observed using an atomic force microscope.

In parallel, the Toulouse laboratory is pursuing its research in robotics. Here, the HRP-2 humanoid which, among other abilities, is able to move cumbersome objects.

The Laboratory for Analysis and Architecture of Systems (LAAS)[1] sits quietly at the heart of the Toulouse science campus, with its 627 researchers, engineers, and technicians on site constantly working on innovative projects that result in more than 900 publications a year.

"Do you know that here was created the first joint laboratory between research and industry? And that France's first cleanroom[2] for scientific research was built here, as early as 1968?" asks Raja Chatila, director of LAAS. Before showing us around the various facilities of the laboratory, which pioneers in informatics, control science, micro- and nanotechnologies, robotics, and artificial intelligence, and where numerous discoveries have been made in the past four decades, he uses the historical floor plans to show us how the laboratory has grown in size, in line with the needs of its 18 research groups. One example is the large area dedicated to the Technology Center–referred to as the "Centrale"–an impressive infrastructure and technological wonder containing a 1500 m² new cleanroom that was inaugurated in 2006 (*see box*).

INTERACTING WITH LIVING ORGANISMS

In this fast-paced environment, what are the new research paths being explored at LAAS? Chatila is delighted to explain: "It's now time to extend our knowledge by developing transversal areas, notably with the life sciences, with which there is strong joint research." And rightly so: Complex technological systems are today designed at the micro- and nanometric scales, those at which living organisms, molecules, and cells function. This opens an entire field of novel applications for these systems, ranging from the diagnosis of diseases to their treatment.

For example, LAAS is currently focused on a major scientific project: the detection of biological species (proteins, DNA, mutant cells, etc.) to allow the observation of chemical interactions at a very small scale and thus improve medical diagnosis. For this purpose, Aurélien Bancaud's team has been developing over the past year specific nanochannel networks, in which DNA strands undergoing replication can be stretched and studied. Potential applications include the detection of replication alterations induced by cancer. But other LAAS projects are also under way: "Over the next few years, new families of integrated micro-systems will appear that use radio frequencies to detect the presence of cellular or macromolecular signatures, but without destroying them," predicts Anne-Marie Gué, coordinator of the Micro- and Nanosystems (Minas) research area. Another example is a "laboratory project on microchips that analyze the red blood cells of patients with malaria." This research uses in particular the so-called "dielectric" properties of cells placed in a liquid: When submitted to an electric field, they polarize and move to a greater or lesser extent, depending on their properties and size.

The creation of artificial objects inspired by nature is also of increasing interest to teams at LAAS. Generic processes, homogeneous and reproducible by industry are being generated by the Technology Center (*see box*). Christophe Vieu, for example, is attempting to reconstruct the flagella that propel certain bacteria by combining artificial processes and natural self-assembly. These flagella could enable targeted propulsion of medicinal nanoparticles.

It is clear that such interactions with the life sciences have greatly modified the approach adopted by these scientists: "We can no longer limit ourselves to designing and producing technical systems," says Gué. "We need to think ahead with experts in the neurosciences, biology, or biochemistry to better understand the properties of the molecular processes at play. And we must also understand the new issues facing society in the field of public health and human-machine interactions.

THE FUTURE IS "ADREAM"

Another important new challenge for LAAS deals entirely with information and communication sciences and technologies, developing the "internet of things" and particularly any type of computing device designed to be mobile. For over two years now, a fully novel, transversal experimental program has been in the works: Adream,[3] a French acronym for "reconfigurable dynamic architectures of autonomous, mobile embedded systems." "This laboratory will be filled with communicating sensors, actuators, cameras, and robots," explains Jean Arlat, coordinator of the Critical Information Systems research area (Sinc).[4] "The setup is designed to improve the mobility of miniaturized communication technologies, whether carried by an individual for their everyday activities or attached to mobile devices and equipment such as robots. Improving their autonomy will also be a key issue, as such modern systems must be able to operate in an unknown space, make decisions, and react in case of adverse events (software errors, malicious faults, unpredicted situations, etc.)." To complete the dozen or so projects of this program, coordinated by Michel Diaz, the scientists will have the use of a brand new 1200 m² instrumented building whose construction will begin in 2010.

In that framework, projects currently referred to as "ambient intelligence" systems, such as FIL and BINAUR, will aim to improve the real-time localization of moving individuals using triangulation (based on three points of reception). The purpose of BINAUR is to provide blind persons in urban areas with an assisted guidance system.

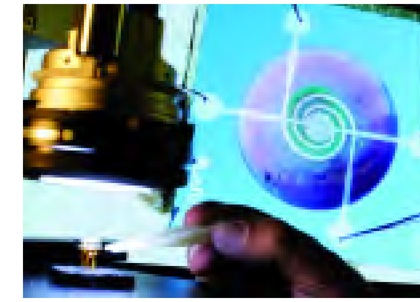
Also in the context of Adream, the emerging European project called "Feel@home," in partnership with France Telecom, is entrusted with developing user-friendly, guaranteed and secure communications for data sharing (photos, films, etc.). One main novelty is that the verification of access rights will rely on non-intrusive techniques that will prevent the tracking of personal information.

Finally, the Adream building will have on its roof and walls a large number of photovoltaic cells that will provide an opportunity to also develop research activities into the optimization of electrical energy conversion and management.

Aude Olivier

1. Laboratoire d'analyse et d'architecture des systèmes (CNRS).
2. A room with a controlled minimal level of environmental contamination (number of dust particles per cubic meter, temperature, humidity, etc.).
3. Architectures dynamiques reconfigurables de systèmes embarqués, autonomes et mobiles.
4. Systèmes informatiques critiques.

Tests of a semi-conducting oxide-based heating sensor for gas detection (pollution, leaks...).



Another field of research at LAAS is mobile communication systems for robots and humans. One objective is to make these machines fully autonomous.

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LAAS' large cleanroom shelters the latest equipment necessary for the creation of micro- and nanosystems.

AT THE CUTTING EDGE OF TECHNOLOGY

"Over the past three years, we have started working on a much larger scale," explains Hugues Granier, research engineer for the new LAAS platform, whose recent extension opened in 2007. The new 1500 m² cleanroom provides all the equipment needed for the design, development, and characterization of microelectronic and optoelectronic components, as well as micro- and nanosystems. This gives France the ability to respond to academic and private research needs regarding systems for biology, health, and the environment.

This technology platform which benefits from the national Basic Technology Research Program, contains equipment of an industrial type (plasma etching, projection lithography, etc.) "that will adequately demonstrate to our partners that it is possible to reproduce our prototypes," explains Granier. The first stepper–an apparatus that can reproduce patterns on a substrate–and more classic photolithographic methods can bring us from micron to nanometric scale. Some other low-cost facilities (screen printing, inkjet machines, etc.) are also available to perform deposits of new materials. Other acquisitions are ongoing such as a molecular beam epitaxy frame,[1] a 1800°C rapid oven, and a wide range of other devices.

A.O.

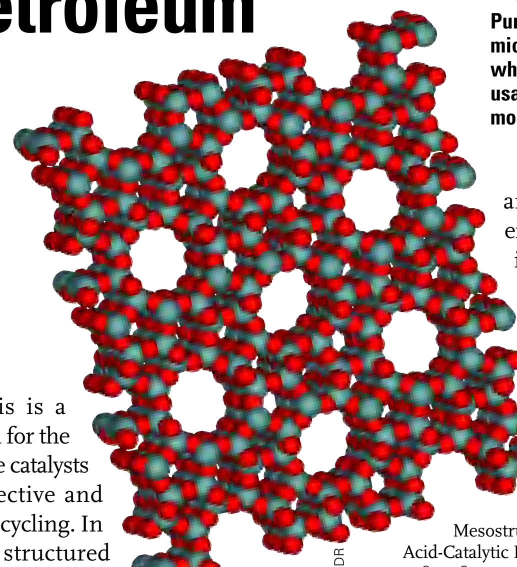
1. This process enables the successive growing of different layers of molecules on a substrate.

Contact information: Hugues Granier, hugues.granier@laas.fr

CHEMISTRY

A Spray to Refine Petroleum

Increasing fuel efficiency usually means burning less oil. Clément Sanchez from LCMCP,[1] in collaboration with Alexandra Chaumonnot at the French Institute of Petroleum (IFP)[2] have decided to tackle this problem at the root, by improving the refining process.



DR

Pure zeolite is microporous, which makes it usable as a molecular sieve.

After oil is extracted from the earth, it must be refined to produce the usable derivatives that power our cars and aircrafts. The petroleum industry uses chemical catalysts that transform heavy molecules of oil into consumable petroleum products, from gasoline to heating oil. The aluminosilicate zeolite microporous crystals that have been used as refining catalysts in the petroleum industry since the 1960s are not ideal for the task. Their pores –usually less than one nanometer across– are too small to efficiently break down larger molecules. An amorphous (non-crystal) aluminosilicate with larger pores was introduced in the 1990s by Mobil researchers, but its low acidity and hydrothermal resistance limited its application.

Sanchez's team and their collaborators addressed the problem by creating a superior aluminosilicate nano-structure using an aerosol spray.[3] The new particles, called LAB,[4] are spherical, sub-micron sized forms with micropores and mesopores that can be "tuned" to measure anywhere between 4 to 50 nanometers across.

Sanchez explains that aluminosilicates are normally synthesized in a chemical solution, which produces considerable waste. By contrast, the aerosol spray process is both quicker and cleaner. A fine mist of a solvent containing organic templating materials and silica and alumina precursors is sprayed into a heating chamber, heated to 350°C so that the solvent–water or ethanol–rapidly evaporates, leaving behind the aluminosilica components that self-assemble into regular, structured solids, which can be collected from a filter.

"All this occurs in a few seconds, and the materials can be frozen into certain compositions and structures that simply cannot be made in a solution," say its inventors. Spray fabrication eliminates several steps required in chemical fabrication, and drastically reduces the comparative amount of waste produced.

When compared to current aluminosilicate catalysts, the LAB particles showed very high catalytic performance, and their activity lasted much longer than the current standard zeolitic catalysts. This is a potential boon for the industry, as the catalysts are more effective and require less recycling. In addition, the structured form and large pore sizes mean that the catalysts will be more effective in refining larger oil molecules, allowing for greater efficiencies in refining heavier fuel "fractions" from a barrel of oil. By extension, this spray process should allow the production of novel nanostructures with potential applications in medical imaging or multifunctional drug delivery systems.[5]

"With increasing demand for heavier fuel and energy, the LAB particles' efficiency and ease of production is a significant development," concludes IFP collaborator Chaumonnot.

Mark Reynolds

1. Laboratoire de chimie de la matière condensée de Paris (CNRS/ Université Paris-VI / ENSCP / Collège de France).
2. Institut français du pétrole.
3. S. Pega et al., "Direct Aerosol Synthesis of Large-Pore Amorphous Mesostructured Aluminosilicates with Superior Acid-Catalytic Properties," *Angew. Chem. Int. Ed.*, 2009. 48: 2784-7
4. Large-pore Aluminosilicates prepared with Basic solutions.
5. J. Lopez et al., "Mesoporous Maghemite-Organosilica Microspheres: a Promising Route Towards Multifunctional Platforms for Smart Diagnosis and Therapy." *J. Mater. Chem.*, 2007. 17: 1563-9.

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IN BRIEF

First Basaltic Micrometeorite

A team from France and the US has reported the discovery of a micrometeorite made of basalt, the first such micrometeorite ever to be identified.[1] This micrometeorite is unlike any other basalt known in the solar system as revealed by isotopic data, mineral chemistry, and trace element abundances. Discovered in Adélie Land in Antarctica in 1991, this asteroid fragment weighs a mere few micrograms. Detailed examination showed that it came neither from the Moon (where basalts are abundant), nor from Mars or from the rare basaltic asteroids which have been sampled. The largest of the basaltic asteroids is called Vesta. Discovered in 1807, it lost around 1% of its mass when it collided with another asteroid less than a billion years ago. Several of the resulting fragments hit the Earth in the form of meteorites, making Vesta the primary source of basaltic meteorites found on our planet. The new micrometeorite may have come from one of the recently discovered basaltic asteroids that are not members of the Vesta family. It provides one of the rare opportunities for scientists to study the formation and evolution of a planetary crust.

1. M. Gounelle et al., "A basaltic micrometeorite from Antarctica: Expanding the inventory of solar system planetary crusts," *PNAS*, 2009. 106: 6904-9.

> Contact information: Matthieu Gounelle, gounelle@mnhn.fr

ECOLOGY

Emperor Penguins: Extinct by 2100?

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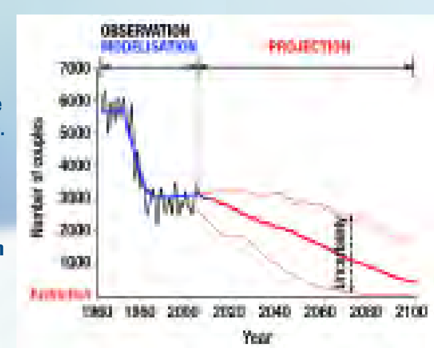
What impact does climate change have on marine ecosystems? For the emperor penguin, it could very well mean extinction. This was revealed by CNRS researchers working in collaboration with two American teams.[1] Found in Antarctica, the emperor penguin is highly sensitive to variations in pack ice, which acts as the locale for the penguins' summer molt (January/ February), for their reproduction in winter, and their food supply. To understand how the predicted reduction in ice will affect the penguins, the researchers looked at demographic monitoring results collected between 1962 and 2005 on a colony of emperor penguins in Adélie Land. They combined these data with IPCC[2] models predicting the future extent of pack ice in Antarctica. The result is patently clear: The emperor penguins of Adélie Land could become extinct between now and 2100 if the polar ice cap continues to melt as predicted. To avoid extinction, emperor penguins will have to adapt (migration, changes to their life cycle, etc.). However, the inability to quickly change their behavior puts them at great risk. In contrast, these climatic changes have turned out to be favorable for a few other species of birds, mainly subtropical or subantarctic species, like some albatross. This work therefore suggests that species in the Southern Hemisphere will reorganize themselves over the coming years to adapt to climate change.

1. S. Jenouvrier et al., "Demographic models and IPCC climate projections predict the decline of an emperor penguin population," *PNAS*, 2009. 106: 1844-7.
2. Intergovernmental Panel on Climate Change.

> Contact information: Henri Weimerskirch, henriw@cebc.cnrs.fr.



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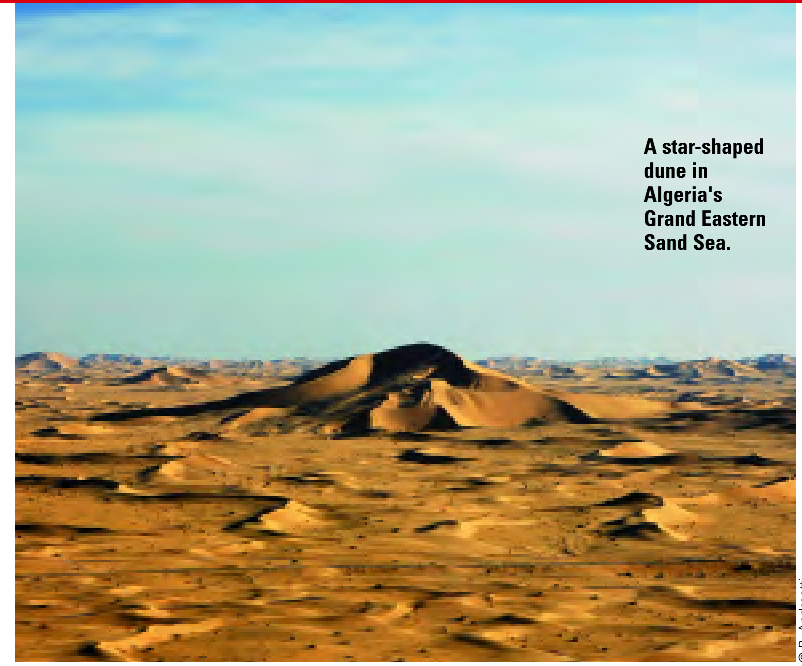
Left: An emperor penguin on a glacier in Adélie Land (Antarctica).

Right: Predictive evolution of the number of emperor penguin couples between 2005 and 2100.



A star-shaped dune in Algeria's Grand Eastern Sand Sea.

© B. Andreotti

PHYSICS

Atmospheric Dunes

The desert, a landscape renowned for its grandeur and mystery, partly owes its wonder to the flawless curves of wind-sculpted dunes. A question that has always puzzled scientists is why some dunes–whether shaped as crescents, stars, or ridges–take on giant proportions, sometimes reaching heights of a hundred meters.

Via remote sensing, aerodynamic calculations, meteorological data, and field measurements, researchers from the Paris-based PMMH laboratory,[1] along with US and Algerian scientists, have now linked dune size to the planet's atmosphere.[2]

Drawing an analogy with dunes found on riverbeds, the research group has linked desert dune size to the depth of the atmospheric layer that touches the Earth's surface, the convective boundary layer (CBL). Wind flow–confined to the CBL by the next atmospheric level, the inversion layer[3]–moves sand grains causing dunes to cluster. Just as river depth influences river dune size, "the inversion layer has a 'stabilizing effect' on sand dune size," explains team member Philippe Claudin. As dunes increase in width and height, they end up "feeling" the limit of the CBL, i.e., the altitude of the inversion layer, and are thus stabilized. The upshot? The deeper the CBL, the more wind-sand interaction, and the larger the dunes.

Given that wide temperature variations swell CBL depth, the team identified another link, pointing out a novel way for gauging average CBL depth. In oceanic areas where temperatures barely fluctuate, the space between giant coastal dunes starts at 300 m, and the CBL averages several hundred meters. Meanwhile, inland, where temperatures vary widely, distances of up to 3.5 km between continental dunes match a CBL depth that can reach several kilometers. It follows that the world's largest dunes are found inland.

Clarifying how dunes form, the new theory also shows how sediments like sand interact with an atmosphere-like fluid. The discovery should further help to reach estimates for conditions in remote areas: For example, dunes on Titan, one of Saturn's moons, can be studied to ascertain CBL depth there.

Fui Lee Luk

1. Physique et mécanique des milieux hétérogènes (CNRS / ESPCI ParisTech / Universities Paris-VI and -VII.).
2. B. Andreotti et al., "Giant Aeolian dune size determined by the average depth of the atmospheric boundary layer," *Nature*, 2009. 457: 1120-3.
3. So called as this layer's air is warmer than air in the layer below, inversing the law of temperature falling as altitude rises.

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PALEOANTHROPOLOGY

Neanderthal Subgroups

Genetic modeling has allowed Marseille-based CNRS researchers[1] to confirm what paleoanthropologists have long suspected: The Neanderthal population was not homogenous, but split into three–perhaps even four–subgroups.

Location (blue, orange, and pink) of the three Neanderthal subgroups in Europe. The blue symbols identify spots where mitochondrial DNA was sequenced.

Paleoanthropological data suggests that during the Middle Pleistocene era, Neanderthals inhabited a geographical area that "stretched from Portugal to Western Siberia, and from Northern Europe to the Middle East."[2] It is believed that the Neanderthal population evolved from *Homo heidelbergensis*, a species also present in Africa, about 400,000 years ago. Approximately 130,000 years ago, this population became what we now refer to as "classic" Neanderthals and began to spread beyond the borders of present-day Europe. The population shift towards Western Asia and the Middle East, and the resulting geographically separated groupings, has left evidence that made researchers question (as early as the 1950s) whether this Neanderthal population might have evolved into different subgroups.

"These regions are geographically distant from one another and are, above all, separated by a number of environmental barriers," says Virginie Fabre. Her work with two other researchers, Silvana Condemi and Anna Degioanni, has now confirmed what many paleoanthropologists believed: There were indeed three different Neanderthal subgroups, one in Western Europe, one around the Mediterranean, and one in Western Asia. "Since current estimates show that the roaming range of Neanderthal subgroups rarely exceeded 10,000 km², it isn't surprising that there was little genetic exchange between distant regions," says Fabre.

The team reached its conclusions by first establishing four measures of genetic variation in DNA sequence including nucleotide diversity and pairwise differences, then creating six population models using non-nucleotidic data provided by paleoanthropology, such as fossils of teeth, limbs, or skulls. Based on these population models, the researchers performed 200 simulations, which included parameters like differing growth and migration rates, or initial population sizes, to create a measure of possible genetic diversity. Once the simulation results were analyzed, the best correspondence with the actual genetic diversity–measured using 15 sequenced samples taken from 12 Neanderthal fossil specimens found since 1997–was the scenario of three derived populations. In fact, the results suggest that there may have even been a fourth subgroup in the Near East, but a lack of genetic material from fossils in the region makes this impossible to confirm for now. They also proved that while there were no substantial migrations between distant populations, there was a certain amount of genetic exchange between localized Neanderthal groups.

While the study concentrated, as Fabre explains, "exclusively on the analysis of Neanderthal population structure and never aimed to deal with the question of the replacement of the Neanderthals by *Homo sapiens*, over 30,000 years ago, our method is appropriate for demographic scenarios and models that simulate the decrease and extinction of a population. It could thus prove very useful to researchers working on the question of Neanderthal extinction."

Tom Ridgway

1. Laboratoire Anthropologie bioculturelle (CNRS / Université de la Méditerranée / Établissement français du sang).
2. V. Fabre et al., "Genetic Evidence of Geographical Groups among Neanderthals," *PloS One*, 2009. 4: e5151.

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BIOPHYSICS

Scans in a Second

The secrets of life lie in macromolecular assemblies that make up an organism's biological machinery, like the genetic code-bearing chromatin, made of proteins and nucleic acids, or molecular motors that turn energy into motion. But the nanometric size of molecules, as well as the complexity of enzymatic substrates and their structural shifts, make these nanomachines tricky to observe.

By successfully masterminding the so-called SOFAST-methyl-TROSY method, an IBS[1] team accomplished the "first-ever Nuclear Magnetic Resonance (NMR) observation of nanomachines with near-atomic resolution, and in the second time-scale,"[2] comments project leader Jérôme Boisbouvier.

The first barrier to overcome was the scale, since the larger the macromolecule, the harder it is to interpret the many NMR signals produced. As NMR detects the hydrogen nuclei only, the IBS team replaced all natural hydrogen atoms in the protein sample by deuterium, then reinserted hydrogen atoms in specific methyl (CH_3) groups, in order to reduce the number of NMR signals. This allowed them to scan assemblies up to 1 megadalton.[3]

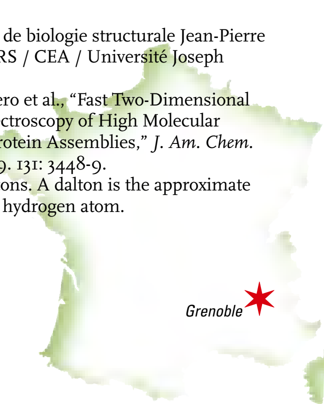
Next, the team maximized sensitivity and resolution via high-field spectrometers with cryogenically-cooled probes at the IBS NMR facility, a national and European research platform.

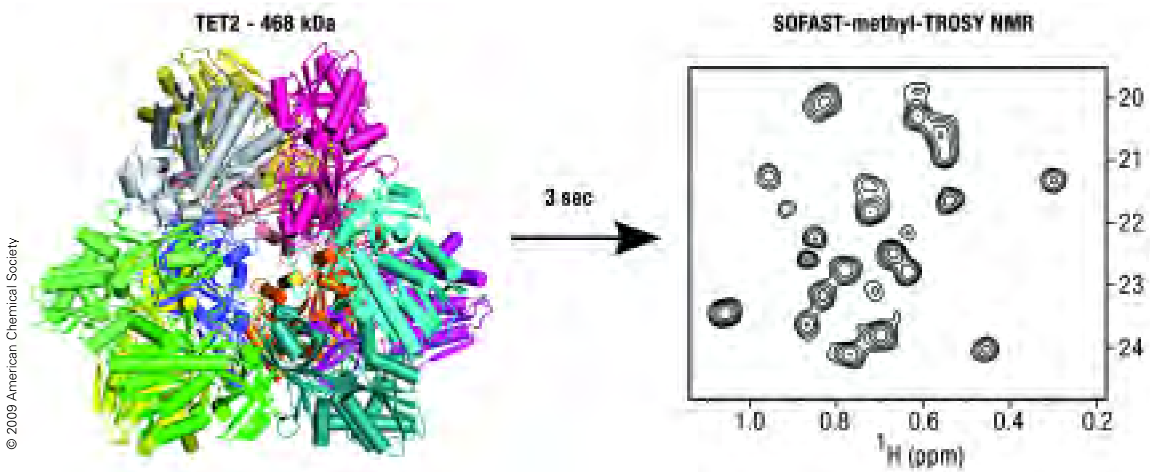
Last but not least, the team managed to reduce to close to a second the time required to probe a biomolecular assembly of up to several hundreds of kDa. This was done by integrating a technique to reduce relaxation time–the time it takes for molecule magnetization to return to equilibrium after an NMR pulse is applied–so that quicker pulses could be delivered. Although the time resolution has already been divided by 100, the team is currently tackling ways to gain yet more speed.

One key advance of this IBS innovation is the start of what Boisbouvier calls "a new field of investigation:" the real-time kinetics of key biological machineries in the heat of action. The new method also promises insight into molecular folding and self-assembly mechanisms.

Fui Lee Luk

1. Institut de biologie structurale Jean-Pierre Ebel (CNRS / CEA / Université Joseph Fourier).
2. C. Amero et al., "Fast Two-Dimensional NMR Spectroscopy of High Molecular Weight Protein Assemblies," *J. Am. Chem. Soc.*, 2009. 131: 3448-9.
3. 10^6 daltons. A dalton is the approximate mass of a hydrogen atom.





Using the SOFAST-methyl-TROSY NMR, a 2D spectrum (right) of the 12 subunit peptidase TET2 (Quarternary sequence on left) can be obtained in just 3 seconds.

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MICROBIOLOGY

Life in the Depths

Hydrothermal vent at the Ashadze site.

A team of geologists and microbiologists, using data from the 2007 Serpentine mission[1] in the mid-Atlantic ridge, that explored the world's deepest hydrothermal vent system, have discovered and isolated a new species of archaebacteria: *Pyrococcus* CH1.[2]

Microbiologist Daniel Prieur and his team,[3] together with other teams from France[4] and China,[5] collected samples from black smokers –deep sea vents–at the Ashadze site, the deepest hydrothermal vent on the planet (4100 m below the surface), 13°N along the Mid-Atlantic Ridge. After enrichment of anaerobic microrganisms under high-pressure and high-temperature conditions, a bacterium was isolated, capable of growing in the lab at temperatures ranging between 80 and 108 °C and under a pressure range of 20 to 120 megapascal (MPa).

What is new about this microorganism is that it requires at least 15 MPa to grow. "It represents the first obligate piezo-hyperthermophilic[6] organism ever isolated," Prieur explains. It belongs to a subgroup of extremophiles which thrive under extreme conditions of high pressure and high temperatures, as can be found at the bottom of the ocean where hot water that has come into contact with the Earth's magma spews out of fissures in the oceanic plates in the form of hydrothermal vents. Other piezophilic microorganisms, but adapted to extremely cold temperatures (called psychrophilic) have previously been found in the Pacific Ocean's Mariana Trench, the deepest and coldest parts of the world's oceans.

"The normal habitat for *Pyrococcus* CH1 is probably even deeper than the black smoker, since it seems to be adapted to conditions that exist below the deep sea floor where the pressure is even higher," says Prieur. Future studies will look for specific proteins involved in adaptation to extreme pressure. "The genome of this microorganism has already been completely sequenced," he concludes.

Karen Dente

1. A six week mission, performed in 2007 by a Franco-Russian team led by Yves Fouquet (Ifremer).
2. X. Zeng et al., "*Pyrococcus* CH1, an obligate piezophilic hyperthermophile: extending the upper pressure-temperature limits for life," *ISME J.*, 2009. 3: 873-6.
3. Laboratoire de microbiologie des environnements extrêmes (CNRS / Université de Bretagne Occidentale / IUEM / Ifremer).
4. Laboratoire des sciences de la terre (CNRS / ENS Lyon / Université Lyon-I).
5. Institute of Oceanography of Xiamen.
6. An organism which grows at high pressures and very high temperatures.

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IN BRIEF

Closing in on the Higgs Boson

We now know a little more about the potential mass of the Higgs boson, the particle predicted by theoretical physics (standard model) but that has until now eluded direct observation. New results from the D0 and CDF experiments carried out on Fermilab's Tevatron particle accelerator in the US, in which CNRS researchers from IN2P3[1] have been participating, now exclude that this mass could be between 160 and 170 GeV/c2. Previous experiments had established that its mass should be higher than 114 GeV/c2 and lower than 185 GeV/c2. The latest results from Fermilab point towards a mass that is either between 170 and 185 GeV/c2, or, more probably, between 114 and 160 GeV/c2.

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NEUROBIOLOGY

Neutralizing Alzheimer's APP Receptor

Researchers have identified a molecule that blocks the appearance of amyloid plaques in the brain of Alzheimer mouse models by binding to Alzheimer's infamous APP receptor. It even restores some of the animal's cognitive functions.

The appearance of amyloid plaques in certain areas of the brain, also called "senile plaques," is the signature of Alzheimer's disease. Amyloid plaques are aggregates of a toxic peptide called beta-amyloid, which clogs up in regions involved in learning and memorization processes, where they stick to neurons, disrupting their ability to communicate and suffocating them to death. As the beta-amyloid invasion progresses, Alzheimer patients' dementia worsens. Blocking the formation of beta-amyloid is thus critical to fighting the disease. The protein is thought to result from the abnormal cleavage of a trans-membrane neuronal receptor called the beta-amyloid precursor protein (APP). Little is known about APP, which is still considered an "orphan" receptor, with no known ligand.

However, researchers from CNRS,[1] together with researchers from The Buck Institute for Age Research, now report identifying an APP ligand.[2] The molecule, netrin-1, is a well-known hormone that helps guide and support nerves and their connections in the brain, but it is also involved in tumor cell survival.

The CNRS team was initially screening for proteins that bind netrin-1 in a cancer research perspective (*see page 37*) and APP turned out to be a strong candidate. "APP wasn't known to be involved in cancer, so we decided to look further in this direction," says lead CNRS researcher Patrick Mehlen.

The researchers first showed that netrin-1 induces a physiological cascade in neurons by binding to APP. They then tested the effect of netrin-1 on the APP cleavage. "We wanted to know whether the presence or absence of netrin-1 would affect the formation of beta-amyloid," says Mehlen.

The team used transgenic mouse models in which APP is overexpressed, leading to the formation of amyloid plaques in brain regions associated with Alzheimer's. When netrin-1 expression was inhibited in such mice, brain slices showed an even denser production of beta-amyloid. "The absence of netrin-1 seems to speed up the APP cleavage," says Mehlen.

To investigate whether netrin-1 could be used therapeutically to avoid the formation of plaques, the researchers grafted tiny pumps delivering netrin-1 continuously in the brain of the Alzheimer mouse models. A regular netrin-1 infusion significantly reduced the formation of beta-amyloid and even partially restored memory in treated mice. "So netrin-1 seems to have both a preventive and a curative action," says Mehlen. The next challenge will be to understand how this restoration process occurs. In the meantime, a smaller and more effective synthetic analog of netrin-1 is being mass-produced.

Clémentine Wallace

1. Laboratoire Apoptose, cancer et développement (CNRS / Centre Léon Bérard / Université Lyon-I).
2. F.C. Lourenço et al., "Netrin-1 interacts with amyloid precursor protein and regulates amyloid-b production," *Cell Death Differ.*, 2009. 16: 655-63

DIAGNOSTIC KIT AVAILABLE SOON

© A. Secci/CNRS

The IHD diagnostic kit can detect Alzheimer biomarkers from red blood cells using fluorescent probes.

A kit that will require only a few drops of blood to screen for Alzheimer's could very well be on the market by 2011. This degenerative disease of the brain affects 26 million elderly people worldwide. Two complementary tests are currently under development by Innovative Health Diagnostics (IHD), a company created last October by Jean de Barry from INCI,[1] together with two other researchers. The company was authorized to develop the invention initially patented by de Barry's team in collaboration with scientists at LMSPC[2] in Strasbourg. "The first test measures conformational changes of protein kinase C (PKC) triggered by an interaction between the beta-amyloid peptide, characteristic of the disease, and the membranes of red blood cells," explains de Barry. "As for the second, it directly detects the presence of the peptide adhering to these membranes." The two assays, already tested on cellular models and animals, are now being validated in humans through clinical studies. The arrival of such a kit on the market could revolutionize diagnosis of this disease. "The method currently used, which combines physical examination, neuropsychological tests, and brain imaging, is 90% reliable, compared to our kit, which is close to 99%," adds de Barry.

1. Institut des neurosciences cellulaires et intégratives (CNRS).
2. Laboratoire des matériaux, surfaces et procédés pour la catalyse (CNRS / Université Strasbourg-I).

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NEUROBIOLOGY

The Advantages of Youth

A team of CNRS-affiliated researchers[1] have recently demonstrated[2] that the new neurons that appear each day in the adult brain present a hitherto unnoticed characteristic: They are hypersensitive to stimulations during the first few weeks of their lives.

Every day, approximately 10,000 neurons are born inside the subventricular region of the adult brain. They are immediately routed towards the olfactory bulb, where some end up integrating pre-existing neuronal networks. "The more neurons integrate existing networks, the greater our memory of smell," says team leader Dr. Pierre-Marie Lledo. However, what scientists find mind-boggling is that a few weeks after their arrival in the bulb, many of these neurons die. "Why carry so many neurons there if it is to have them disappear a few weeks later? It seems like such a waste," adds Lledo. To try to elucidate this phenomenon, the team set out to study the characteristics of young neurons.

Lledo's team genetically modified stem cells in the subventricular region of mice so that nascent neurons were fluorescent and their trajectory could be followed. Through electrophysiological recordings, the researchers discovered that young neurons, when they reach the bulb, become hypersensitive to excitatory inputs, a form of synaptic plasticity thought to be important for learning and memory. After a few weeks, some of these neurons integrate pre-existing neuronal networks, while others don't and subsequently die. "What happens is that neurons that have not received a vital type of information during their hypersensitive period are eliminated," says Lledo. In general, approximately half of the young neurons in the bulb die after a few weeks. However this quantity varies according to the amount of external stimulation. The more stimulation, the more neurons integrate existing networks.

These findings might explain why therapeutic strategies relying on grafting neurons inside the brain to cure neurodegenerative diseases are currently unsuccessful. "If neurons inside other regions of the brain behave the same way, then obviously a single neuronal graft will not be sufficient to restore cerebral function," says Lledo. "Half of them will end up dying. It is therefore a constant flow of new neurons that would be needed to restore full function."

Clémentine Wallace

1. Laboratoire Perception et mémoire, (CNRS / Institut Pasteur).
2. A. Nissant et al., "Adult neurogenesis promotes synaptic plasticity in the olfactory bulb," *Nat. Neurosci.*, 2009. 12: 728-30.

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ECONOMICS

Boom and Bust in the Amazon

Conversion of forest for agriculture and cattle ranching is now seen as the major cause of deforestation in the Brazilian Amazon.

© A. Lees/University of East Anglia

The Amazon rainforest, vital for global biodiversity and climate regulation, is also one of the poorest regions in Brazil. Policy makers have long argued that logging, followed by cattle ranching and agriculture, were the best path for the region's legitimate aspirations to economic development.

Yet a recent study published in *Science*[1] shows a very different reality, claiming that populations in areas where deforestation occurs go through a period of boom and bust, which leaves the inhabitants in no better economic condition than before the process starts. For this study, Ana Rodrigues from Montpellier's CEFE,[2] together with researchers from the UK and Brazil, contrasted two sets of data. The first was supplied by the deforestation monitoring project PRODES[3] using Landsat satellite imagery to compare forest cover between 1997 and 2000. It was used for identifying municipalities at different stages in relation to the so-called "deforestation frontier" (edging southwest into the Amazon). From these images, researchers were able to classify municipalities into 7 phases of development, ranging from the pre-frontier, with relatively intact forest cover and little deforestation activity, through the active frontier, with high deforestation activity and declining forest cover, to the post-frontier, with little forest left, and again little activity.

The researchers then used the 2000 Brazilian Atlas of Human Development nation-wide census to obtain the Human Development Index (HDI) for each municipality, a measure that combines life expectancy, literacy, and income per capita. They found that development improves more rapidly–faster than the national average–as deforestation begins, but then decreases and falls below average when the deforestation process is well advanced.

"Our results suggest that the development path that has been followed so far is not desirable, neither from the human nor from the biodiversity conservation perspectives," says Rodrigues. "What is needed is a development model that leads to a sustained improvement in people's well-being without the loss of this region's amazing natural resources."

Saman Musacchio

1. Ana S. L. Rodrigues et al., "Boom-and-bust development patterns across the Amazon deforestation frontier," *Science*, 2009. 324: 1435-7.
2. Centre d'écologie fonctionnelle et évolutive (CNRS / Universités Montpellier-I, -II, -III / ENSA Montpellier / CIRAD / EPHE Paris).
3. The PRODES (Deforestation Project) is funded and operated by Brazil's National Institute for Spatial Research (INPE).

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Visual rendition of the interaction between the repressor EthR (blue) and its inhibitor (pink).

© A.Baulard/Institut Pasteur

MICROBIOLOGY

Overcoming Resistance

With the appearance of antimicrobial-resistant organisms, infectious diseases are increasingly difficult to treat. Two new studies further our understanding of how to better fight infectious diseases such as tuberculosis and malaria.

The treatment of infectious diseases often leads to the appearance of resistant microbial strains. Patients infected with resistant strains must undergo longer and more complicated treatments, requiring the use of powerful drugs that are toxic for microbes but also for patients, some of whom suffer severe side effects.

For instance, effective antibiotics currently exist to fight tuberculosis, but problems of compliance, especially in developing countries where education lacks, lead to the appearance of multidrug resistant strains (MDR-TB). The only option for MDR-TB infected-patients is to follow a two-year regimen involving the use of ethionamide, an antibiotic highly toxic for the liver. "Forty percent of patients end up discontinuing this treatment. They feel like the medication is making them sicker than the disease," explains researcher Alain Baulard.[1] "But we have no other alternative."

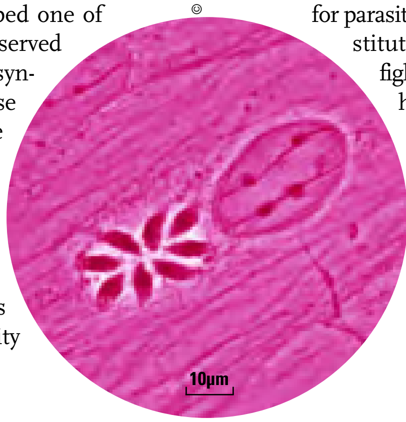
Yet now, Baulard's team reports[2] the discovery of molecules that, by increasing the bacterium's sensitivity to ethionamide, enable lowering doses of the antibiotic needed to cure MDR-TB in mice. "If we could lower doses in humans, side effects would be more bearable, and compliance would increase," says Baulard.

What the team initially discovered is a gene, called *ethA*, from the TB bacillus, which increases the microbe's vulnerability to ethionamide. Unfortunately, *ethA* is naturally repressed by a protein called EthR. The goal was to find a way to lift EthR's repression. "We got lucky," says Baulard. Using crystallography to analyze EthR's structure, the team unexpectedly trapped one of its natural inhibitors, which served as a model to create smaller synthetic compounds. When these synthetic EthR inhibitors were administered in combination with ethionamide to TB-infected mice, the doses of the antibiotic needed to cure mice could be reduced by three. "If we could lower doses by a third in humans, toxicity would fall tremendously," says Baulard. Human trials could start in the coming three years if the molecules prove safe.

On another front, Mohamed-Ali Hakimi's team[3] reports discovering molecules to fight parasites of the apicomplexa family, such as malaria's *Plasmodium*.[4] "These molecules act on one of the parasite's vital pathway, one that it cannot easily modify to adapt," says Hakimi. Initially, the team was looking for inhibitors of the parasites' histone deacetylase enzymes (HDAC)–a family of enzymes found in humans as well as in microbes. During the screening process, the team discovered that a group of inhibitors, cyclotetrapeptides, are very efficient against the parasite HDAC3, but not against human HDACs. The researchers identified the site targeted by the inhibitor. "This site only exists in parasites. This is why cyclotetrapeptides do not affect humans," says Hakimi.

Further studies showed that HDAC3 is central for parasite proliferation and thus constitutes an interesting target to fight parasite development. "We have discovered a potent inhibitor which targets the parasite specifically," concludes Hakimi, "but also a new target for future drug development to fight malaria and other diseases where the apicomplexa family of parasites is involved."

Clémentine Wallace



© M.-A. Kahimi

A characteristic rosette of 8 parasites in a human cell infected by *Toxoplasma gondii*.

1. Laboratoire Médecine cellulaire et moléculaire (CNRS / Inserm / Institut Pasteur de Lille/ Universités Lille-I and -II).
2. N. Willand et al., "Synthetic EthR inhibitors boost antituberculous activity of ethionamide," *Nature Med.*, 2009. 15: 537-44.
3. Laboratoire Adaptation et pathogénie des microorganismes (CNRS / Université Grenoble-I).
4. A. Bougdour et al., "Drug inhibition of HDAC3 and epigenetic control of differentiation in Apicomplexa parasites," *J. Exp. Med.*, 2009. 206: 953-66.

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HOW BACTERIA RESIST

Fatty acids are indispensable for the synthesis of bacterial membranes. Researchers have thus recently developed antibiotics that block the bacterial synthesis of fatty acids. However, a recent study[1] reveals that Gram positive bacteria, which include pathogens responsible for pneumonia or nosocomial infections, can sidestep the action of these antibiotics both *in vivo* and *in vitro* when fatty acids are available in the environment. The authors showed that mutants not containing the gene targeted by the antibiotic, therefore unable to synthesize fatty acids and presumably destined to die, were able to hijack fatty acids from the environment and survive. These findings suggest that when these bacteria infect the bloodstream, where fatty acids are widely available, such antibiotics might not be effective. However, "this doesn't exclude using them in conditions where fatty acids are unavailable, or when specific fatty acids are required, such as in mycobacteria," says researcher Claire Poyart.[2]

C.W.

1. S. Brinster, "Type II fatty acid synthesis is not a suitable antibiotic target for Gram-positive pathogens," *Nature*, 2009. 458: 83-6.
2. Institut Cochin (CNRS / Inserm / Université Paris-V).

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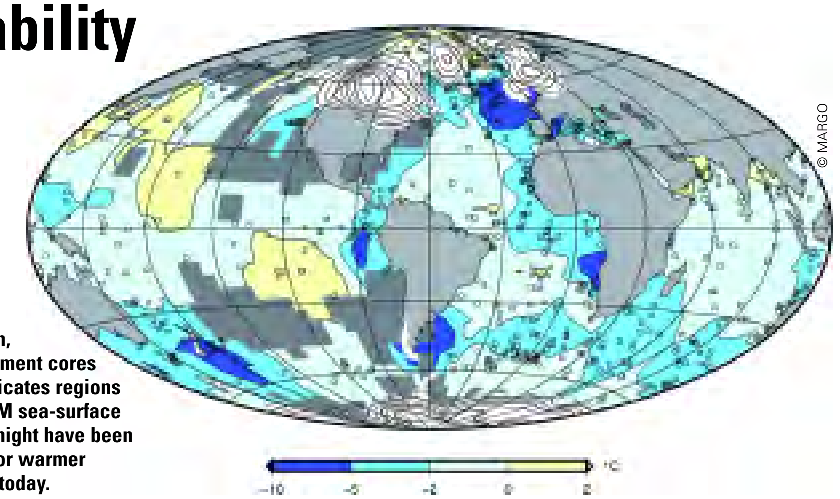
PALEOCLIMATOLOGY

Improving Climate Model Reliability



© MARGO

MARGO reconstruction, based on sediment cores (squares), indicates regions where the LGM sea-surface temperature might have been colder (blue) or warmer (yellow) than today.

An international group of scientists,[1] all paleoceanographers and paleoclimatologists, have compiled sediment core data from around the globe to estimate sea-surface temperatures during the Last Glacial Maximum (LGM: 19,000 to 23,000 years Before Present). "The aim of the MARGO project (Multiproxy Approach for the Reconstruction of the Glacial Ocean Surface) is to reconstruct the climate of the past so we can understand present times better and predict the climate of the future," explains CNRS researcher Claire Waelbroeck from LSCE.[2] "We reanalyzed all available data in a homogeneous way."

After five years, this ambitious project has revealed two major findings.[3] Firstly, sea ice cover over the northern seas and the North Atlantic Ocean during the LGM time period was not present all year long, as previously believed, but partially melted in summer. Secondly, it pointed out a major east to west gradient of surface temperatures in all ocean basins, something that climate models do not reproduce. From a statistical point of view, MARGO is more robust than previous reconstructions, such as CLIMAP (carried out in the 1970s). The geographic coverage is large, combining the data from 696 points around the world. Moreover, the newly published multi-proxy estimates combine results from six different climate indicators based on microfossil species compositions (planktonic foraminifera, diatoms, radiolaria, and dinoflagellate counts) and geochemical measurements (alkenone[4] unsaturation ratios and magnesium/calcium ratios of foraminifera). Using this unique set of data, the researchers were able to identify some weaknesses in the models used by the IPCC (Intergovernmental Panel on Climate Change). "By providing the means to test such models, MARGO should lead to more reliable predictions of climate change and its consequences," hopes Claire Waelbroeck.

Samantha Maguire

1. From Australia, Canada, France, Germany, Norway, Spain, Taiwan, Tunisia, the UK, and the US.
2. LSCE/IPSL (CNRS / CEA / Université Versailles Saint-Quentin).
3. MARGO Project Members, "Constraints on the magnitude and patterns of ocean cooling at the Last Glacial Maximum," *Nature Geoscience*, 2009. 2: 127-132.
4. Alkenones are organic compounds produced by unicellular algae.

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IN BRIEF

Towards Hydrogen Mass Production

The use of hydrogen as a clean energy source is one solution to today's energy challenges. But its production from water electrolysis suffers many drawbacks: it is very inefficient, costly, and polluting. Researchers from CNRS laboratories, working in collaboration with the firms SCT[1] and AREVA NP, have for the first time succeeded in producing hydrogen in significant quantities by means of a new method. Their novel technology is based on several innovations, such as carrying out the electrolysis under pressure (between 50 and 100 bars), lowering the operating temperature by nearly 200°C, and using commercial alloys. It could in the near future be developed on a large scale and be used to obtain hydrogen more cheaply and with zero greenhouse gas emissions. Hydrogen, which contains more energy than natural gas and is non-polluting and non-toxic, could gradually replace fossil fuels and meet most of our energy needs.

1. A world leader in metal-ceramic composites.

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ECOPHYSIOLOGY

Tracking Turtles

In 2008, 100 female turtles were fitted with tiny data recorders which will trace their migration until they return, in 2010-2011. Meanwhile, each spring and summer, turtles that arrive on the beach will be measured and weighed.

© S. Unterthiner

© Photos : J.-Y. Georges

Since March, a beach in French Guiana has been taken over by researchers, on location to study marine turtles in their reproductive season and try to retrace the mysterious route that leads them back to their nesting site.

When leatherback turtles come ashore to lay eggs, one of their largest nesting sites is La Plage des Hattes in French Guiana, close to the Surinamese border. These giant sea turtles, living testimonies of the prehistoric age (their origin goes back 200 million years), are a fascinating crowd-drawer. In March, Jean-Yves Georges and his team from Strasbourg's IPHC[1] moved to Awala Yalimapo to monitor the giant turtles during their nesting season. Until the end of July, these scientists will become night owls, seeking out female turtles as they nest.

"We have been studying this population since 2000," explains Georges, "but French researchers have been observing and marking leatherback turtles in Guiana since 1977." Last year, as part of a project tracing turtle migration and reproduction called MIRETTE,[2] funded by the French National Research Agency (ANR), a hundred female turtles were fitted on their rear flippers with tiny data recorders, specifically developed at IPHC. These recorders will tell us about their migrations over the next two or three years between two consecutive nesting seasons, and help solve an intriguing mystery, and one of MIRETTE's fundamental objectives: Why are these reproductive seasons separated by two or three years?

We know very little about these giant turtles, on average 400 kg and 2 m long. "No one can even really tell you how long they live," adds Georges. Nonetheless, their lifespan must be of at least several decades, as the same animals marked in the 1970s are still making their way back to Les Hattes. Researchers from IPHC are trying to determine whether the conservation efforts made to protect the leatherback turtle, considered "critically endangered" since 2000 by the International Union for Conservation of Nature, have been of any help. To find out, Georges and colleagues are attempting to learn more about the day-to-day activities of these females during their migration.

This year, very few turtles fitted with recorders in 2008 will return. "Only 1 to 2% of females return after a year," says Georges. The researchers will nevertheless monitor the turtles that arrive, measure and weigh the animals, count the eggs and sample blood and subcutaneous fat. "Blood analysis tells us about the turtles' nutritional and hormonal state," explains Georges. Their fat reveals what they have eaten and in what region, because biochemical and isotopic studies (carbon and nitrogen) can show whether the diet was mostly made up of jellyfish, squid, fish, or small crustaceans–as well as where these foods came from. In 2008, 2000 female turtles dug nests in the sand of Les Hattes, out of a world population estimated to be around 30,000–there is no data on the number of males. An encouraging factor was that four out of ten arriving turtles were unmarked, showing that the leatherback population in the Atlantic is growing. During this nesting season, each female returns to make a nest every ten days for two to three months, and will lay an average of 80 eggs in each.

Researchers need to be patient, since most of the turtles they fitted with recorders last year will not return before 2010 or 2011. These recorders are the size of a small matchbox and weigh 60 g. They have probes to record pressure, temperature, and light, and save this data every one or two minutes on a memory card. The recorder runs on a battery that lasts four years. "This is considerable progress, compared to the satellite-tracked Argos beacons we used before, which are expensive, heavy, and only work for a few months. These older devices were inadequate for studying the entire life cycle and hampered the turtles' movement, as we recently showed that the beacon and its harness reduced their swimming speed by 20%."

To detect the migrations of these leatherback turtles, the team uses a clever method: The recorders measure the light levels around the animals when they surface. The researchers calculate the time of sunrise, sunset, and noon for each day from this data. Then, using astronomical calculations, they can obtain the daily latitude and longitude of a turtle's position. This method has an accuracy of 50-100 km, which can be improved by IPHC-developed GPS trackers, fitted on 40 of the 100 turtles being followed.

Using this latest equipment, the MIRETTE team hopes to trace the leatherbacks' entire journey and gain insight on their feeding behavior. "We will not only know more about their diet, but also see how they adapt to the rapid increase in jellyfish populations expected with global warming," Georges concludes.

Denis Delbecq

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2. Migration et reproduction chez les tortues marines: trajectoires écophysiologiques.

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OLIVIER VOINNET

Making Noise about Gene Silencing

Olivier Voinnet has been awarded the 2009 EMBO Gold Medal for his pioneering work on small interfering RNA (siRNA) in plants: the latest award for this young researcher on the path to a model career.

At just 36, Olivier Voinnet is already used to receiving awards. The prestigious European Molecular Biology Organization (EMBO), of which he is a permanent member, has just awarded him its coveted 2009 Gold Medal. But that is only the last in a series of prestigious prizes. Last year, four years after a bronze medal, CNRS rewarded him with a silver medal, an extremely rare privilege for such a young researcher. He has also received the 2006 Grand Prize of the Schlumberger Foundation for education and research, and the 2007 Liliane Bettencourt Life Sciences Award.

This young geneticist, a senior researcher at CNRS' IBMP[1] in Strasbourg, specializes in the role of a particular type of ribonucleic acid (RNA), which is currently paving the road to his success.

RNA is the "inverse" copy of deoxyribonucleic acid (DNA), which carries the genetic code of every individual organism. RNA is mostly known for its role as a messenger: It transfers information from the genetic code to the cellular machinery that constructs proteins in all living things. "But other, much smaller, pieces of RNA also exist, and these work as inhibitors," explains the young researcher. In plain language, they block the expression of a gene. This is the RNA silencing phenomenon, discovered in the 1990s, which Voinnet heard about as an undergraduate and which inspired him to study molecular biology after a few dissatisfying years in "prep classes." "Rote learning without critical thinking didn't interest me at all..." he remembers, as someone much more interested in fundamental processes. As RNA interference had just been discovered in plants,[2] he chose plant biology for his master's degree at France's National Agronomics Institute, where he specialized in biodiversity and adaptation of cultivated plants. "This RNA, about which we have known very little for a long time, is invaluable for plant development," he explains. "It allows stem cells, all initially identical, to differentiate and become cells of a stem, a leaf, etc., with all their specificities. And once this identity has been acquired, it needs to be maintained." In fact, a cell would quickly lose control if the microRNAs weren't there to inhibit deregulation.

© J.-F. Dars/CNRS Photothèque

During his PhD in England in the laboratory of his mentor David Baulcombe, a pioneer in RNA interference, Voinnet discovered another facet of these microRNAs: their antiviral role. This earned him the "Young Scientist of the year award" in 2002 from the prestigious magazine *Science*. Could these interfering RNAs have medicinal applications? "It's still too soon to envisage medical uses," he quickly adds, even though in the US they have already been tested against the AIDS virus and for cases of macular degeneration, a disease of the retina which causes loss of central vision. "Injecting RNA mimicking our own genetic regulation system to cause interference is still very hazardous, as we don't yet have a full understanding of the underlying mechanism," he warns.

Just like these small silencing RNAs which are now making themselves heard, Voinnet's discoveries could very well contribute to a revolution in genetics. Looking ahead, we could perhaps one day simply "cancel" any gene expression *in vivo* using knowledge from this research.

Charline Zeitoun

1. Institut de biologie moléculaire des plantes (CNRS).
2. In 2006, eight years after their fundamental discovery on this subject, the Americans Andrew Z. Fire and Craig C. Mello received the Nobel Prize in medicine.

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AWARDS

The Fondation France-Israel Prize

On June 11th, the Fondation France-Israel awarded its Prix d'Excellence Scientifique to two young researchers for their advances in renewable energy, the chosen theme for the 2009 prize. On the Israeli side, the prize goes to Michael Bendikov from the Weizman Institute, who is developing materials whose properties could be used to improve the efficiency of solar cells. On the French side, the prize goes to Yves Delannoy, professor at the Institut polytechnique de Grenoble and a researcher at the SIMAP lab.[1] He has developed the use of electromagnetic fields to fine-tune processes for purifying the silicium used in photovoltaic cells. Awarded each year, this prize, sponsored by CNRS, aims to highlight and bring together researchers working in neighboring fields, and to favor exchanges between the two countries.

> www.fondation-france-israel.org

1. Laboratoire Science et ingénierie, des matériaux et procédés (CNRS / Université Grenoble-I / Institut polytechnique de Grenoble).

INTERNATIONAL YEAR OF ASTRONOMY 2009

The Mysteries of our UNIVERSE

The universe was born approximately 14 billion years ago. First to appear were the elementary building blocks of matter, soon to be followed by light. As it rapidly began to expand, matter started forming huge structures–clusters, filaments, and sheets–within which appeared the first galaxies, gigantic assemblages of billions of stars. In some cases, these stars were surrounded by a swarm of planets on which life could emerge, as it did on Earth. From the Big Bang to the emergence of the first living cells, how each of these stages begin in this epic drama is still subject to much speculation. To celebrate the International Year of Astronomy, CNRS International Magazine looks into the mysteries of the origins of the universe.

Infinity in a Second

There are mysteries we may never solve. The origin of the universe is one of them, and one that physicists, cosmologists, and philosophers have puzzled over for millennia. Yet it was only in the early 20th century that scientists discovered that they could travel back in time, at least through their equations, rewinding its history all the way back to its origin, the famous Big Bang. And although there is a long way to go before scientists reach a consensus on the exact scenario, cosmologists are increasingly convinced that it is within their grasp.

Traveling back through time, one may be surprised to learn that the greatest questions surround a very short time-period, namely the universe's first second. As Jean-Philippe Uzan, from the Astrophysics Institute in Paris (IAP),[1] points out, "After the first second of the Big Bang, the temperature was close to 10 billion kelvins, and everyone is more or less in agreement about what happened (*see illustration*). There is no longer any doubt that the universe was expanding then and that it emerged from a hot, dense phase."

THE ORIGINAL CONTENT

In fact, central to the problem is understanding what happened during this very first second, starting with the question of what the universe was made of at that moment. "And to find out what type of matter the universe contained, we need to turn to particle physics," explains Uzan. "The problem, though, is that the current model–the standard model–is only valid up to energy densities that are rapidly exceeded as you go back in time." For example, cosmologists believe that one millionth of a second (10^{-6} second) after the Big Bang, quarks joined together to form protons and neutrons. But like all the other particles of matter, quarks appeared a long time before, probably before 10^{-12} seconds after the Big Bang. For that time-period, known as the Grand Unification Era (*see illustration p. 20*), we have yet to construct a theory that describes elementary particles and their interactions.

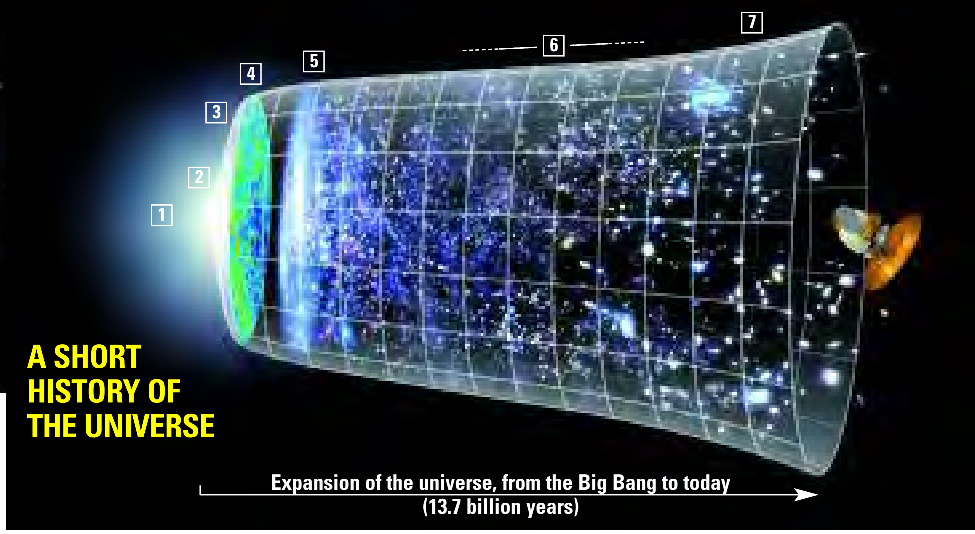
THE STANDARD MODEL describes elementary particles and their strong, weak, and electromagnetic interactions. Gravitational force does not yet fit into the theory.

Although the universe was already populated with particles that we know–quarks, electrons, etc.–it must also have harbored other particles that are today unknown. Physicists think that some of these particles might make up the elusive "dark matter." Although it has never been directly observed, its gravity is thought to give the universe and galaxies their structure, and scientists believe it is far more abundant than ordinary matter. Furthermore, according to our current theoretical understanding, at this time in the distant past, there should have been as much matter as antimatter.

Scientists believe that every particle is associated with an antiparticle–absolutely identical to it, but with an opposite electrical charge. For instance, the antiparticle of the electron is the positron. Yet astonishingly, today's universe contains almost nothing but ordinary matter, and the reason for this lack of symmetry is not yet understood. Something CERN's[2] giant accelerator, the Large Hadron Collider (LHC), might be able to elucidate in the coming years. "It will give us access to physics that goes beyond the standard model," adds Uzan. This means that we should soon improve our understanding of the state of matter during the universe's primordial phase."

HOW IT UNRAVELLED

When it comes to the geometry of the primordial universe, cosmologists have constructed elegant theories about the evolution of space-time, a concept first introduced by Einstein in his >



A SHORT HISTORY OF THE UNIVERSE

CNRS International Magazine n° 14 July 2009

> theory of relativity. For instance, specialists believe that approximately 10^{-35} seconds after the Big Bang, the universe underwent an extremely rapid phase of expansion–called "inflation"–during which its size increased by an incredible several billion orders of magnitude (*see illustrations p. 19 and below*). For Thibault Damour, tenured professor at France's Institut des Hautes Études Scientifiques (IHES), "there is a broad consensus on inflation, although it remains a speculative model." The European Space Agency's (ESA) Planck satellite, successfully launched this May, might shed some light on the exact nature of inflation, by measuring its precise effects on the properties of fossil radiation, known as the cosmic microwave background (CMB).

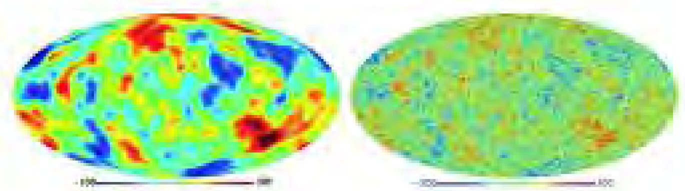
THEORY OF RELATIVITY
A theory developed by Einstein to describe gravity and in which the notions of space and time are replaced by space-time. The geometry of this space-time is determined by the matter distribution and is the source of the gravitational force.

IN THE BEGINNING WAS NAUGHT

Turning back the clock further, we come to what scientists believe to be the last stage before the Big Bang: the "Planck wall," which took place approximately 10^{-43} seconds after the Big Bang. At this stage, today's physics is powerless. As Uzan puts it, "during this period, gravity becomes quantum– and the problem is that we don't yet have a quantum theory of gravity." There is a need for a theory that unifies general relativity, which describes how space-time changes under the effect of gravity, and quantum mechanics, the theory of the infinitesimally small. This has led to a host of hypotheses that paint a truly mind-boggling picture of the birth of the universe. Many of these theories stem from string theory. Extremely complex and still highly speculative, string theory emerged in the 1970s with the aim of uniting the two irreconcilable theories of physics: quantum mechanics and gravity. According to this theory, the fundamental building blocks of the universe are not discrete particles but tiny linear filaments called strings. The strings vibrate in a space-time that has many more than our classical four dimensions (the three dimensions of space, plus that of time).

Some researchers have constructed hypotheses that envisage a time before the Big Bang. For instance, Pierre Binetruy, from the Astroparticle physics and cosmology laboratory (APC)[3] in Paris, has developed a theory where a Big Bang is created by the collision of two four-dimensional universes. "We hypothesize that there are several universes which sometimes collide," Binetruy explains. "Admittedly, with this kind of approach we don't know about the physics at the precise moment of the Big Bang, but are able to describe in detail the state of the universe immediately before and after." In this hypothesis, the universe therefore existed before the Big Bang, which was nothing more than one episode in a never-ending history.

COSMIC MICROWAVE BACKGROUND (CMB) RADIATION
This radiation, emitted some 380,000 years after the Big Bang and still detectable today, is a precious witness to the very young universe. It therefore carries essential information about inflation.



Thermal map of the cosmic background radiation, from the COBE mission (left), then in higher resolution by Planck (right). Temperatures increase from blue to red.

Meanwhile, Damour, together with Marc Henneaux and Hermann Nicolai, has developed an approach in which space-time emerges from an earlier situation: "According to our theory, as you approach the singularity–the Big Bang–space vanishes. Nothing remains but time, from which space emerged." As Damour himself recognizes, "all this is highly speculative, but it is nonetheless extremely precise mathematically, and ties in with sound parts of string theory."

THE BARRIER OF PROOF

Will we ever be able to confirm, or simply derive facts from these abstract theories? Indirectly, perhaps. If physicists manage to demonstrate the validity of string theory, if only in part, it will make some of these hypotheses more credible. "I believe that cosmology is at a turning point," says Nathalie Deruelle, also from APC. "Admittedly, a new theoretical model comes out every day. A new understanding of our universe will surely emerge from this ferment of ideas."

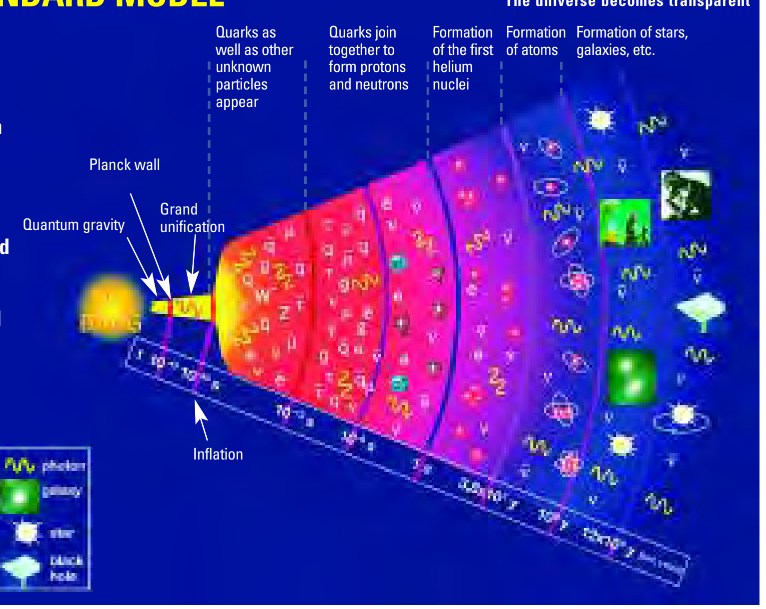
Will such a model enable us to understand the mysteries of the origin of the universe? It's hard to say. According to Étienne Klein, from the French Atomic Energy Commission (CEA),[4] "to make headway, [science] needs an 'already there,' a starting point–one made up of existing principles, laws, or objects. However, the absolute origin of the universe is not part of the 'already-there,' since it corresponds to the emergence of something in the absence of any other thing. [...] That's why the question of the origin of the universe remains unanswerable."[5] Perhaps a purely philosophical question after all.

Mathieu Grousson

1. Institut d'astrophysique de Paris (CNRS / Université Paris-VI).
2. European Organization for Nuclear Research.
3. Astroparticule et cosmologie (CNRS / CEA / Université Paris-VII / Observatoire de Paris).
4. Commissariat à l'énergie atomique.
5. Etienne Klein, "Mystères de l'Univers," *Le Monde*, November 21, 2008.

THE UNIVERSE ACCORDING TO THE STANDARD MODEL

Since the Big Bang, the primordial universe has gone through a number of stages, during which particles, and then atoms and light gradually emerged, followed by the formation of stars and galaxies. This is the story as told by the "standard model" theory used today.



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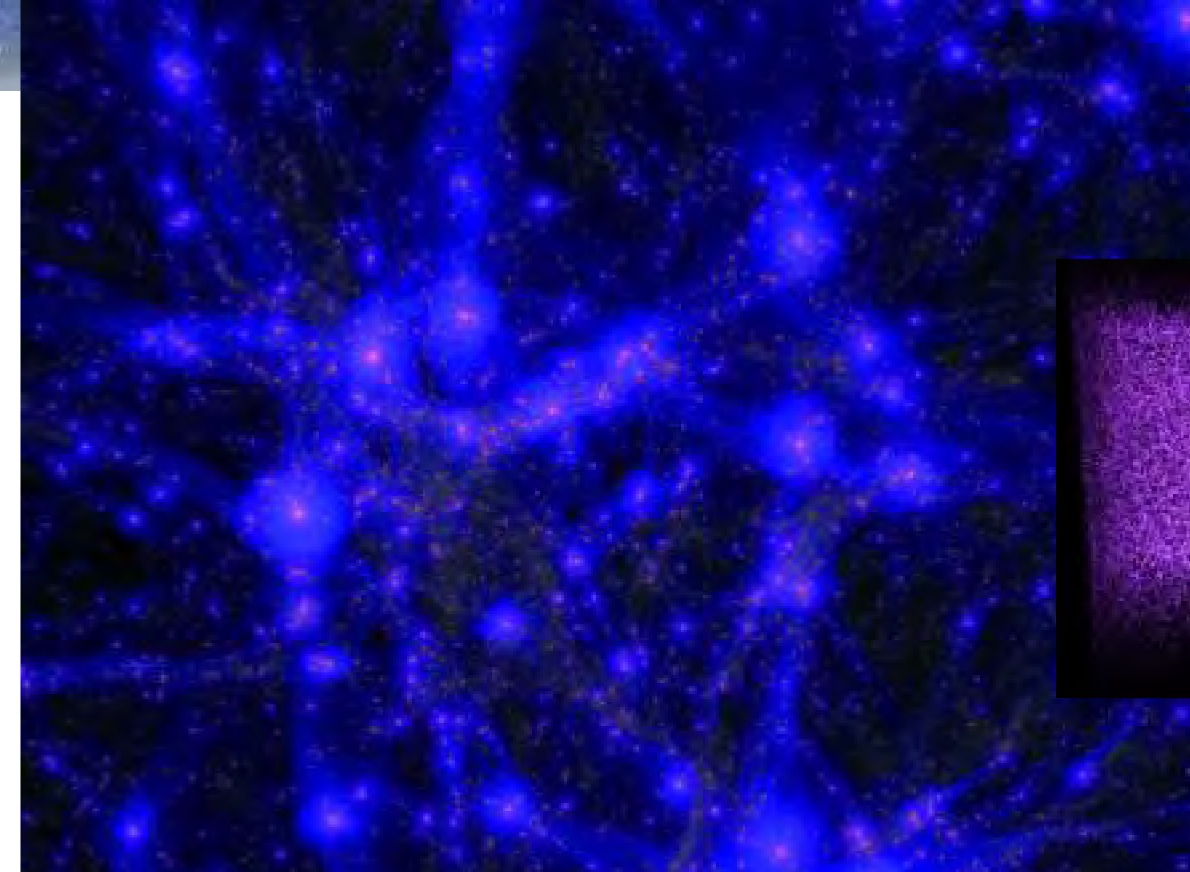
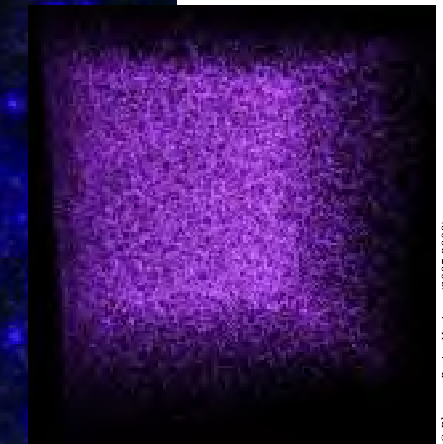


Cosmological Structures



The evolution of part of the universe–a chunk 150 million light years across–has been modeled by the Horizon project team. Long filaments of matter surrounded by almost totally empty voids can be seen (opposite). Another simulation (above) covers nearly half the universe.

Stars are grouped together in galaxies. Galaxies form clusters, filaments, and sheets. On a large scale, the universe appears highly organized. But just how was it able to form these patterns that alternate between empty voids and regions of highly concentrated matter?

In other words, how was the primordial soup able to give rise to such complexity? According to François Bouchet, from IAP, "ever since Georges Lemaître's work in the 1920s, the Belgian astronomer who first formulated the Big Bang theory, cosmologists have believed that the essential mechanism by which structures form is gravity. This is thought to have acted on the initial conditions of the universe, which contained tiny spatial fluctuations in density." So a few lumps in the primordial soup, together with the force of gravity, were probably enough to give rise to the complexity we observe today.

THE COMPOSITION OF THE UNIVERSE
The universe is thought to be made up of 0.4% visible ordinary matter, 26.6% "hidden" dark matter (of which 3.6% is non-visible ordinary matter), and 73% dark energy. Dark energy is a mysterious force which has existed since the first instants of the universe, and which has recently been accelerating its expansion.

CLUES FROM FOSSIL RADIATION

In the 1980s, cosmologists began hypothesizing that in the universe's very first moments, space-time must have been perturbed by irregular fluctuations of quantum origin. "These ripples then expanded to cosmological distances," Bouchet continues. These first instants have bequeathed an invaluable legacy to astrophysicists, encoded in properties of the cosmic microwave background radiation (CMB) first discovered in 1964. In a way, CMB represents the first light emitted by the universe. NASA's Cosmic Background Explorer satellite (COBE), operational during the 1980s, revealed the existence of tiny irregularities in the fossil radiation, which are the imprint of these primordial fluctuations. Their amplitude and distribution in the sky were subsequently mapped more accurately by NASA's Wilkinson Microwave Anisotropy Probe satellite (WMAP). Once examined in the light of theory, these data enabled scientists to get a better understanding of the composition of the universe. This was the missing ingredient needed to develop models that could accurately simulate the formation of the structures of the universe.

Such models are at the heart of the French project Horizon[1] which has been ongoing since 2001. It is the most ambitious cosmological numerical simulation project in the world, and brings together around 20 researchers, several of whom are from CNRS. The aim is to simulate the evolution of a significant chunk of the universe over a period of 13.5 billion years. "Just as climatologists model climate by numerically solving the physical equations that govern its evolution from an initial configuration, we have reconstructed the history of the universe," explains project-leader Romain Teyssier, from AIM,[2] a leading French astrophysics laboratory. Scientists fed into their computer the initial content of the universe and the spatial distribution of the primordial fluctuations as revealed by the CMB, and started solving the equations of gravitation from 380,000 years after the Big Bang until today. "We placed ourselves in an expanding universe as described by general relativity, and which integrates a priori the effects of dark energy. And we computed the evolution of two 'fluids,' one representing dark matter, the other ordinary matter," Teyssier explains.

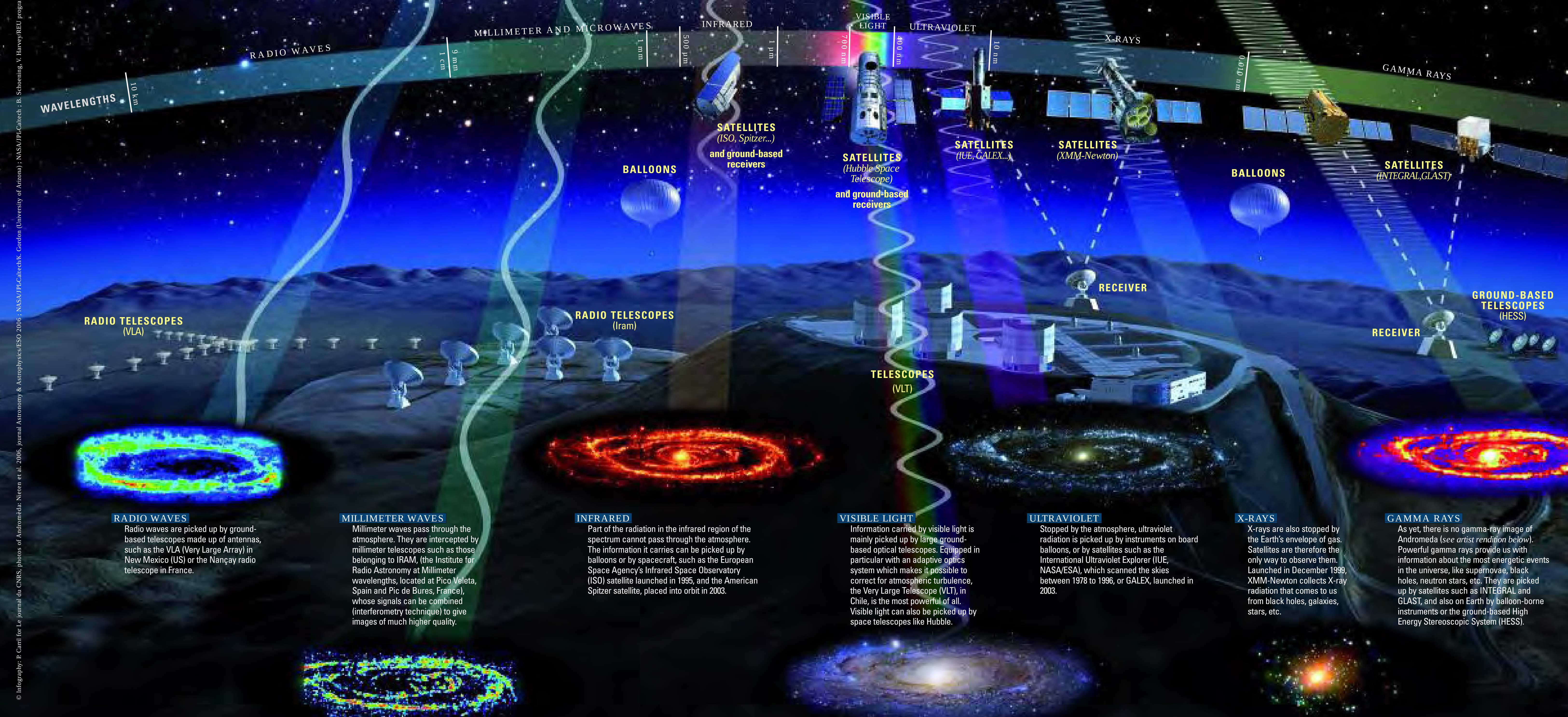
MODELING THE BIRTH OF THE UNIVERSE

In an initial model carried out in 2006-2007, the Horizon researchers simulated the evolution of a chunk of the universe 150 million light years across. This enabled them to observe the formation of galaxies that were astonishingly close to reality. In summer 2007, they repeated the experiment using the CEA's Bull civil supercomputer. This time, they simulated a sphere with a radius of six billion light years with no less than 70 billion particles. Amazingly, the simulation reconstructed a universe as it would be seen by an Earthbound observer looking at half of the visible universe.

Once processed, the images obtained were staggering, and almost identical to real photographs. As their 'model' universe became older, the astrophysicists observed how the primordial fluctuations became amplified under the effect of gravity, with visible matter falling into increasingly concentrated regions of Continued page 24 >

A MULTIFACETED GALAXY

This illustration is composed of various views of the Andromeda galaxy, the spiral galaxy closest to ours, situated a mere 2 million light years away, and in many ways very similar to our own Milky Way. Ground-based telescopes, balloons, and satellites, of which only a few famous examples are shown here, can be used to observe the same celestial object at different wavelengths. All these images make up the different pieces of a jigsaw. When they are put together, they make up a complete picture of the celestial object. When the radiation is invisible to the eye, the images are colorized so that the subtle differences in intensity of the radiation emitted by the body can be seen. In the early 17th century, when Galileo first pointed his telescope to the heavens, all he could see was the visible light that comes to us from the stars and planets. Today, when astronomers study a celestial body, they are able to make use of the information carried by the entire electro-magnetic spectrum, of which visible light is only a small part. Sometimes the electromagnetic radiation (like radio waves or visible light) can pass through Earth's atmosphere, and all that is needed are ground-based receivers to pick up the radiation and obtain information about distant galaxies or nearby planets. But other types of radiation, such as X-rays and ultraviolet, are stopped by Earth's atmosphere, making instruments in space the only ones able to collect the information they carry. However, all these different types of electromagnetic waves are not the universe's only messengers. Today, scientists are on the lookout for cosmic rays with the Pierre Auger Observatory, neutrinos using the underwater detector Antares, and, soon, gravitational waves with the VIRGO detector. Information can also be obtained from samples brought back by spacecraft.



RADIO WAVES
Radio waves are picked up by ground-based telescopes made up of antennas, such as the VLA (Very Large Array) in New Mexico (US) or the Nançay radio telescope in France.

MILLIMETER WAVES
Millimeter waves pass through the atmosphere. They are intercepted by millimeter telescopes such as those belonging to IRAM, (the Institute for Radio Astronomy at Millimeter wavelengths, located at Pico Veleta, Spain and Plc de Bures, France), whose signals can be combined (interferometry technique) to give images of much higher quality.

INFRARED
Part of the radiation in the infrared region of the spectrum cannot pass through the atmosphere. The information it carries can be picked up by balloons or by spacecraft, such as the European Space Agency's Infrared Space Observatory (ISO) satellite launched in 1995, and the American Spitzer satellite, placed into orbit in 2003.

VISIBLE LIGHT
Information carried by visible light is mainly picked up by large ground-based optical telescopes. Equipped in particular with an adaptive optics system which makes it possible to correct for atmospheric turbulence, the Very Large Telescope (VLT), in Chile, is the most powerful of all. Visible light can also be picked up by space telescopes like Hubble.

ULTRAVIOLET
Stopped by the atmosphere, ultraviolet radiation is picked up by instruments on board balloons, or by satellites such as the International Ultraviolet Explorer (IUE, NASA/ESA), which scanned the skies between 1978 to 1996, or GALEX, launched in 2003.

X-RAYS
X-rays are also stopped by the Earth's envelope of gas. Satellites are therefore the only way to observe them. Launched in December 1999, XMM-Newton collects X-ray radiation that comes to us from black holes, galaxies, stars, etc.

GAMMA RAYS
As yet, there is no gamma-ray image of Andromeda (*see artist rendition below*). Powerful gamma rays provide us with information about the most energetic events in the universe, like supernovae, black holes, neutron stars, etc. They are picked up by satellites such as INTEGRAL and GLAST, and also on Earth by balloon-borne instruments or the ground-based High Energy Stereoscopic System (HESS).

> dark matter (dark matter "halos"), forming stars and galaxies. The galaxies organized themselves into a kind of web-like foam, leaving huge spaces completely devoid of matter. "Our results are in extremely close agreement with very large-scale surveys of the galaxies," Teyssier points out. These include the VIMOS VLT Deep Survey (VVDS), which uses the Visible Multi-Object Spectrograph (VIMOS) on ESO's Very Large Telescope (VLT) in Chile, to quantify the evolution of 90% of the history of the universe.

"This agreement validates the scenario of a universe in which the formation of structures is dominated by the gravitational attraction exerted by the dark matter halos that emerged from the primordial fluctuations," continues Teyssier. In other words, these famous primordial lumps would really be at the origin of our universe's organization.

SEEING BEYOND THE LIMITS

So do scientists now have a definitive answer as to how these structures formed? Not yet. As Guilaine Lagache, from IAS[3] in Orsay explains, "these simulations account for the evolution of dark matter halos very well. But we still have to use various empirical recipes for the physics of ordinary matter, hiding the fact that we can't grasp the physics of the phenomena as a whole."

For instance, astrophysicists still have to make much theoretical headway before being able to model the formation of some very "real objects," like the giant galaxies that appear some three billion years after the Big Bang, too early to fit with the theory. As for Teyssier, he's already dreaming of a future generation of computer models which would enable us to recreate the entire visible universe, or even beyond. "These types of models could let us see much farther than any real sky observation instrument we design," he concludes.

Mathieu Grousson

1. www.projet-horizon.fr
2. Astrophysique interactions multi-échelles (CNRS / CEA / Université Paris-VII).
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ECHOES OF THE BIG BANG

Information about the history of the universe comes to us via electromagnetic radiation in various forms such as visible light, infrared, radio waves and high-energy gamma rays.[1] Scientists are now also hoping to be able to detect gravitational waves, distortions in space-time that move at the speed of light. Predicted by Einstein's theory of general relativity, they are believed to have been produced at the birth of the universe or during cataclysmic events such as the explosion of stars at the end of their life. "Unlike light, these waves interact very weakly with matter and travel through space without being significantly altered, whatever the medium they pass through," explains Éric Gourgoulhon, from LUTH[2] in Meudon. But this property also makes them very hard to detect. In the next few months, this will be the mission of the European detector VIRGO, currently being built near Pisa, Italy. "VIRGO should enable us to access many compact objects from which light never escapes, such as the cores of supernovae, or systems of black holes that orbit each other," Gourgoulhon says. In ten years or so, the space interferometer LISA may detect very low frequency gravitational waves that would be undetectable on Earth. This would provide us with information emitted just after the Big Bang, enabling us to go back beyond the fossil radiation emitted 380,000 years after the birth of the universe.

M.G.

© ESA

Artist rendering of LISA, three spacecraft that fly in a triangle formation searching for gravitational waves.

1. High energy photons emitted during very violent events, such as the explosion of massive stars (supernovae).
2. Laboratoire de l'Univers et de ses théories (CNRS / Observatoire de Paris / Université Paris-VII).

Contact: Éric Gourgoulhon,
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Above: The Sombrero galaxy, M104, with its spectacular bulge, photographed by the Very Large Telescope (VLT) in Chile.

Right: M51, known as the Whirlpool spiral galaxy, and its companion galaxy NGC 5195.

© NASA, ESA, S. Beckwith (STScI) and the Hubble Heritage Team (STScI/AURA)

Enter the Galaxies

Take several hundred billion stars, add a considerable mass of gas, sprinkle some dust, and you have a galaxy–one of the "islands" in space where the universe's visible matter is concentrated. To reconstruct their evolution and origins, astronomers also use light, since the light arriving from far away informs on past events of our universe, which is approximately 14 billion years old.

"It turns out that the further away you look, the less galaxies look like our own," explains Pierre-Alain Duc from AIM.[1] Far, far away, both in distance and in time, at a period when the universe was one or two billion years old, and where observations are still too scarce, there is an abundance of blue dwarf galaxies–small structures containing a lot of gas and rich in hot stars. Then, a little closer to us, when the universe was half the age it is today, galaxies were irregularly shaped and not clustered together. Even closer to our own Milky Way, clusters start forming, which can sometimes contain up to a thousand galaxies. Within these clusters, most of them are spiral galaxies that attract and stabilize each other. Such galaxies are complex, evolved structures with a central bulge and arms that stretch out into space.

> At every moment, we see the Sun as it was 8 minutes earlier: our own star is at a distance of 8 light minutes, which means that its light takes 8 minutes to reach us. Similarly, we see a star located 1000 light years away as it was a 1000 years ago.

MERGING STRUCTURES

"This reflects the general evolutionary model of the universe," Duc continues. "Today's elaborate objects–like bulge-rich spiral and elliptical galaxies grouped together in clusters–are the result of the merging together of smaller, isolated galaxies which were born shortly after the Big Bang." This evolutionary model–called hierarchical–tells us that in the universe, under the effect of the gravitational attraction exerted by matter, small structures merge little by little, forming bigger, more elaborate structures as they evolve.

> **ACTIVE GALACTIC NUCLEI (AGN)**
> These are compact regions located in the center of certain galaxies. They are extremely luminous at wavelengths in several regions of the electromagnetic spectrum. It is widely believed that these regions are home to giant, so-called supermassive black holes.

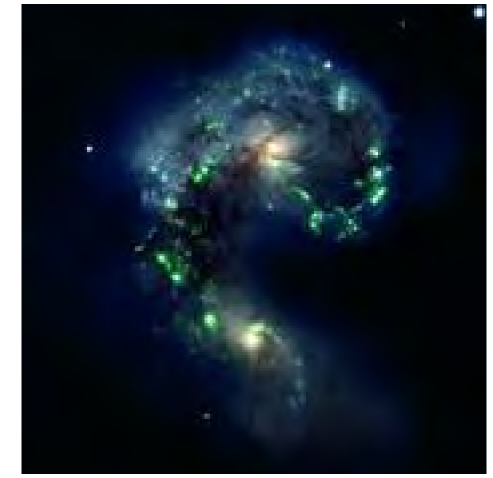
But this hierarchical model, a broad outline of the history of galaxies, does not however account for certain observations. For instance, why do we find spiral galaxies–which, as we have seen are highly evolved structures–in the early universe, a mere one billion years after the Big Bang? This puzzling fact, among many others, appears to show that the hierarchical model has its flaws. "We now believe that another phenomenon could also play a part: the very tenuous gas found between the galaxies," Duc explains. The small structures that are already formed attract this extremely thin primordial gas. And this accretion speeds up their evolution. So, right from the early age of the universe, collisions and interactions got under way, sometimes forming massive objects such as active galactic nuclei (AGN).

It is gravity exerted by stars and gas that leads to coalescence of small structures and attraction of intergalactic gas. But for specialists, there is simply not enough visible matter to enable these structures to hold together, and that is where "dark matter" comes in.

The problem first came to light in the 1970s, when, after studying 200 galaxies, the American scientist Vera Rubin observed that the speed of the peripheral stars was far too high given all the mass visible in the central regions. In order to explain why these stars don't escape from their galaxy, it is necessary to postulate the existence of hidden matter that holds them in through its gravitational force. "We can observe the same thing for larger structures, such as clusters of galaxies," explains Françoise Combes, from LERMA,[2] a lab specialized in astrophysical matter. This "hidden" dark matter is thought to make up 22.6% of the entire universe.

HIDDEN MATTER

To solve the theoretical problem raised by this invisible and unfound dark matter, the hypothesis put forth by Israeli scientist Mordehai Milgrom, from the Weizmann Institute, required that Newton's law of universal gravitation be modified.



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Above: NGC 4038 and 4039, known as the "Antennae," a pair of interacting galaxies.

According to the MOND theory (for Modified Newtonian dynamics), at low acceleration (for instance, far from the center of the Milky Way) the force of gravity falls off less quickly: it is inversely proportional to the distance, rather than to its square. This theoretical trick thus makes it possible to do without the enigmatic dark matter. Although we are far from reaching consensus on this theory, it resurfaces on a regular basis. This is because dark matter, which is being actively searched for in all its forms, has remained much too elusive.

Researchers are not giving up, however, now focusing on a small part of dark matter (3.6% of the entire universe) that might be made up of invisible ordinary matter and reside in the outskirts of galaxies. "Galactic outer parts contain a large amount of cold gas in the form of hydrogen molecules, which doesn't glow and remains undetectable except for its gravitational effects," Combes explains. There are other hypotheses that postulate the existence of massive exotic particles, but they are thought to be quite hard to detect since they react very little with ordinary matter. Such particles could be found in the halos of galaxies or in filaments of gas in the intergalactic medium. The only way to spot them would be to catch them in action, bending light rays and distorting images of distant stars.

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> **NEWTON'S LAW OF UNIVERSAL GRAVITATION**
> The law postulates that the gravitational force between two objects is inversely proportional to the square of the distance between them.

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The Life of Stars

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Close-up of the famous Horsehead nebula, in the Orion constellation. At the base of the head, young stars in formation can be observed.

Within galaxies, there exist cold clouds where countless infernos are waiting to be born: the stars. These stellar nurseries–or molecular clouds, as astronomers call them–do not emit visible light, and appear on astronomical images as dark regions that stand out against colorful wisps of gas. "These are regions where the gas is dense: 1000 to 10,000 particles per cubic centimeter, whereas elsewhere in the interstellar medium, there are between 1 to 100 particles per cubic centimeter. In addition, these regions are free from any stars which might warm them up," explains Patrick Hennebelle, from LERMA.[1] As a result, their temperature fluctuates around -263°C (10 K).

A BRIGHT FUTURE

Using numerical simulations and ground-based telescope observations, astronomers have managed to reconstruct in broad outline the birth and evolution of stars. And this all begins when matter collapses in on itself. A fragment of around one thousandth of a solar mass, made up of dust and gas, suddenly contracts, or collapses, under the effect of its own gravity. It becomes isolated from the surrounding gas, heats up, and forms the embryo of a star–known as a protostar. A small part of its cocoon of gas and dust then forms an accretion disc around the nascent star, which has already begun to glow, "heated by its own contraction," as explains Nicolas Grosso, from the Astronomical Observatory in Strasbourg.[2] When the temperature in its core reaches about 10 million degrees Celsius, thermonuclear fusion reactions get under way, as the star starts converting its hydrogen into helium. The star's long life–called its main sequence–now begins, which can last anywhere between several million years–for the most massive stars–to over ten billion years for the very lightest stars, whose mass does not exceed a tenth of the Sun's mass. Our Sun, for example, is on its main sequence.

Over the course of its life, the star continues to consume its hydrogen. Once the hydrogen has been converted into helium in its core, the fusion of the peripheral hydrogen suddenly begins, turning the star into a red giant, which will continue to shine by burning increasingly heavy elements.

UNSTABLE BEGINNINGS

So just what are the first events in the life of a star? "When the protostar forms, it is surrounded by a rotating disc of dust and gas, which lasts for several million years," explains Jérôme Bouvier, from LAOG.[3] This is quite a unique environment. "The coronae of young stars emit 10,000 times more X-rays than the Sun at the maximum of its activity cycle," Grosso explains. X-ray flares, which are of magnetic origin, are also far more frequent and energetic than on the Sun." These heat and ionize part of the matter in the disc, which falls onto the star. But as these stars continuously acquire matter, they also eject matter at right angles to the disc. Bouvier explains that "these emissions slow down the surrounding disk, as its matter is also blasted by X-rays and UV radiation from the star." As a result, the circumstellar disc disappears and the star, which is still contracting, spins at an increasingly faster rate. This stage lasts several million years. "Understanding the early childhood of stars is crucial, for this is also when planets can form." Once the circumstellar disc is gone, any hope to form a planet around the star vanishes forever. "Then, nuclear fusion reactions start within the star, fully bringing it into adulthood.

> **CONVECTIVE ZONE**
> The outer layer of a star, where matter is constantly stirred up, removing heat from the core: the hottest part rises, cools, and falls again, and the cycle starts all over again.

STAR MYSTERIES

From birth to adulthood, the life of stars has become fairly familiar to researchers, but many questions remain unanswered. For example, just what goes on inside stars? Recently, CNES's COROT satellite measured the oscillations of the surface of three stars similar to our own Sun, a field known as stellar seismology. The amplitude of these oscillations helps us build hypotheses about the internal structure of these stars, since hollow and filled objects vibrate differently. Through these findings, astronomers hope to measure the depth of part of the convective zone.

Another enigma about stars concerns their mass at the moment of their birth. In the Milky Way, for instance, the mass of new stars formed per year is the equivalent of three solar masses. But how many of these end up being small, medium-sized, or large stars? "Various theories have been proposed and are still being debated. One of them is that at their birth, most stars weigh about 0.3 solar masses. Then, as a result of turbulence in the medium, some stars are swept away and travel through matter-rich regions, thus growing by accretion of gas," Hennebelle explains.

Another unresolved question has to do with the environment necessary for star formation. For example, astronomers are surprised by the low rate of star birth in our part of the universe. As previously mentioned, every year, the mass of new stars formed in the Milky Way is only the equivalent of three times the mass of our own Sun, with an average number of 10 stars formed. "And yet the reservoir of gas able to form stars is of the order of a billion solar masses," explains Hennebelle. "Assuming that only gravity operates in this medium, and taking into account the time needed to form a protostar, there should be 300 times more formed every year!" Specialists believe there must be a phenomenon that counters the action of gravity. It was long suspected that this might be a magnetic field, but such a field can only move particles that carry an electric charge (like ions), and cold clouds are electrically neutral since they are made up of molecular gas.

In the past five years, scientists have suggested turbulence in certain regions of the universe might explain such a low rate of star birth. It turns out that the cold, molecular cloud where stars are born is a highly turbulent medium. Such instability may counter the gravitational collapse that triggers the formation of future stars, and considerably slow down the rate at which they form. There are various possible candidates as to the cause of this turbulence, such as the powerful jets of matter produced by young stars, or the explosions of old stars–supernovae–that blast off their outer envelopes into space, and a host of other phenomena.

With the recent launch of the Herschel space observatory and the Atacama Large Millimeter Arrays presently under construction, significant advances are expected regarding our knowledge of the star formation process in coming years.

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Planets Under Construction

There are probably billions of planets orbiting their suns in our galaxy alone, and every month, new ones are discovered. Exoplanets–planets that exist outside our own solar system–have definitely garnered attention in the last ten years. But, as amazing as these discoveries are, they haven't yet helped us solve a basic mystery: the birth of planets. Since they are so distant, exoplanets have so far yielded very little information about the conditions in which they formed. So in the meantime, astronomers continue to make do with the planets in range of their instruments: the ones in our own solar system.

To understand the events that led to the birth of planets, researchers have built a model of the first ten million years that followed the appearance of our star at the heart of its interstellar cloud. When our star formed, the region of gas and dust surrounding it flattened out. In this so-called protoplanetary disc, particles of matter, ranging from micrometer- to centimeter-sized grains, began sticking together to become massive balls of matter called planetesimals, which continued to grow until they reached sizes of around a 1000 kilometers across. These bodies are then believed to have clumped together, forming gas giants like Jupiter, Saturn, Uranus, and Neptune, as well as rocky planets like Earth and Mars.

MATTER FROM SPACE

Although this process has been confirmed in broad outline, the details–especially how it begins–are poorly understood. Exactly what solids are present in the solar nebula from the start? How do they clump together to form asteroids, comets, planets, or moons?

To answer these questions, a number of astronomers, like those working at CPRG[1] or LEME,[2] highly specialized in cosmochemistry and planetology research, examine samples that have arrived from space. This includes chondrites, which have arrived almost unchanged in the last 4.567 billion years (the age of our solar system). Many of these rocks yield evidence about the physical and chemical changes that have taken place in the immediate environment of the Sun. For instance, the team led by François Robert from LMCM[3] can reconstruct the past by comparing different types of celestial objects: meteorites fallen to Earth, micrometeorites recovered from the icy wastes of Antarctica, and, since the return of NASA's Stardust space mission, constituents of the tail of a comet. This long-term work, which consists in analyzing the chemical, isotopic, petrographic, and mineralogical characteristics of such materials, is slowly unraveling the chain of events that led to today's solar system. The researchers have recently made a surprising discovery: Nuclear reactions may have taken place in the primitive protoplanetary disc, contradicting all existing theories on the subject.

THE FORMATION OF THE SOLAR SYSTEM

Another mystery surrounds the configuration of our solar system. How did the distribution of gaseous and rocky planets we see today come about? Alessandro Morbidelli, at the Cassiopée laboratory[4] in Nice, is one of France's leading specialists for modeling the history of the dynamics of our solar system. He is trying to understand how the various families of objects–asteroids, comets, planetoids, satellites, and planets–that formed in the protoplanetary disc interacted with one another via >

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The nearest exoplanet to our solar system (artist rendition). This Jupiter-sized planet orbits around its star, Epsilon Eridani, situated 10.5 light years away.

> gravity, to end in their current distribution. In 2005, his work made it possible to understand the late heavy bombardment (LHB) that the Moon underwent 3.9 billion years ago. We now know that it was caused by changes in the orbits of Jupiter, Saturn, Uranus, and Neptune, which, surprisingly, are thought to have formed much closer to the Sun than their present location.

Morbidelli and his colleagues would now also like to discover why the cores of these gas giants–and then the gas giants themselves–didn't migrate under the effect of gravity to eventually be absorbed by the Sun. They have managed to solve part of the puzzle. For them, if our solar system still has gas giants, it is due to the similarity in the sizes of Jupiter and Saturn. It would seem that the combined effect of their gravity prevented our four massive gas giants from being consumed by the Sun.

THE HUNT FOR EXOPLANETS

Finally, ever since the 1995 discovery of the first exoplanet, 51 Pegasi b, a gas giant with a mass about half that of Jupiter, we have known that there are planetary systems around stars other than our own. "This discovery had a major impact on the field and was a turning point in the spheres of both theory and observation," explains Anne-Marie Lagrange, director of CNRS' "Origin of planets and life" program and an exoplanet specialist at LAOG.

Due to their far away location, and engulfed by the light of their nearest star, images of exoplanets are extremely difficult to obtain. In 2004, a team from LAOG including Lagrange and Gaël Chauvin was the first to get an image, using the NACO adaptive optics instrument on ESO's VLT in Chile.[5]

Yet it is only now, after four years and via collaboration with other scientists that they repeated this feat, taking an image of a planet located 8 astronomical units (AU) from its star (closer than Saturn would be to the Sun).

In any case, the data provided by the study of some 300 exoplanets have already upset several dogmas. The major casualty of these findings has been the current ranking of planets. The discovery in 1995 of 51 Pegasi b, a gas giant that orbits very close to its star in a mere four days, forced astronomers to shelve the model which placed the rocky planets–Mercury, Venus, Earth, and Mars–at the center of planetary systems, and the gas giants–Jupiter, Saturn, Uranus, and Neptune–at the periphery. This explains the relentless efforts in processing all this incoming data, which is rapidly confirming that the organization of our solar system is probably unusual. Besides, the study of the composition of exoplanets will inform us on their origins, as shown in 2002 by Tristan Guillot, from the Cassiopée lab in Nice, who used the first model of atmospheric circulation on giant exoplanets. Guillot explained how the gas giant HD209458b–an exoplanet called a Pegasid, since it is comparable to 51 Pegasi b–essentially made of hydrogen and helium, could have a size 35% larger than our Jupiter and a very small core. "This is due to intense irradiation from its star and strong winds in its atmosphere," he comments. Then, in May 2006, Guillot went even further by discovering a connection between the heavy metal content of such Pegasids and that of their stars. This is a completely novel relationship between exoplanets and stars, and a first step to better understanding the way planetary systems form.

Vahé Ter Minassian

ASTRONOMICAL UNITS
An astronomical unit is equivalent to the mean distance between the Earth and the Sun, around 150 million km.

1. Centre de recherches pétrographiques et géochimiques (CNRS).
2. Laboratoire d'études de la matière extraterrestre (CNRS / Muséum national d'histoire naturelle).
3. Laboratoire de minéralogie et cosmochimie du muséum (CNRS / Muséum national d'histoire naturelle).
4. Cosmologie astrophysique stellaire & solaire de planétologie et de mécanique des fluides (CNRS / Observatoire de la côte d'Azur / Université de Nice).
5. A second-generation VLT instrument for exoplanet imaging is being built by LAOG, under the supervision of Jean-Luc Beuzit.

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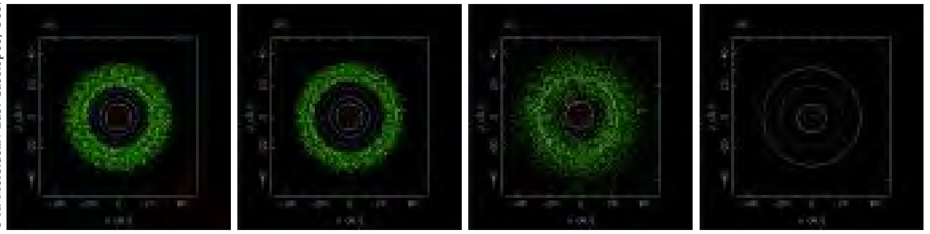
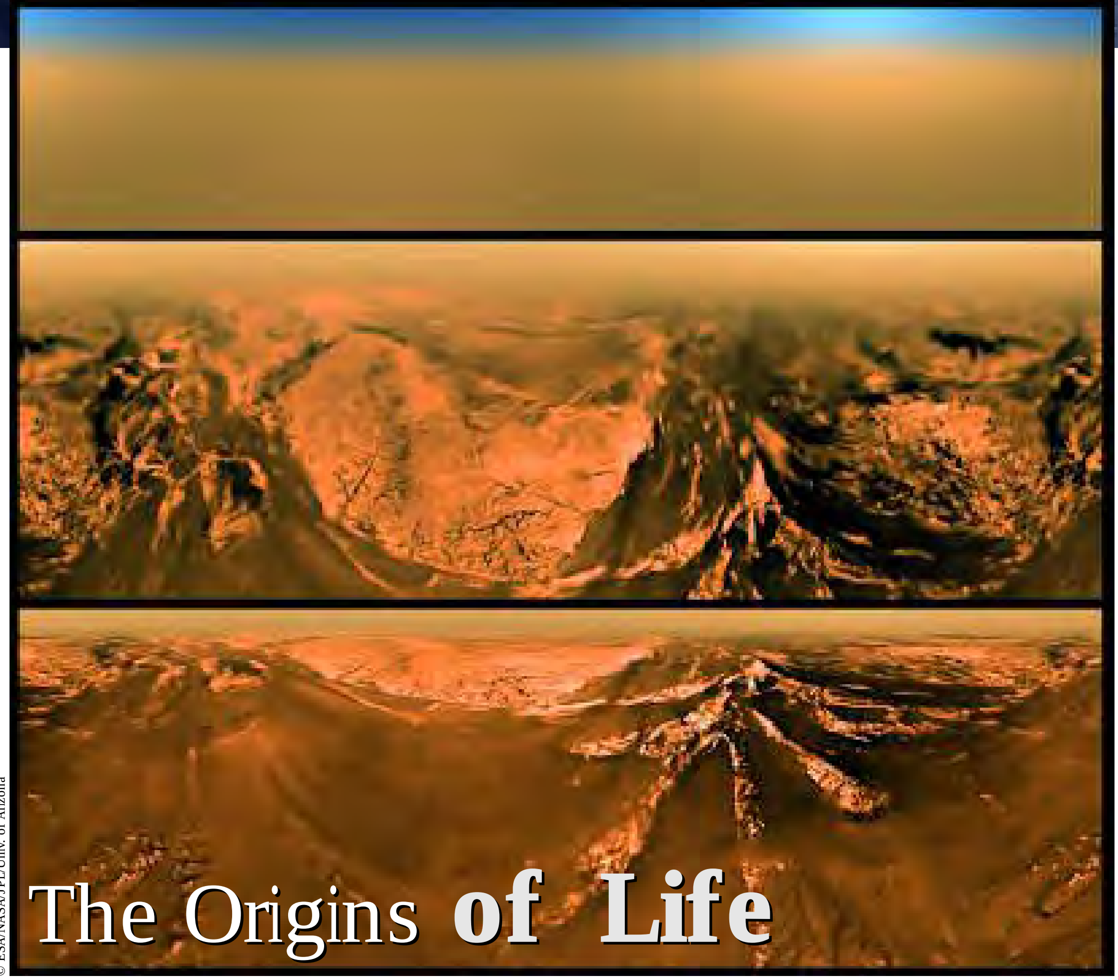
Model of the evolution of the solar system during the first billion years after its creation, with the orbits of the planets around the Sun (circles) and the disc of tiny planets that surrounded them.





The surface of Titan, Saturn's largest moon, at three different altitudes, as reconstituted from data from the Huygens spacecraft, which arrived at its destination in 2005.

The Origins of Life

How did life first appear on Earth? And does it exist elsewhere in the universe? These two questions, far from insignificant, are closely linked–and a long way from being answered. Today, the quest for life's origins, the subject of a discipline called astrobiology (also known as exobiology), brings together not only astronomers, but also biologists, paleontologists, and chemists.

In all these fields there are a host of unanswered questions, ranging from the origins of life on Earth, the conditions that enabled it to appear, to the elementary building blocks on which life was based.

For instance, just when did life first appear? By studying fossils, paleontologists have established that the first living organism must have appeared on our planet at least 4 billion years ago. This date is very imprecise, since clues are few and far between. However, scientists are gradually making headway with a number of studies documenting traces of early life in rocks. In July 2008, for example, researchers at the Bioemco laboratory,[1] working in collaboration with three other groups, showed that there was already life on Earth 3.5 billion years ago by analyzing a rock dating from that time.

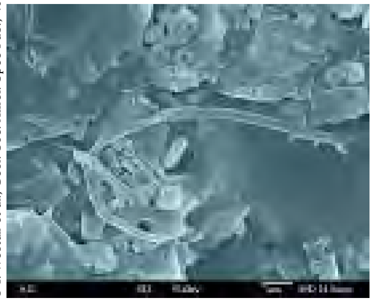
CONDITIONS FOR LIFE

Knowledge of the conditions present on Earth at that time is critical to understanding ancient life on Earth. An entire area of astrobiology is today dedicated to extending research in this field.

There are many different areas of research: tracing biosignatures, determining the origin of water on our planet (which most likely arrived in cometary showers), or studying the physical and chemical characteristics of the atmosphere and oceans in which life first appeared. For example, Manolo Gouy's team, working in evolutionary biology at Villeurbanne's BBE,[2] together with computer scientists from LIRMM,[3] have recently shown that LUCA, the last universal common ancestor of all living organisms, lived at moderate temperatures of less than 50°C. Later on, possibly during a period of particularly heavy asteroid bombardment, life had to survive a hotter environment (around 70°C), before again adapting to increasingly low temperatures until the present day.

Another burning question surrounds the origin of the organic molecules that make up the nucleotides and amino acids of life's machinery. Where were they created? Some believe that they were synthesized on the ocean bed close to hydrothermal vents, or alternatively near volcanoes or deep underground, while others believe that they originated in the interstellar medium. "Both hypotheses are probably correct, since these molecules could have had a terrestrial origin, and also arrived in carbonaceous meteorites, micrometeorites, and comets," explains Frances Westall, from the Center for Molecular Biophysics (CBM)[4] and director of the CNRS research group on Exobiology (2006-2008). "Using data collected by the European Space Agency's (ESA) Huygens spacecraft in January 2005 on Titan, one of Saturn's moons, we hope to better understand chemical reactions that lead to prebiotic chemistry–the chemistry that doesn't involve biological molecules–which must have existed on the very early Earth, and which is still at work on Titan."

BIOSIGNATURES
These are chemical, isotopic, and morphological traces left by biological activity.



Fossil micro-organisms, 3.445 billion years old. These invaluable traces of the origins of life were discovered in sediments in Pilbara, Australia.

TO BE OR NOT TO BE

Lastly, how did these molecules, once created, self-assemble to form life? What did the common ancestor of all of today's organisms look like? Although a number of complex scenarios have been presented, a recent hypothesis suggests ribonucleic acid (RNA) made up the first metabolism of all, in other words, the first machinery where chemical and energy transformations characteristic of life operated spontaneously.

The reason for this surprising idea is "the discovery, around 15 years ago, that RNA was able to carry out the essential functions of life," explains Marie-Christine Maurel, from the ANBioPhy laboratory,[5] and currently chair of the Scientific board of CNRS' interdisciplinary program "Origin of planets and life," set up in 2006.

"RNA can carry genetic information while at the same time performing catalytic action in the same way as proteins. The current idea is that the primeval world might have been constituted of primitive lifeforms like 'viroids.' Unlike viruses, these plant pathogens are made up of free RNA–i.e., RNA without an associated membrane. And this makes them ideal candidates for having given rise to life."

There is still the second big question for astrobiology: Where and how can we find traces of extraterrestrial life? Current programs, like SETI (Search for Extra-Terrestrial Intelligence), are attempting to locate advanced intelligence by detecting electromagnetic emissions that could be produced by alien civilizations. Other programs seek to find traces of biological activity, or even of small bacteria-like organisms. For instance, starting in 2016, ESA's ExoMars spacecraft will attempt to determine whether a rudimentary lifeform has ever lived, or still lives, on the red planet. And in 2020, the Darwin mission project–a network of telescopes in space–will be launched to detect signs of life on exoplanets. This means finding ways of detecting gaseous compounds of biological origin in the atmospheres of such planets. Lastly, as part of an ESA project dubbed "Bluedot," some researchers are working on techniques for spotting "ocean planets," hypothetical celestial objects whose distinctive feature, if they exist, is that they are completely covered with water, a favorable environment for the development of life.

Vahé Ter Minassian

RIBONUCLEIC ACID OR RNA
A molecule whose chemical composition is very similar to that of DNA (ribose instead of deoxyribose and uracile instead of thymine), but whose 3D structure is very different. It performs many functions in the cell, such as carrying genetic information, enzymatic reactions, etc.

1. Biogéochimie et écologie des milieux continentaux (CNRS / Université Paris-VI / Inra / Agroparistech jr étude pôle aliment / École normale supérieure Paris).
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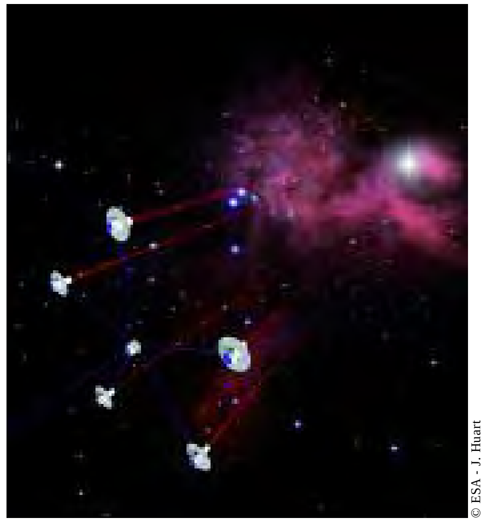
3. Laboratoire d'informatique, de robotique et de microélectronique de Montpellier (CNRS / Université Montpellier-II).
4. Centre de biophysique moléculaire (CNRS).
5. Acides Nucléiques et BioPhotonique (CNRS / Université Paris-VI).



Starting in 2020, the European Darwin project, a flotilla of six space telescopes, should help us study exoplanets and perhaps find traces of life there.

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ARCHEOLOGY

Shielded TREASURES

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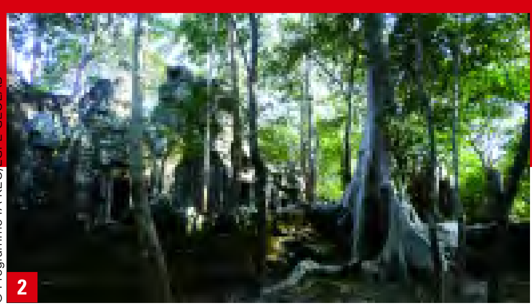

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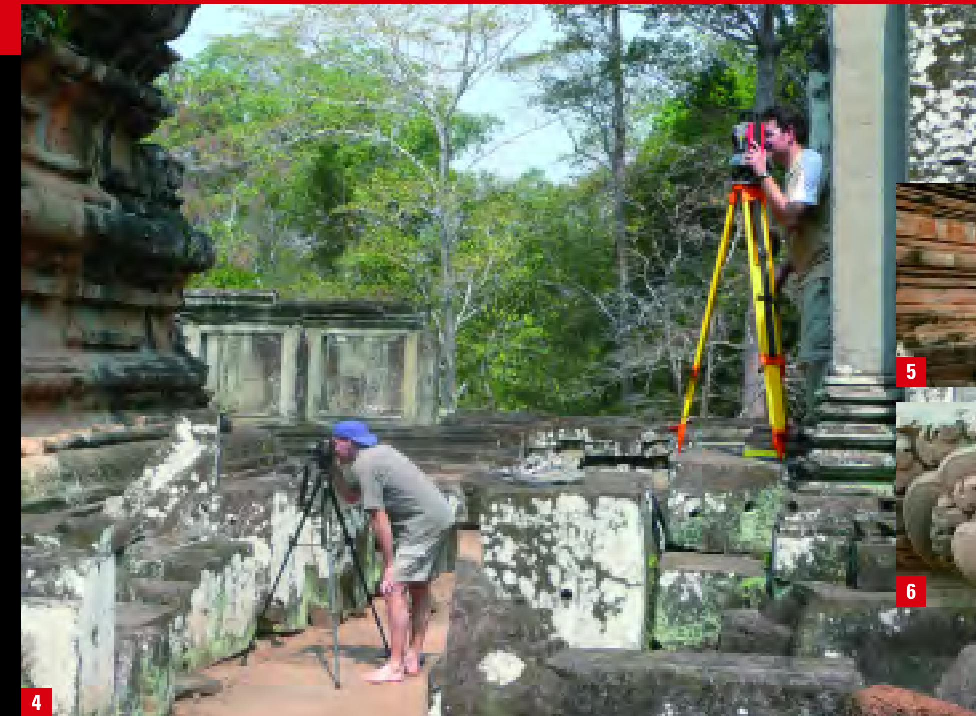
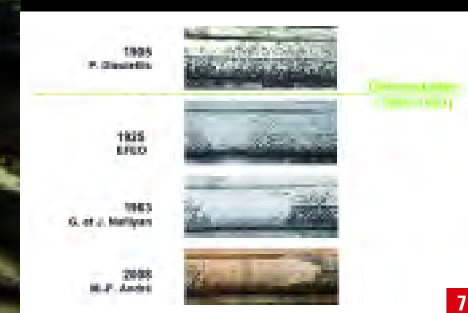
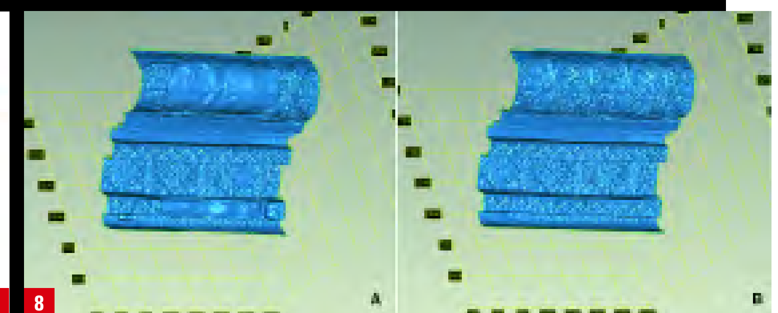
Every year, more than a million tourists flock to Angkor, Cambodia, to admire its temples. Large parts of the site have been cleared and expanded to let tourists walk through the monuments of the thousand-year old ancient capital of the Khmer kings. Yet without the tropical forest cover which has been protecting them for centuries, these temples are subject to increased deterioration due to atmospheric conditions. A group of French researchers has been travelling there to investigate the phenomenon.







The ritual has not changed since 2006. Each year, a team of stone erosion experts from Clermont-Ferrand's Geolab[1] heads off to Angkor during December's dry season to take measurements on the Ta Keo temple mountain. After three field trips, the researchers are still overwhelmed by the experience. "It's incredible to be able to work on a World Heritage site," says Marie-Françoise André, professor of physical geography at Blaise Pascal University, in Clermont-Ferrand. The sprawling carved stone city, which at one point covered 400 km^2, and as much as 3000 km^2 taking into account the surrounding settlement, remains the largest man-made urban area predating the industrial era–even larger than the Mayan or ancient Chinese. At its height, the imperial capital had between 500,000 and 1 million inhabitants.

But today, the surroundings look more like the set of an Indiana Jones movie. The site is still marked by its centuries-long slumber. In some temples, powerful plant tentacles clasp the lintels of stone doors, snake their way around bas-reliefs, and shatter delicately carved deities and dancers. But the Geolab researchers are more concerned by another form of erosion, silent but lethal, which awaits the temples once they are freed from the grasp of forest: atmospheric erosion, caused by wind, rain, and sun, among others.

Before carrying out any survey work, the team needed permission from UNESCO and from the Authority for the Protection and Management of Angkor and the Region of Siem Reap (Apsara). They also had to select an ideal "case temple" from among several dozen monuments. "We honed in on Ta Keo in 2006, as it hadn't undergone any remodeling or restoration since it was built–around 1000 A.D.–which seemed too good to be true." The temple was abandoned around 1280, and the jungle rapidly took over, covering the temple for six centuries before it was cleared in about 1920. Since then, Ta Keo, with direct exposure to sunshine, monsoon rains, and tourists, has been steadily deteriorating. Apart from the significant erosion, >

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1 and **2** The forest protects the temples from the burning sun and monsoon rains.

3 Cleared around 1920, the Ta Keo temple, the focus of this study, has been continuously deteriorating ever since.

4 In February 2008, 200 reference points were measured using laser cameras to reconstruct the area's topography in 3D. The photogrammetric view then makes it possible to use historical photographs and calculate eroded surfaces for the date of each image.

5 Lasergrammetry is used to obtain a precise measurement and data on erosion damage through time. Placed on a tripod, the short range/high resolution laser scanner needs low light levels, which means a dimming tarp must be used.

6 A red sticker, placed in this case on a lotus petal carved in sandstone, is used as a reference point in photogrammetry.

7 Thousand-year old bas-reliefs flaked soon after the forest was cleared, as witnessed by this erosion scar which has grown throughout the 20th century.

8 The 2008 laser scanning campaign let researchers visualize in 3D the current state of deterioration of moldings (left) and allowed them to compare it with the original state, reconstructed from the rare intact areas (right).

9 Erosion affects bas-reliefs in different ways. Shown here are radial cracks, the first step of a deterioration process which ends with the formation of spectacular erosion scars. These can be as large as 1 m long and 30 cm wide.

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10 **The contact sponge method was developed by curators in Florence to test the permeability of stone. If the water–the main vector for deterioration–stays on the stone surface, then it is in good condition.**

11 **Temperature and humidity sensors help define the level of environmental stress on a temple that has been cleared from forest. These sensors are placed at various points on the temple to show the differences in thermal behavior related to the microtopography of moldings. The sensors are active all year long.**

12 **and** **13** **Under the forest cover, in a relatively humid environment, white, grey, and greenish lichen colonize the stone and protect it by keeping water on the surface. They form a protective screen between atmospheric agents and the monuments' stone.**

> Ta Keo was also chosen for another reason: The temple has a surprisingly well-documented history. Not only were there architectural, stylistic, and epigraphic studies carried out by the French School of Asian Studies (EFEO), notably by the architect Jacques Dumarçay in 1967, but there were also photo documents at the National Asian art museum in Paris (Musée Guimet). "These Archives show the temple before and after the forest was cleared. By comparing them with our own survey data, we can visually quantify the deterioration of the temple and measure the impact of environmental stress over the course of the century."

With this data in hand, the researchers planned six field trips between 2008 and 2012 and began evaluating the damaged surfaces and volumes, using specialized equipment. Franck Vautier and Olivier Voldoire, experts in new 3D spatialization techniques, started taking measurements on the first level of the central pyramid's eastern side in 2008. "This is the level for which we have the best iconographic data, with photos dating as far back as 1905," says André.

Photogrammetry makes it possible to correct for distortion in photos taken with different lighting, definition, or focal points, before adding them to a metric repository. With this technique, the various photos taken between 1905 and 2008 can be accurately superimposed. The team can then measure the deteriorated surfaces and reconstruct the rate of contemporary damage to the stone. The engineers also use laser scanning technology on decorated surfaces to make very high-definition (300 micrometers) 3D models of sculpted motifs and a volumetric estimate of eroded parts.

The team also uses other techniques, like climate monitoring. This involves placing sensors, the size of watch batteries, at different points around the temple. These sensors are programmed to simultaneously measure temperature and humidity, in order to gauge the impact of climate depending on the stone's exposure. The data obtained, when compared with those from sensors placed on a temple buried in the jungle, have already shown that atmospheric factors have less of an impact on temples under thick vegetation cover.

Further analysis of the photos shows that clearing the temples of forest may even have greatly increased the speed at which the sculptures are deteriorating. Eventually, the Geolab team hopes to put forward a predictive scenario for increased damage to the archeological site at Angkor. It could then help define sustainable management strategies, some of which partly involve the simple maintenance or restoration of a protective forest screen around the temples. This proposal has recently been met with favorable reviews from Apsara, partly due to the fact that travelers come largely to admire this unusual blending of tree and stone.

Camille Lamotte

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A FRANCO-GERMAN INSTITUTE

Breaking Language Barriers

The Institute for Multilingual and Multimedia Information (IMMI), a new Franco-German institute founded in Orsay, will use new technology to link spoken words with their written counterparts and navigate from one language to another.

It's not quite the tower of Babel, but a brand new Franco-German institute has high hopes of breaking down language barriers like never before. This Orsay-based institute called IMMI,[1] dedicated to multimedia language technologies, brings together the Rhenish-Westphalian Technical University Aachen (RTWH) and the University of Karlsruhe (UKA), both in Germany, with CNRS' LIMSI,[2] a computer science laboratory specialized in language and speech processing. The joint institute will house powerful tools for its researchers, based on the newest available technologies. "Those developed by both the institute members and the other partners of the Quaero program, started in 2008 (*see box*), will be able to transcribe a speech or conversation, recognize the language and translate it, identify the speaker by his face or voice, and make automatic summaries of texts or website contents," explains IMMI director Joseph Mariani. To do this, the institute's scientists–who will eventually be a hundred strong–will work on the development of new language technologies. "Notably on speech and language processing, machine translation (whether this be text to text, speech to text, or even speech to speech), processing of multilingual documents or indexing of multimedia documents," continues Mariani, "because these are the skills of the three founding laboratories."

The research teams bring together computer scientists, linguists, sociologists, and specialists in ergonomics, with a common methodological approach: "statistical learning and evaluation based on corpora," explains Mariani. In simple terms, to improve the automatic textual transcription of sound data (speeches or radio broadcasts, for example), sound files and their corresponding transcriptions are fed into the system, which analyses them and "learns" to associate a given sound with its transcription. The larger the sound and text corpora provided for training, the better the statistical model–and the better the system's transcriptions.

Preparations for IMMI have been underway for some time. As early as December 2007, the three founding partners created an International Joint Unit (UMI) to facilitate the institute's management. Then, last December, to bring their research under a common umbrella, they formed a European Associated Laboratory (LEA IMMI-Labs), to which the Paris-Sud University was associated. Funding is provided by the Quaero program, CNRS, RWTH, UKA, Paris-Sud University, the Essonne departmental council, and the Digiteo Advanced Thematic Research Network, which jointly contribute to covering the costs of construction, computing equipment and functioning. Within three years, it is hoped that IMMI researchers will be working in their new 3000 m^2 building, built close to LIMSI, in Orsay.

On completion, the institute will be one of the world's largest centers dedicated to this field of research. Its role will also be very important in Europe, where more than 20 languages are spoken. "We seek to develop technologies that will allow European citizens to use their own tongue and easily switch from one language to another," says Joseph Mariani. The laboratory could, for example, create natural language processing or translation tools for the 23 official European languages, a much needed service also for numerous European institutions like the European Commission, Parliament, Patent Office, Digital Library, and Security Agency.

Virginie Lepetit

1. Institute for Multilingual and Multimedia Information.
2. Laboratoire d'informatique pour la mécanique et les sciences de l'ingénieur (CNRS / Universités Paris-VI and XI).

A MULTIMEDIA PROGRAM

The Quaero program aims to produce advanced information technologies to process multimedia data (text, speech, music, images, and video) and use them to develop innovative applications: search engines, communication portals, content digitization, personalized video, digital media assets management, etc. Quaero is a five-year research program (2008-2013) involving more than 20 partners from public research and industry. It has a budget close to €200 million.

V.L.

> **http://www.quaero.org**

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Creating a Scientific "Entente Amicale"

Research and development activities in the United Kingdom account for an estimated 5.5% of all scientific research worldwide. Over the 10-year period between 1998 and 2008, it was the world's second-largest producer of scientific papers, right behind the US.[1]

Its productivity is particularly remarkable given the fact that UK spending on R&D, calculated as a percentage of GDP, lags behind many of its European neighbors. The British government has pledged to increase total R&D investment from a current level of around 1.8% of GDP to 2.5% by 2014. It keenly encourages collaboration between private enterprise and academic institutions, as well as the rapid transfer of the fruits of research into the economy. The private sector is by far the biggest single source of R&D funding in the UK. In 2007, it financed 52% of all R&D (including funding by private, non-profit organizations at 5%). The public sector accounted for 31% of funds, and the rest (17%) was provided by foreign investment, such as through parent companies or foreign contracts.

In June 2009, the government Department for Innovation, Universities and Skills was merged with that of Business, Enterprise and Regulatory Reform to form the Department for Business Innovation and Skills (BIS). It is now the umbrella organization for most state funding of scientific research. The BIS is also directly responsible for higher education policy in England, while in the rest of the UK–Scotland, Wales and Northern Ireland–this is decided by local government education departments. All UK universities, except one, are state-financed, and are autonomous bodies which alone decide their syllabi and research structures and partners.

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The UK counts 109 universities and 169 Higher Education institutions, where the bulk of scientific research in the country is performed. An increasing number of universities have created departments dedicated to attracting private sector funding for research.

The BIS is the parent body that finances seven national Research Councils (RCs) which in turn fund specific fields of fundamental research on a UK-wide basis. They represent the largest single source of public funding for research, and are each allocated separate disciplines: arts and humanities, biotechnology and biological sciences, engineering and physical sciences, economic and social sciences, medical research, natural environment research, and science and technology. All seven RCs share a total yearly budget of about €4.7 billion (£4 billion), while a further yearly total of €2.3 billion is provided for scientific research by various government departments (such as the Department of Health for medical research).

Other institutions that play a significant role in financing research include the Royal Society, an independent academy for the promotion of excellence in science, engineering, and technology, the Royal Academy of Engineering, the Academy of Medical Sciences and, for humanities and social sciences, the British Academy.

Private, non-profit organizations also play a key role. These notably include the Wellcome Trust, an independent charity which, with a capital of about €15.3 billion (£13 billion), is the UK's largest non-governmental source of funding for biomedical research.

Saint John's College in Cambridge, UK.

© C. Dutton/Grand Tour/Corbis

IN FIGURES

- **61** million inhabitants
- **180,450** researchers (2006)
- **£25.4** billion spent on R&D (2007)
- **1.79%** of GDP invested in R&D (2007)
- **3509** CNRS missions in the UK (2006)

In terms of international collaborations, the highest collaborative research is with US institutions. However, the overall number of French-British co-publications has continued to rise over recent years, currently making the UK the second most important European partner for CNRS in terms of co-publications (behind Germany). It is also the third-ranked destination outside France for the number of individual CNRS research missions in Europe, while British researchers affiliated to CNRS in France represent the third largest foreign contingent from the European Research Area, at 14%, behind those from Germany (21%) and Italy (18%).

The principal fields of joint research between CNRS and UK institutions involve Earth sciences and astronomy (26%), physics (25%), fundamental biology (15%) and chemistry (11%). This year, the CNRS Office of European Affairs (DAE)[2] is providing funding for 37 joint research projects, 21 of which have a duration of several years.

EMPHASIS ON MATHEMATICS

Set up in 2008, the GDRE French-British Network in Representation Theory formalized 2007 collaborative agreements with the Engineering and Physical Sciences Research Council (EPSRC). This GDRE brings together UK researchers from two universities in Scotland and five institutions in France. It links several hundred mathematicians who correspond regularly and meet in workshops several times a year to further this field of mathematics, particularly developed in both countries and which provides important applications notably for theoretical physics. "In France, we have a pretty unique tradition of working in networks, and it is difficult to find an equivalent elsewhere in Europe," explains Jean-Marc Gambaudo, former CNRS deputy scientific director responsible for mathematics. "This opportunity was facilitated after the UK's EPSRC created its own national network. It is an important opportunity for French researchers to broaden their horizons by collaborating with a country that has a very dynamic research environment."

These include one European Associated Laboratory (LEA) called "Thalamic Function in Health and Disease States" set up in 2008 between a team led by Professor Vincenzo Crunelli[3] from the University of Cardiff and another led by CNRS Research Director Nathalie Leresche from Paris-VI University.[4] They are investigating underlying information processing in the thalamus networks, which play a pivotal role in physiological functions, such as sleep, as well as in diverse pathologies like depression, chronic pain, and Parkinson's.

Social sciences, astrophysics, engineering, and mathematics are the fields of 13 European and International Research Networks (GDREs and GDRIs) involving CNRS and UK researchers. These include a GDRE to be created this year called "Dawn of the Gamma-Ray Bursts (GRBs)," which also involves Italian and German teams. It aims to unveil the nature of the early universe by deepening knowledge of GRBs, the most powerful explosions since the Big Bang. Another GDRE is the "French-British Network in Representation Theory" (*see box*), reinforcing a recent development in cooperation in the field of mathematics.

This year will also see the renewal of an International Research Network (GDRI) on the subject of nanotubes, now enlarged to "Graphene and Nanotubes: Science and Applications -GNT," involving Cambridge University and other European and Canadian partners.

In addition, CNRS funds seven International Programs for Scientific Cooperation (PICS) in the disciplines of physics, biochemistry, and the environment, social, and life sciences, while an agreement signed last year with the Royal Society created several two-year joint research projects in all fields of natural sciences.

Finally, CNRS researchers also collaborate with UK colleagues under the structure of the 20-year-old "Alliance programme," established by the French Ministry of Foreign and European Affairs and the British Council in 1989 to promote scientific cooperation between the two countries, and which has helped develop the flourishing relations concretized today.

Jason Brown

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Mihai Barboiu
Chemical Attraction


© E. Perrin/CNRS Photothèque

Brilliant is not too strong a word to qualify the career of Mihail Barboiu, though he himself values modesty. Now forty, this Romanian chemist heads a team dedicated to adaptive supramolecular nanosystems at IEM[1] in Montpellier. This entails studying the properties of biological membranes, numerous varieties of which exist in nature that have an interesting ability to let certain molecules pass through them while forming a barrier against others.

Barboiu thus develops novel materials and systems with innovative properties and a range of applications, as proven by the number of patents that have been filed. For example, his team has developed a membrane that is ten times more conductive than those currently used in fuel cells. Two patents have been filed for materials that allow the sequestration of CO_2, and others in the healthcare industry. These finds are somewhat fortuitous, as is often the case for major scientific discoveries: "Conductive polymers were found following a manipulation error, in the same way that Fleming discovered penicillin by neglecting his biological cultures during a summer break", recalls Barboiu, whose destiny, on the other hand, owes nothing to chance.

At school, in his hometown of Pascani in Northern Romania, the young Barboiu was already fascinated by science. He participated in the Chemistry Olympiad and represented his country at an international level on two occasions. Soon after, he entered the Polytechnic University of Bucharest, where he qualified as an engineer in organic chemistry. During his studies, his professor, Constantin Luca, allocated him some lab space where he could let his imagination run free–and this earned him his first publication at the age of 23. Barboiu followed it with a thesis on "The use of hybrid materials for molecular recognition," while at the same time working at a Bucharest research center. "Within three years, I was heading my own research team," he distinctly remembers. A collaboration was then initiated with Montpellier's LMPM,[2] so that his doctorate was eventually completed under dual supervision. In 1999, already looking for a postdoctoral position, Barboiu was given an exceptional opportunity: A lectureship at one of the world's most elite scholarly institutions, the Collège de France, carried out in the Strasbourg laboratory headed by the eminent Professor Jean-Marie Lehn, Nobel Prize winner for Chemistry in 1987. The team had managed to artificially reproduce the coiling-uncoiling motions of natural proteins. "It was a dream come true, as I was a great admirer of Jean-Marie Lehn! Working in a lab headed by a Nobel laureate was the most incredible opportunity in the world for a young scientist."

Two years later, Barboiu joined CNRS to work at the IEM in Montpellier. He decorated his new office with photographs of the teachers who had inspired him, such as Constantin Luca, Louis Cot, and Jean-Marie Lehn. His talent was further acknowledged in 2004 when he won the European Research Young Investigator Prize for his project on the evolution of dynamic systems at the interface between chemistry, biology, and physics. That same year, he was appointed senior researcher and focused his work on biological membranes. Undoubtedly, this scientist is following the paths trodden by his mentors.

Caroline Dangléant

1. Institut européen des membranes (CNRS / École nationale supérieure de chimie Montpellier / Université Montpellier-II).
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NETRIS-PHARMA

Decoy' Drugs to Fight Cancer

Taking a closer look at dependence receptors has propulsed this French start-up to the forefront of cancer research, paving the way for a new type of treatment to fight tumors.

The young start-up Netris-Pharma, created by two Lyon-based CNRS researchers in June 2008, has already proved that a company does not always need a great deal of time to show its worth. Netris-Pharma is already being courted by a number of large pharmaceutical firms–not much of a surprise as the small biotechnology company is riding a wave of promising cancer-treatment research. The new therapy currently in the works particularly targets metastatic breast cancers, secondary tumors that develop after cancer cells have spread from a distant primary tumor. These forms are today considered incurable.

The innovative therapy is based on the discovery of 'dependence receptors'–a family of receptors first identified in 1998 by one of Netris-Pharma's cofounders, Patrick Mehlen, director of the Apoptosis, Cancer, and Development lab[1] at the CLB[2] in Lyon. "These cell surface receptors usually cause the death of any cell that multiplies uncontrollably," explains Agnès Bernet, the other cofounder and researcher at the same laboratory. "But cancerous cells produce molecules known as 'ligands' that fix onto the dependence receptors and prevent tumor cells from dying."

Netris-Pharma researchers analyzed tissues sampled from cancer patients, and showed that in 60% of metastatic breast cancers, the tumor cells make an abnormally high quantity of one of these ligands, called netrin-1. "This gave us the idea of developing 'decoy' molecules, capable of trapping the ligands and preventing them from binding to the receptors, meaning that the cancerous cells would die," adds Bernet.

She and her colleagues have already developed a first decoy molecule they named Anetrin, which effectively traps the netrin-1 ligand. But more molecules are already on the way: the scientists hope to produce 15 or so more, capable of trapping ligands of other dependence receptors discovered at the laboratory. This will provide an entire set of new treatments targeting tumor cells. "To bring this research to fruition, we are eager to rapidly establish collaborations with pharmaceutical companies so as to hand over the rights to exploit and develop our discoveries; this will help us finance our research on other receptor/ligand pairs. Collaboration contracts with a number of pharmaceutical companies and investors are already under review," explains Bernet.

The start-up hopes to part with its first license by 2010, for an estimated price of over €10 million. "We will be quite cautious in handing out the license, and might even decide to rely on investors to test the molecules' efficiency on humans ourselves," says Bernet.

In the meantime, Netris-Pharma continues its research with the €1 million support already obtained from private business sponsorship and public funding from the country's National Research Agency (ANR) and the Ministry for Higher Education and Research.

Kheira Bettayeb

1. Apoptose, cancer et développement (CNRS / Université Lyon-I / Centre anticancéreux Léon Berard).
2. Centre anticancéreux Léon Bérard.

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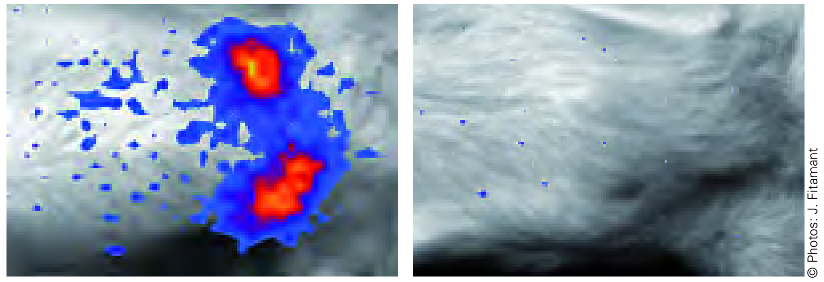

In mice, the molecule developed by Netris-Pharma, based on dependence receptors, proved effective (right) against pulmonary breast metastasis (left, in red and blue).
© Photos : J. Fitamant

WORKING IN A FRENCH LAB, PRACTICAL INFORMATION:

The Kastler Foundation (FNAK): Helps foreign researchers settle in France and maintains contact after their departure.
→ www.fnak.fr

Foreign embassies and consulates in France:
→ www.diplomatie.gouv.fr/annuaire/

French embassies and consulates abroad:
→ www.expatries.diplomatie.gouv.fr/annuaires/annuaires.htm

Association Bernard Gregory: This association helps young PhDs from any discipline make the transition into business.
→ www.abg.asso.fr

France Contact will help you plan and arrange your stay in France:
→ www.francecontact.net

Edufrance: Information on France's higher education programs–course enlistment, grant and fellowship applications.
→ www.edufrance.fr

GRANTS/FELLOWSHIPS

FRANCO-PORTUGUESE COOPERATION
CNRS and Portugal's FCT are calling for cooperative project submission for the year 2010. A one month mission to establish the cooperation can be financed up to €2400 to cover stay and travel expenses.
→ **Deadline:** September 30, 2009.
→ **Contact Information:**
At CNRS: Ilias Petalas, ilias.petalas@cnrs-dir.fr
At FCT: Manuela Rodrigues da Silva, rodrigues.silva@fct.mctes.pt

EURAXESS
This portal provides information on grants, fellowships, or positions available throughout Europe as well as practical information (accommodation, childcare and schools, healthcare...) for each country.
→ **http://ec.europa.eu/euraxess/**

FRANCO-JAPANESE PROGRAM
The JST and CNRS invite Japanese and French researchers to submit proposals for cooperative research projects on "Structure and Function of Biomolecules: Response Mechanism to Environments." Projects will be funded for a period of three years, starting in January 2010.
→ **Deadline:** September 28, 2009.
→ **Contact Information:**
Monique Benoit, monique.benoit@cnrs-dir.fr

MARIE CURIE ACTIONS
This EU program provides numerous fellowships and grants facilitating research mobility in Europe.
→ **http://cordis.europa.eu/mariecurie-actions/**

EXCHANGES WITH RUSSIA AND THE UKRAINE
Accomodations for up to one month can be funded for exchanges between CNRS and the Russian or Ukrainian Academy of Sciences, on projects co-submitted by both partners for the coming two years.
→ **Deadline:** September 30, 2009.
→ **Contact information:**
CNRS: Caroline Danilovic, caroline.danilovic@cnrs-dir.fr
Russia: Serguei M. Turin, smturin@presidium.ras.ru
Ukraine: Elena Myronchuk, elena.myronchuk@nas.gov.ua

FRANCO-SPANISH AGREEMENT
The agreement established between CNRS and CSIC to strengthen scientific cooperation includes a mobility programme to support exchanges of scientists for periods of up to six months. Proposals must be submitted by both partner labs. Financing will pay for accommodation and running costs up to €2000 per month, as well as travel expenses, starting January 2010.
→ **Deadline:** September 30, 2009.
→ **Contact Information:**
At CNRS: Ilias Petalas, ilias.petalas@cnrs-dir.fr
At CSIC: Carmen Cabellos, c.cabellos@orgc.csic.es

ÉGIDE
Égide is a non-profit organization that manages French government international mobility programs. Many funding opportunities are listed. Most content is in English.
→ **www.egide.asso.fr**

4TH INTERNATIONAL POLAR YEAR

Job Well Done

A researcher records walrus cries around Igloolik (Nunavut, Canada).

© I. Charrier/CNRS Photothèque/NAMC/IPEV

The 4th International Polar Year (IPY) has now drawn to a close. To assess its achievements, researchers and political decision-makers met in Paris last May for a final symposium.

With a consolidated investment of €30 million in support of no fewer than 34 programs, France has demonstrated its unfailing commitment to research in the polar regions. According to Gérard Jugie, director of the Paul-Emile Victor French Polar Institute (IPEV), one particularly important aspect of this 4th IPY has been its "bipolar" scientific approach. Indeed, for the first time, the two poles have not been considered separately, but in interaction with the global system of the planet. "The 4th IPY was deliberately designed and implemented to ensure as many scientific projects in the Arctic as in Antarctica," explains Jugie. It has thus been possible to study the essential role played by both poles in atmospheric and marine current circulation, which directly condition the Earth's climate. Similarly, the thickness of icecaps, the melting of which is likely to cause a rise in sea levels, has been simultaneously measured in both Antarctica and Greenland.

Another achievement of the 4th IPY has been the bolstering of Antarctica's Franco-Italian Concordia research station, and the legacy it will have for European science. This exceptional logistical tool, which first opened in 2005, should be available to other countries in the future. Jugie is enthusiastic: "We want the European Union to be able to develop major scientific programs there, while at the same time respecting the international collaboration that prevails in Antarctica."

However, the revelation of the 4th IPY was its unprecedented international mobilization regarding the Arctic, where ice melt is accelerating, opening new sea routes and making deep gas and oil deposits accessible. Since 1998, the governments of countries around the Arctic basin (the US, Canada, Denmark (Greenland), Norway, Russia, Iceland, Finland, and Sweden) have joined together within the Arctic Council to draw up policies for the sustainable development and protection of the Arctic Ocean. In January 2007, they set up the Sustained Arctic Observing Networks (SAON), an observatory that pools the results of research carried out throughout the region. Building on the already strong collaborative ties that exist between American and French researchers (particularly from CNRS and IPEV), France's participation in the SAON was made official in February 2009. "If we are to contribute effectively to this observatory, we have to be associated with a country that borders the ocean. The US thus sponsored us through the National Science Foundation (NSF)," explains Jugie, who visited Washington last March to work with the NSF on identifying research subjects and sites common to both countries. CNRS and IPEV will coordinate the research activities of French teams in the Arctic region, who will share their know-how and existing resources. These include the Franco-German base on Spitzberg, satellite facilities, and the Marion-Dufresne survey ship, a complete oceanographic base equipped with on-board laboratories.

Is it possible to envisage an Arctic Treaty, like the Antarctic Treaty that arose from the 3rd IPY in 1959? "The situation is very different," explains Jugie. "Antarctica is an uninhabited continent, while the Arctic is an ocean, subject to maritime law, around which live peoples who belong to sovereign states." Caution must therefore prevail when attempting any negotiations. The next important meeting is the United Nations Climate Conference in Copenhagen in December 2009, where decisions will be made as to commitments arising from the Kyoto protocol starting in 2012.

Isoline Fontaine

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ENVIRONMENT

Mines Under Surveillance

The Raglan nickel mine, in the north of the Ungava Peninsula in Quebec. In the foreground, a stone landmark –or Inuksuk–indicates the presence of Inuits.

© P. Olivier/Ministère des Ressources naturelles et de la Faune du Québec

With consequential changes to the landscape and the emission of toxic agents that can affect fauna and flora, mining poses a serious threat to the environment. This is even more so in vulnerable environments like Northern Canada or tropical regions, which often harbor significant mineral deposits, but are already being affected by climate change. How can we measure the environmental consequences of a mining project, and contain any further damage? Following a CNRS proposal, an international observatory on mining environments has been created and is nearing completion. Two CNRS institutes, INSU[1] and INEE,[2] both specialists in environmental sciences, initiated the project, working in partnership with the French Institute for Research on Development (IRD)[3] and the Ministry of Natural Resources and Wildlife in Quebec.

The observatory will be located at two sites: one in the Raglan mining complex on the Ungava Peninsula in Quebec, the other in southern New Caledonia. It will ensure–with the help of the local populations (Inuit and Kanak)–the continuous monitoring of the environment before, during, and after the exploitation of new nickel deposits. This will include studies on biodiversity, chemical analyses of water, air, and soil, as well as surveys among the local inhabitants. "It will enable a full assessment of the environmental impact of mining activities," explains Bruno Goffé, deputy scientific director for Earth Sciences at INSU, and the project's initiator.

Participants in the program met on March 23-24 of this year in Aix-en-Provence to coordinate the program's scientific activities. Calls for projects should soon be issued, targeting research laboratories working in these areas. "These observation sites will provide us with two comparable 'probes' on both sides of the planet, both organized around the massive exploitation of nickel deposits and recording and analyzing the environmental effects of human activities on vulnerable natural regions and the populations who live there," continues Goffé. This project also provides a good opportunity to increase the awareness of mining companies–partners in this program–to the importance of their activities in increasingly vulnerable environments due to global warming.

Fabrice Demarthon

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2. Institut écologie et environnement.
3. Institut de recherche pour le développement.

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AGREEMENT

New Agreement with Bayer Cropscience

On March 30th, 2009, in Paris, CNRS and Bayer Cropscience–a subsidiary of the Bayer Group, a leader in crop protection innovations and plant biotechnologies–renewed their four-year framework agreement, initially signed in 2005. Joint research projects will focus on providing food for the world population in the context of climate change, the idea being to improve plant stress tolerance and increase harvest yields. The company will thus invest some €4 million in joint projects with different CNRS laboratories. For Arnold Migus, CNRS director general, the first four years of this collaboration have been very fruitful, and "renewal of this framework agreement should enable an increase in scientific and technological interactions, especially in the fields of plant health and more environmentally-friendly processes."

IN BRIEF

SOLEIL Shines in South Africa

On April 16th, 2009, a Memorandum of Understanding for using the synchrotron French national facility SOLEIL was signed between the National Research Foundation of South Africa and SOLEIL. This agreement will provide more opportunities for South African scientists to work with their French counterparts in the field of synchrotron technology and in sciences using synchrotron radiation as a multidisciplinary research instrument. Two projects co-submitted by South African and French teams to the most recent SOLEIL call for proposals were allocated beamtime on two different beamlines. SOLEIL is a civil society jointly created in 2001 by CNRS (72%) and CEA[1] (28%) for building and operating the national synchrotron radiation source.

1. Commissariat à l'énergie atomique.

> **Contact Information:**
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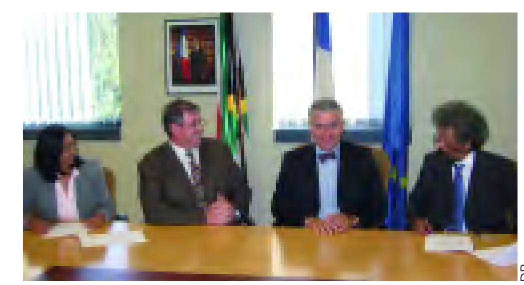
At SOLEIL: Jean-Pierre Caminade, jean-pierre.caminade@synchrotron-soleil.fr



DR

Left to right: Dr Maharaj and Dr Van Jaarsveld of the NRF, Mr Orliange of the French Embassy and Mr Kriger of the NRF, signing the memorandum in Pretoria.

LINGUISTICS

Endangered Languages

The world's linguistic diversity is in danger. CNRS linguists are racing against the clock to record endangered languages before they completely disappear.

Children from the Rai ethnic group (Eastern Nepal) no longer speak Thulung Rai, their group's language.

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Languages around the world are disappearing at an astonishing rate. According to UNESCO's recently published *Atlas of the World's Languages in Danger*, an online database tracking language status across the globe,[1] half of the 6700 languages currently spoken around the world will probably disappear over the next century. These are often unwritten, transmitted from one generation to the next, meaning that once the last speaker dies, so do all traces of the language. Although linguists have no power to reverse this trend, they are doing their best to record these languages before it is too late.

A number of linguists at CNRS, many of whom contributed data used in the UNESCO Atlas, carry out what is known as descriptive work, collecting and analyzing data on endangered languages before they are extinct. They go on location to interact with a community, often over a period of several years, to learn and record its language. The linguist's work will usually result in a dictionary, a grammatical description and a collection of "stories." These are traditional stories, conversations, recipes, personal narratives, but also materials relevant to experts such as names and usage of plants, recordings of religious ceremonies, family lineages and incest "laws," origin myths that may hold clues to geological events... This kind of information can be very useful to many scientists, including botanists, ethnographers, geologists, sociologists, or even historians.

CNRS laboratories working in the field either focus all their research on a specific geographical area or study a number of geographical areas at once. LLACAN,[2] for example, is a geographically oriented lab which specializes in languages of Sub-Saharan Africa. It is one of three such labs at CNRS, together with CELIA,[3] which studies native languages of the Americas (particularly those spoken in Latin America), and CRLAO,[4] a lab which focuses on the linguistics of East Asia and carries out documentation projects on minority languages of Southwestern China.

Other laboratories that have a strong commitment to endangered languages work across the globe, notably DDL,[5] which runs a special program on endangered languages called AALLED,[6] and LACITO,[7] where the bulk of research is on purely oral languages and cultures from around the world.

In all cases, the collected field data is the basis for analytic work. It can be used to group languages into families (language classification), to recreate what earlier stages of the languages looked and sounded like (language reconstruction), to learn more about how neighboring languages influence one another's sounds and structures (language contact), study these sounds and structures (phonology, morphology, syntax), and determine whether they are unique to a single language or common to many (language typology).

One crucial factor in language preservation is data storage: The collected data needs to be safeguarded for future generations, and it needs to be accessible to community members and to academics. CNRS has created the CRDO[8] for this purpose, an online archive of linguistic materials that will be constantly updated as technologies evolve.

LACITO has its own archive (hosted at CRDO) dedicated to rare languages, where the materials can be viewed and listened to directly from an online interface,[9] with sound recordings synchronized with transcriptions and translations. This is a far cry from the early days of linguistic fieldwork, when researchers had no choice but to keep their (non-digital) recordings to themselves.

Aimée Lahaussois

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2. Langage, langues et culture d'Afrique noire (CNRS-Inalco).
3. Centre d'études des langues indigènes d'Amérique (CNRS / IRD /Inalco / Université Paris-VII).
4. Centre de recherches linguistiques sur l'Asie orientale (EHESS / CNRS / Inalco).
5. Dynamique du langage (CNRS / Université Lyon-II).
6. Afrique Amérique latine langues en danger: www.ddl.ish-lyon.cnrs.fr/aalled/index.html
7. Langues et civilisations à tradition orale (CNRS / Universités Paris-III and -IV)
8. Centre de ressources sur la description de l'oral. http://crdo.up.univ-aix.fr
9. http://lacito.vjf.cnrs.fr/archivage/index.htm

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INTERNATIONAL COOPERATION

Skin Research

On may 15th, the "SkinChroma" European Associated Laboratory was created. It associates for four years the French IGBMC[1] from Illkirch and the BAYGEN Institute from Szeged (Hungaria) on a project dedicated to understanding the role of chromatin remodeling complexes in skin inflammatory chronicle diseases. This research, led by Laszlo Tora (CNRS) and Istvàn Nagy (BAYGEN) could identify regulatory networks involved in cellular differentiation and cancer, and ultimately lead to the development of drugs that would control chromatin remodeling.

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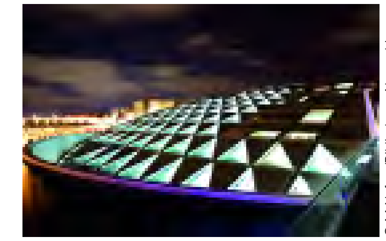
Partnership with the Bibliotheca Alexandrina



The Bibliotheca Alexandrina by night.

© M.Nafea /Bibliotheca Alexandrina

A framework agreement for the study and safekeeping of Near and Middle Eastern heritage was signed in Paris on June 15th by Catherine Bréchignac, CNRS president, and Dr Ismail Serageldin, director of the Bibliotheca Alexandrina (Egypt). This agreement will enable researchers from both institutions to work on joint programs and to exchange their know-how in several areas like conservation, the production and history of epigraphic materials, numismatics, or the East's musical heritage... The partnership will also be strengthened through the development of online documentary databases, exchanges of personnel and materials, and the joint promotion of research results. The agreement follows Bréchignac's official visit to Egypt last February, which also made it possible to begin work on the Year of French research and Technology in Egypt, scheduled for 2010.

Brazilian Analyses

Last April, CNRS and UESC (Universidade Estadual de Santa Cruz) created the International Associated Laboratory IFAP[1] in Brazil, an institute dedicated to research and physicochemical analyses. The new Institute will be verifying–for Latin America and French Guiana–the quality of products for export and import, such as agricultural products, meat and fish, as well as raw materials. One of IFAP's objectives is to set up a reference center associated with the Service central d'analyse at CNRS, a service unit whose mission includes carrying out physicochemical analyses for institutional and private laboratories. But IFAP will also be training high-level specialists in instrumentation, and developing novel methodologies for chemical and physicochemical analyses in numerous sectors including the environment, medicine, agriculture, and the chemical and oil industries.

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Viruses Under Scrutiny

The International Joint Unit (UMI) "Unit of Virus Host Cell Interactions" (UVHCI) was inaugurated on June 26th, 2009. Associating the University Joseph Fourier, the EMBL Grenoble Outstation and CNRS, it aims to pursue international research in structural and molecular biology, focused–but not exclusively–on virus-host cell interactions and the development of associated techniques. UVHCI is in particular involved in research on AIDS and the flu virus.

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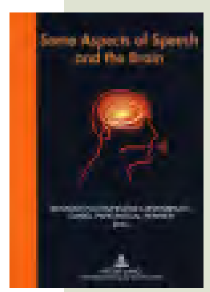
Books

Some Aspects of Speech and the Brain

Susanne Fuchs, Hélène Lœvenbruck, Daniel Pape, and Pascal Perrier (Bern: Peter Lang). 2009. 405 pages. Price: €64

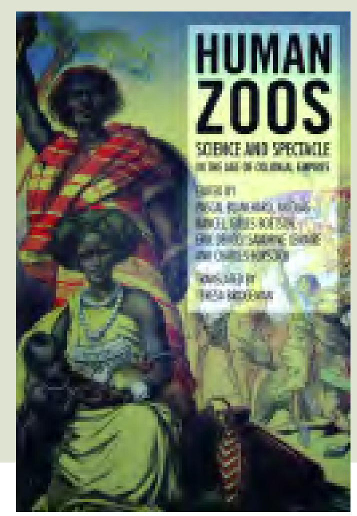


What happens in the brain when humans are both producing or listening to speech? This is the main focus of this book, written by researchers at some of the foremost European laboratories in the fields of linguistics, phonetics, psychology, cognitive sciences, and neurosciences. It includes a collection of 13 articles that review the progress achieved over the last 20 years in these areas. A large part of the book deals with brain activation in speech and language pathologies: language-related aspects in epilepsy, Parkinson's disease, dyslexia, and stuttering.

Human Zoos: Science and Spectacle in the Age of Empire

Pascal Blanchard, Nicolas Bancel, Gilles Boëtsch, Eric Deroo, Sandrine Lemaire, and Charles Forsdick, Eds. Trans. Teresa Bridgeman (Liverpool: Liverpool University Press). 2009. 352 pages. Price: £19.95

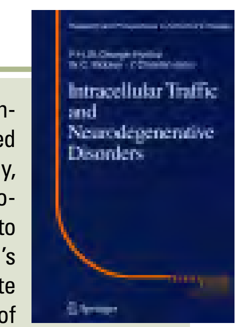
"Human zoos," forgotten symbols of the colonial era, have been totally repressed in our collective memory. In these "anthropo-zoological" exhibitions, "exotic" individuals were placed alongside wild beasts and presented behind bars or in enclosures. Based on the best-selling French volume *Zoos Humains* but with a number of newly commissioned chapters, *Human Zoos* puts into perspective the "spectacularization" of the Other, a process that is at the origin of contemporary stereotypes and of the construction of our own identities. This is a unique book on a crucial phenomenon, which takes us to the heart of Western fantasies, and allows us to understand the genesis of identity in Japan, Europe, and North America.



Neurobiology of "Umwelt:" How Living Beings Perceive the World (Research and Perspectives in Neurosciences)

Alain Berthoz and Yves Christen, Eds. (Berlin-Heidelberg: Springer). 2009. 158 pages. Price: €139

At the beginning of the 20th century, German biologist Jakob von Uexküll created the concept of "Umwelt" to denote the environment as experienced by a subject. Today, neuroscience provides a new way to look at the brain's capability to create a representation of the world. At the same time, behavioral specialists are demonstrating that animals have a richer mental universe than previously believed. Philosophical reflection is thus linked to more experimental and objective data. Nearly a century after the publication of von Uexküll's founding work (*Umwelt und Innenwelt der Tiere* was published in 1909), neurobiologists, psychologists, sociologists, anthropologists, ethologists, and philosophers revisit his concept in the light of modern science.



CNRS in Brief

The **Centre National de la Recherche Scientifique** (National Center for Scientific Research) is a government-funded research organization under the administrative authority of France's Ministry of Research.

Facts…

Founded in 1939 by governmental decree, CNRS has the following missions:
- To evalulate and carry out all research capable of advancing knowledge and bringing social, cultural, and economic benefits to society
- To contribute to the application and promotion of research results
- To develop scientific communication
- To support research training
- To participate in the analysis of the national and international scientific climate and its potential for evolution in order to develop a national policy

CNRS research units are spread throughout France, and employ a large body of permanent researchers, engineers, technicians, and administrative staff. Laboratories are all on four-year, renewable contracts, with bi-annual evaluations. There are two types of labs:
- **CNRS labs:** fully funded and managed by CNRS
- **Joint labs:** partnered with universities, other research organizations, or industry

As the largest fundamental research organization in Europe, CNRS is involved in all scientific fields, organized into the following areas of research:
- Life sciences
- Physics
- Chemistry
- Mathematics
- Computer science
- Earth sciences and Astronomy
- Humanities and Social sciences
- Environmental sciences and Sustainable development
- Engineering

CNRS conducts some twenty interdisciplinary programs in order to promote exchange between fields, ensure economic and technological development, and solve complex societal problems.
→ www.cnrs.fr/prg/PIR/liste.htm

The CNRS annual budget represents one-quarter of French public spending on civilian research. This funding comes from various sources:
- Government and public funding
- CNRS funds, primarily from industrial and EU research contracts and royalties on patents, licenses, and services provided

… And Figures

Budget for 2009
€3.36 billion of which €607 million comes from revenues generated by CNRS contracts

Personnel
32,000 employees: 11,600 researchers, 14,400 engineers and technical staff, and 6000 non-permanent employees

Organization
- 9 thematic institutes
- 19 regional offices, ensuring decentralized direct management of laboratories
- 1100 research units–90% are joint research laboratories with universities and industry

Industrial Relations (2007)
- 1680 contracts signed by CNRS with industry in 2007
- 30 current agreements with major internat-ional industrial groups
- 3103 patent families
- 729 licenses and other financially remune-rating active acts
- €58.2 million in royalties
- 394 companies created between 1999 and 2008

DAE AND DRI, TWO OFFICES DEVOTED TO INTERNATIONAL RELATIONS

CNRS carries out research activities throughout the world, in collaboration with local partners, thus pursuing an active international policy.

The Office of European Affairs (DAE) and the Office of International Relations (DRI) coordinate and implement the policies of CNRS in Europe and the rest of the world, and maintain direct relations with its institutional partners abroad. The DAE and the DRI promote cooperation between CNRS laboratories and foreign research teams through a set of structured collaborative instruments developed for this purpose. At the same time, they coordinate CNRS actions with those of other French and international research organizations as well as the activities of the Ministries of Research and Foreign Affairs.

To carry out their mission, the DAE and the DRI–with head offices in Paris–rely on a network of eight representative offices abroad, as well as on the science and technology offices in French embassies around the world.

IN NUMBERS:

Exchange agreements: 85 (with 60 countries)

Foreign visiting scientists: 5000 (PhD students, post-docs, and visiting researchers)

Permanent foreign staff members:
> About 1700 researchers of whom more than 1200 come from Europe

> **International Programs for Scientific Cooperation (PICS):** 363
> **International Associated Laboratories (LEA + LIA):** 89
> **International Research Groups (GDRE + GDRI):** 90
> **International Joint Units (UMI):** 18

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AMAZING IMAGES

Fibers Across the Brain

Could these fluorescent seaweeds have been brought back from the depths of an ocean? From the depths indeed, but from those of our brain. This is a 3D reconstruction of bundles of nerve fibers found in white matter, the inner part of our brain.
To create this map, researchers at CI-NAPS[1] in Caen used Diffusion Magnetic Resonance Imaging and tractography, an image processing technique that makes it possible to follow the path of fibers in 3D, as well as their orientation (left to right in red, front to back in green, and upwards in blue). The map shows specific networks of nerve fibers from the brainstem, the region found between the brain and the spinal cord. Each bundle represents thousands of fibers which connect the different regions of the brain. Because disorder in these brain fibers is related to pathologies such as Alzheimer's or schizophrenia, this type of *in vivo* 3D reconstruction is of major interest for early detection in at risk patients, or to investigate the evolution of the disease. **I.F.**

1. Centre d'Imagerie-Neurosciences et d'Applications aux Pathologies (CNRS / CEA / Université de Caen Basse-Normandie / Université Paris-Descartes).

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