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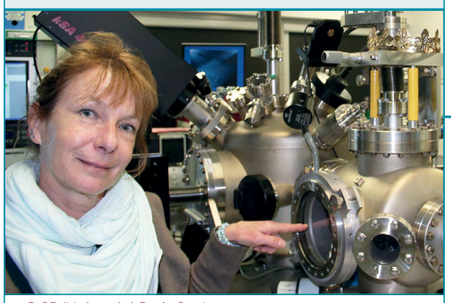
PRIZES & AWARDS

RESEARCHERS



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Agnès Barthélémy, from the CNRS/Thales Physics laboratory (UMPhy – UPSaclay, CNRS, Thales) was awarded **the 2021 IUPAP Magnetism Award and Néel Medal** for her work on magnetic and ferroelectric materials.

Bérengère Dubrulle, from the Condensed Matter Physics laboratory (SPEC – UPSaclay, CEA, CNRS) received the **2021 Lewis Fry Richardson Medal** from the European Geosciences Union (EGU) for her work on fluid dynamics.

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Christophe Junot, head of the Medicines and Healthcare Technologies Department (DMTS – UPSaclay, CEA) and the Pharmacology and Immunoanalysis Unit (SPI – UPSaclay, CEA, INRAE), was appointed **Knight of the Legion of Honour**. This distinction recognises his career in the field of biosensing for therapeutic and diagnostic purposes.

Julien Lagarde, a clinical neurologist and researcher at the Paris-Saclay Multimodal Biomedical Imaging Laboratory (BioMaps – UPSaclay, CEA, CNRS, INSERM) has been awarded the **Joël Ménard Prize** by the Fondation Alzheimer (Clinical and Translational Research category) for his work on pathophysiological mechanisms of neurodegenerative diseases using molecular imaging tools (PET).

Michel Masella and **Raphaël Guérois** from the Institute for Integrative Biology of the Cell (I2BC – UPSaclay, CEA, CNRS) (Computational Biologics category) and Nicolas Tournier from the Frédéric Joliot Hospital Service (SHFJ – UPSaclay, CEA) (Nanobody Explorative Technology category) have won the **2021 Sanofi iTechAwards.**

Antoine Strugarek, from the Department of Astrophysics (DAp – UPSaclay, CEA), has received the **2021 MERAC Prize for the Best Early Career Researcher in Theoretical Astrophysics** from the European Astronomical Society (EAS).

Bertrand Thirion, who leads the PARIETAL team (UPSaclay, Inria, CEA) in the NeuroSpin department, is a research director at Inria and director of the Institut DATAIA Paris-Saclay. He was appointed **Knight of the National Order of Merit** in recognition of his research work on statistical modelling of brain function using neuroimaging data.

Antoine Browaeys, from the Charles Fabry Laboratory (LCF – UPSaclay, IOGS, CNRS) and **Cathy Clerbaux**, from the Atmospheres, Space Observations Laboratory (LATMOS – UVSQ, CNRS, Sorbonne Univ.) have received a **2021 silver medal from the CNRS**.

Wadih Ghattas, from the Orsay Institute of Molecular Chemistry and Materials (ICMMO – UPSaclay, CNRS), **Marie-Aline Martin-Drumel**, from the Orsay Institute of Molecular Sciences (ISMO – UPSaclay, CNRS), **Freek Massee**, from the Laboratory of Solid State Physics (LPS – UPSaclay, CNRS) and **Sylvia Matzen**, from the Centre for Nanosciences and Nanotechnology (C2N – UPSaclay, CNRS, Univ. de Paris) have been awarded a **2021 bronze medal by the CNRS**.

Daniel Berveiller, from the Laboratory of Ecology, Systematics and Evolution (ESE – UPSaclay, CNRS, AgroParisTech), and **Véronique Puill**, from the Laboratory of the Physics of the two infinities – Irène Joliot-Curie (IJCLab – UPSaclay, CNRS, Univ. de Paris) have been awarded a **2021 crystal medal by the CNRS**.

The animated film "Le Nobel Chevelu" (The Hairy Nobel), created in partnership with the Physics Reimagined (La Physique Autrement) research team (UPSaclay), received the **audience award for the best short film** at the 2021 International science and cinema meetings.

STUDENTS

© Jean-Marie Fischbach

The team from the **Fundamental Physics Master's course** at Université Paris-Saclay were awarded **1st place at the 2021 French Physicist Tournament**, organised by the youth division of the French Physics Society.

Clotilde Chambreuil, **Alexandre Daby-Seesaram**, **Matthieu Diaz**, **Héloïse Rostagni** and **Ronan Scanff**, PhD students at the Laboratory of Mechanics and Technology (LMT – UPSaclay, ENS Paris Saclay, CNRS, Sorbonne Univ.) are the **winners of a global hackathon in coding**, organised as part of a junior workshop during the WCCM-ECCOMAS 2021 world conference.

Marie-Sophie de Clippele (ENS Paris-Saclay) has won the **"Valois – Young Researchers 2020" thesis prize** awarded by the French Ministry of Culture.

Lesly-Ann Daniel, a PhD student at the Systems and Technology Integration Laboratory (LIST – UPSaclay, CEA), has been awarded the **2020 France L'Oréal-UNESCO Rising Talent Prize for women in science** for her work on software safety analysis.

Maxime Maheu has been awarded the **Young researchers Prize from the Fondation Bettencourt-Schueller** for his thesis work in experimental psychology at the Cognitive Neuroimaging Unit (UNICOG/NeuroSpin – UPSaclay, Inserm, CEA, CNRS).

Virginie Sellier has been awarded the **2021 OZCAR prize** for her PhD work carried out at the Laboratory of Climate and Environmental Sciences (LSCE – UPSaclay, CNRS, CEA, UVSQ).

The **Sport, Leisure and Event Management Master's course** (SLEM) at Université Paris-Saclay came **3rd in the Eduniversal 2021 rankings**, which ranks the best Master's courses in Sport Management in France.

COMPANIES/ PROJECTS

The **INSPEX project**, a portable environmental perception device for the visually impaired, developed at LIST (UPSaclay, CEA) was awarded the **"Étoiles de l'Europe 2020" prize**.

Junior CentraleSupélec, the school's Junior Entreprise, was awarded the **2021 Prize for the Best Junior Enterprise in Europe 2021** for the third year running, as well as the **Most Impactful Project 2021 prize**.

The **POFiné project** is a nutritious gourmet dessert that has been specially designed for elderly people. The project is led by students from AgroParisTech, and won the **Université Paris-Saclay 2021 Student Entrepreneurship Day (JEE)** organised by the Pépite PEIPS network, in the "Product – advanced stage" category. It also won **the Silver Award** and **the Innovation Nutrition prize at the ECOTROPHELIA competition**.

EDITOR'S LETTER

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At the start of summer 2021, Université Paris-Saclay strengthened its position as a world-class research-intensive university – a joyous prelude to our return to campus in September. For the second year in a row, the University was ranked 1st in the world for Mathematics, 9th for Physics and 12th for Agricultural Sciences in the Global Ranking of Academic Subjects (GRAS). The University also secured spots in the global top 50 for eleven subjects, proving its research excellence once again. Université Paris-Saclay was ranked 22nd in the world for Clinical Medicine (1st in France), 29th for Statistics and performed well globally in various engineering subjects (29th for Telecommunication Engineering, 30th for Biotechnology, 32nd for Automation & Control, and 41st for Mechanical Engineering). The University also made excellent progress in Pharmacy & Pharmaceutical Sciences, ranking 30th globally, and Chemistry, coming 49th.

This new issue of *L'Édition* builds on these excellent distinctions, showcasing major research results that bring together a range of disciplines and demonstrate the excellence of the laboratory teams in our faculties, Grandes Écoles and the national research organisations who work closely alongside us. You will learn about recent research findings in blockchain, and their scientific, technological and legal challenges, in response to the sector's recent developments, which question both data access and security. Faced with an economic model that is becoming increasingly controversial, other research teams have been investigating and experimenting with new sustainable economic models as part of a circular economy approach. Whether these topics simply coincide with the agenda of scientific publications, or are current trends that research universities are observing first hand today, you can read all about them in this issue.

To celebrate our performance in Mathematics, Physics and Chemistry, we have dedicated two of our articles to our research in these fields. From ultra-short timescales and the infinitely small, to the infinitely large and the cosmic microwave background, we invite you on a journey at the speed of light to discover our femtosecond lasers and offer you a glimpse into the world of Physics and beyond. Simply dizzying!

And what about health, you might ask? In this issue, we take a look at our laboratory technology transfers to start-ups, with almost 50% of our innovations in healthcare.

A very special issue of *L'Édition* awaits you. I hope that you have a wonderful summer, and I look forward to harvesting our scientific efforts together in September for the coming year. I will be delighted to welcome you back along the green pathways on our campuses when you can, as they ever so surely spring back to life.

Sylvie Retailleau,
President of Université Paris-Saclay

Keywords
Student entrepreneurship – ITTE Master's course – Art and optics – BOPA Chair

Title

Student entrepreneurship at Université Paris-Saclay

© Eva Olah – IUT de Sceaux

© David Olivier Bouchez – Institut d'Optique

Increasing numbers of students are becoming involved in entrepreneurship, whether they are motivated by sheer curiosity, want to take part in a meaningful field or have a genuine business project. In order to best respond to these new aspirations, Université Paris-Saclay, its constituent faculties and institutes, *Grandes Écoles*, and associate institutions are providing several options for students to discover and/or learn about entrepreneurship throughout their courses.

When students were asked about their professional aspirations, nearly 40% of them mentioned entrepreneurship as a possible option during the course of their career. "*Today's generation sees entrepreneurship as an important option to pursue in an uncertain economic climate,*" points out Pascal Corbel, the Entrepreneurship Coordinator at Université Paris-Saclay. With this in mind, for several years, the University has been increasing its initiatives to support this trend as effectively as possible. Entrepreneurship is now present at all levels within the University through initiation courses, degree programmes and specific courses of study, with mentors to act as guides.

Courses to discover entrepreneurship

Being tempted by an entrepreneurial adventure is one thing. Understanding the nuts and bolts of it is another. The Maturaction programme was launched in 2019 to enable students to take this step and familiarise themselves with the process of becoming an entrepreneur. "*The idea is to offer groups with different profiles and levels of study the opportunity to test their entrepreneurial flair by giving them the chance to manage innovative research projects, based on real-life cases from the University's laboratories,*" explains Pascal Corbel. During evening workshops, students are asked to think about possible industrial applications, based on scientific results, and assess their potential in teams.

In the University's *Grandes Écoles*, raising awareness about entrepreneurship among student engineers also starts very early, often as soon as the first year. This can be as part of hackathons, like at the Institut d'Optique Graduate School, or during the Startup week at CentraleSupélec.

Degree programmes for students at Université Paris-Saclay

The University offers several study options for students who are already aware of entrepreneurship and wish to go further. A student in full-time academic or continuing education programmes, with or without a business project, can study one of four university degrees (Entrepreneurship; Creation and Development of Innovative Start-ups; Entrepreneurship, Law, Digital; Intrapreneurship) during in-person or remote evening classes and learn how to design, launch or develop a business.

In the 3rd year (L3), students who already have an entrepreneurial project can opt for the vocational degree in Management and Administration of Organisations at the Sceaux Technical Institute (IUT), which takes on 24 students each year. "*Our objective is to teach students about the different aspects of business creation and put them in touch with the entrepreneurial community at Paris-Saclay. In short, to support them as closely as possible until they take their first steps!*" explains Nathalie Claret, who jointly manages the degree course.

At a higher level, those who are looking to specialise in entrepreneurship-related professions can opt for the Master's degree in Strategic Management, and specialise in Entrepreneurship and Innovative Project Management at the Jean Monnet Faculty (Law, Economics and Management), which can be studied remotely. "*At the end of the course, they will either set up their own business or take up positions as innovation managers or consultants in support organisations for entrepreneurs,*" explains Pascal Corbel, who manages the Master's course.

Another option for entrepreneurs who have already graduated is to study for an inter-institutional student entrepreneur degree (D2E), run by the Pépite PEIPS network of young entrepreneurs in the Paris-Saclay region. It provides graduates with an individual entrepreneurial support programme while allowing them to enjoy the benefits of the French national student entrepreneur status. "*Designed as a pre-incubator programme, the D2E promotes action-based learning. It equips students with skills which are useful for business creation, but which can also be used in companies,*" explains Florence Law, Head of the D2E programme.

PhD candidates who want to learn how to promote their research and be entrepreneurial can study the Doctor'Preneuriales course. Its

modules are taught by innovation and business creation professionals from the University and its partners.

Courses of study for engineering students at the University's *Grandes Écoles*

The University's *Grandes Écoles* are often forerunners in entrepreneurship. They also offer specific entrepreneurship courses or programmes, such as the *Itinéraire Entrepreneuriat* course at AgroParisTech, which offers students support for a business creation project or a new transferable activity while pursuing their studies. These *Grandes Écoles* go as far as to offer integrated incubators, such as the Food In'Lab at AgroParisTech. Since 2006, students at the Institut d'Optique have been able to join the Innovation-Entrepreneurs course (FIE) in their second year. "*Students are put in charge of very real technological business projects. They have weekly support, over periods of several weeks, at one of our three entrepreneurial '503' centres, as well as the guidance of some fifty tutors to breathe life into their project as a team. It is a powerful experience and one from which they emerge transformed,*" explains David Olivier Bouchez, Head of the FIE programme. At CentraleSupélec, in addition to the Entrepreneurship course which can be accessed in the first year, students in their third year can opt to join the long-standing Entrepreneurship programme created in 2000, or the new Innovation and Intrapreneurship course launched in 2020. "*Aside from educating them, the aim is to place our students at the heart of a community of entrepreneurs, investment funds, a fablab and an incubator, etc., and to best prepare them for the future,*" says Jean-François Galloüin, a professor at CentraleSupélec.

https://www.universite-paris-saclay.fr/formation/entrepreneuriat-etudiant

Title

A Master's to learn about responsible tourism

In the spirit of civic responsibility, Université Paris-Saclay is now offering a Master's in Ecological and Tourism Transition Engineering (ITTE – *Ingénierie de la transition touristique et écologique*). While it is still not very widespread in France, this type of specialisation in sustainable and responsible tourism represents the future of the tourism industry. "*It's about encouraging a change in tourism today by reducing its impact on the environment and respecting local cultures more,*" says Frédéric Leriche, Head of the ITTE Master's course. As of September 2021, the course will be available to second-year students enrolled in the Master's degree in Regional Management and Local Development. Studied as an apprenticeship, it offers twelve weeks of work-study courses from September to March, followed by five to six months of full immersion in a host organisation. "*The aim of the course is the professional development of our students,*" points out Frédéric Leriche. To do so, students are taught in real-life situations with expert work on tourism development projects, in partnership with the Yvelines departmental council.

https://www.universite-paris-saclay.fr/formation/master/gestion-des-territoires-et-developpement-local/m2-master-ingenierie-de-la-transition-touristique-et-ecologique

Title

Transforming science into art

© Christophe Peus

Supported by the Diagonale Paris-Saclay, the teaching unit "Art and Optics", is available to scientists who are passionate about art. Accessible to third year students studying the Physics and Applications undergraduate degree, it was designed by Gaël Latour, a lecturer at Université Paris-Saclay, and Mathilde Lavenne, an artist-videographer, with the help of the association, Societies. "*This course is an introduction to heritage science. No previous art experience is necessary,*" points out the scientist. Through twelve two-hour sessions, the duo share a new vision of research with some twenty students. They introduce the students to the basics of drawing as well as certain optical imaging techniques through various activities at the interface of the two disciplines. Throughout the semester, the students can give free rein to their imaginations, making several artistic creations including sketches and watercolours, and creating an individual piece based on scientific images collected during visits to heritage science laboratories.

http://hebergement.universite-paris-saclay.fr/l3papp/?page_id=6232

Title

The BOPA innovation chair – digital technology to improve operating room practice

© Chaire BOPA

Created in January 2020 and based at the Paul-Brousse AP-HP hospital, the Augmented Operating Unit chair (BOPA – *Bloc Opératoire Augmenté*) brings together those involved in the operating room, engineers and researchers from Université Paris-Saclay, Inria and CNAM. "*The project aims to transform the way invasive treatments are performed in the broadest sense,*" explains Professor Eric Vibert, a surgeon at the Paul-Brousse AP-HP hospital, a professor at the Paris-Saclay Faculty of Medicine and the chair's founder. The chair hosts a mock operating room to test augmented reality, collective robotics and communication systems and improve operating room practices. It contributes to increasing the senses of its participants (through sight, touch and speech) and developing tele-expertise and new learning methods.

http://www.chaire-bopa.fr/

Title

Sky and space – Earth and Space Science in the spotlight!

© Maroun Habib

© Les ptits cueilleurs d'étoiles

With summer approaching, there are even more opportunities to look up to the sky. These special moments are at the heart of several initiatives and events taking place throughout the summer.

Two years after the first "On the Moon Again" event, during which 1,350 events took place in 77 countries, astronomy enthusiasts are once again being called to take to the streets with their telescopes from 16 to 18 July 2021. "*When you place a telescope in the middle of a street, most of the people you meet have never imagined being able to see the moon up close. It's the best way to bring astronomy to the people and spark interest,*" says Sylvain Bouley, a planetologist at the Paris-Saclay Geosciences laboratory (GEOPS – Univ. Paris-Saclay, CNRS) and the event's coordinator.

The researcher is also president of the "*Les p'tits cueilleurs d'étoiles*" association (The little star gatherers), which was created in 2016 and delights children in hospitals across France. "*We dress up as astronauts and show them a small meteorite. This creates a sense of wonder which acts as starting point to talk about the stars and listen to the children*." The association also organises evenings for telescope observation, get-togethers and virtual reality launches into orbit. "*It is important that the children enjoy themselves before any learning takes place. It is a chance for both the children and their parents to have a break*."

This is also the aim of the "*Du Big Bang aux big bands*" festival (From the Big Bang to Big Bands), which will be organising its second edition on 3 July. Discussions with astrophysicists, concerts, live observations from major observatories and many other surprises are planned throughout the night on the "Le Sense of Wonder" YouTube channel. "*The aim of the festival is to have some fun and combine art with science,*" explains Hervé Dole, an astrophysicist and Vice-President of Art, Culture, Science and Society at Université Paris-Saclay.

However, the festival would not have been complete without the radio contact planned on 17 June with the astronaut Thomas Pesquet, who is currently in orbit on the International Space Station. The event was hosted by French journalist Fred Courant, astronaut Claudie Haigneré, researcher Raphaël Haumont, and others. The radio contact was also broadcast in lecture halls across the plateau de Saclay campus, the Jean Monnet Faculty, UVSQ and online.

https://www.onthemoonagain.org/

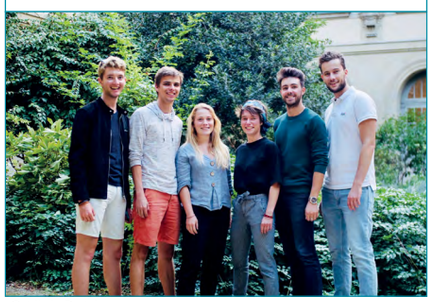
http://lesptitscueilleursdetoiles.fr/

http://www.dubigbangauxbigbands.fr/

https://www.youtube.com/watch?v=rYuhW9uE-JLU&ab_channel=Universit%C3%A9Paris-Saclay

Title

A polar expedition for the climate



© Niels Dutrievoz

Six students from the *Écoles Nationales Supérieures* (one of which is ENS Paris-Saclay) are preparing for an eight-month expedition to Antarctica on board a polar sailing boat. They will be leaving for the Antarctique 2.0°C project in September 2021, accompanied by three sailors and in collaboration with French and international laboratories. Using their combined skills and knowledge in biology, chemistry, geosciences and sociology, they will be measuring the impact of the climate and humans on southern ecosystems. Their goal is to document, educate and raise awareness about climate issues among the general public and young people using a digital logbook which will be sent to teachers in over 200 French primary schools. "*It is so much more than just a cross-disciplinary scientific expedition – it is also an awareness-raising educational mission,*" says Niels Dutrievoz, one of the project's creators. A series of videos, several podcasts and a YouTube channel will also be made available with the support of the expedition's sponsors: sailor Clarisse Crémer, researcher Delphine Lannuzel, journalist Jamy Gourmaud and explorer Mike Horn.

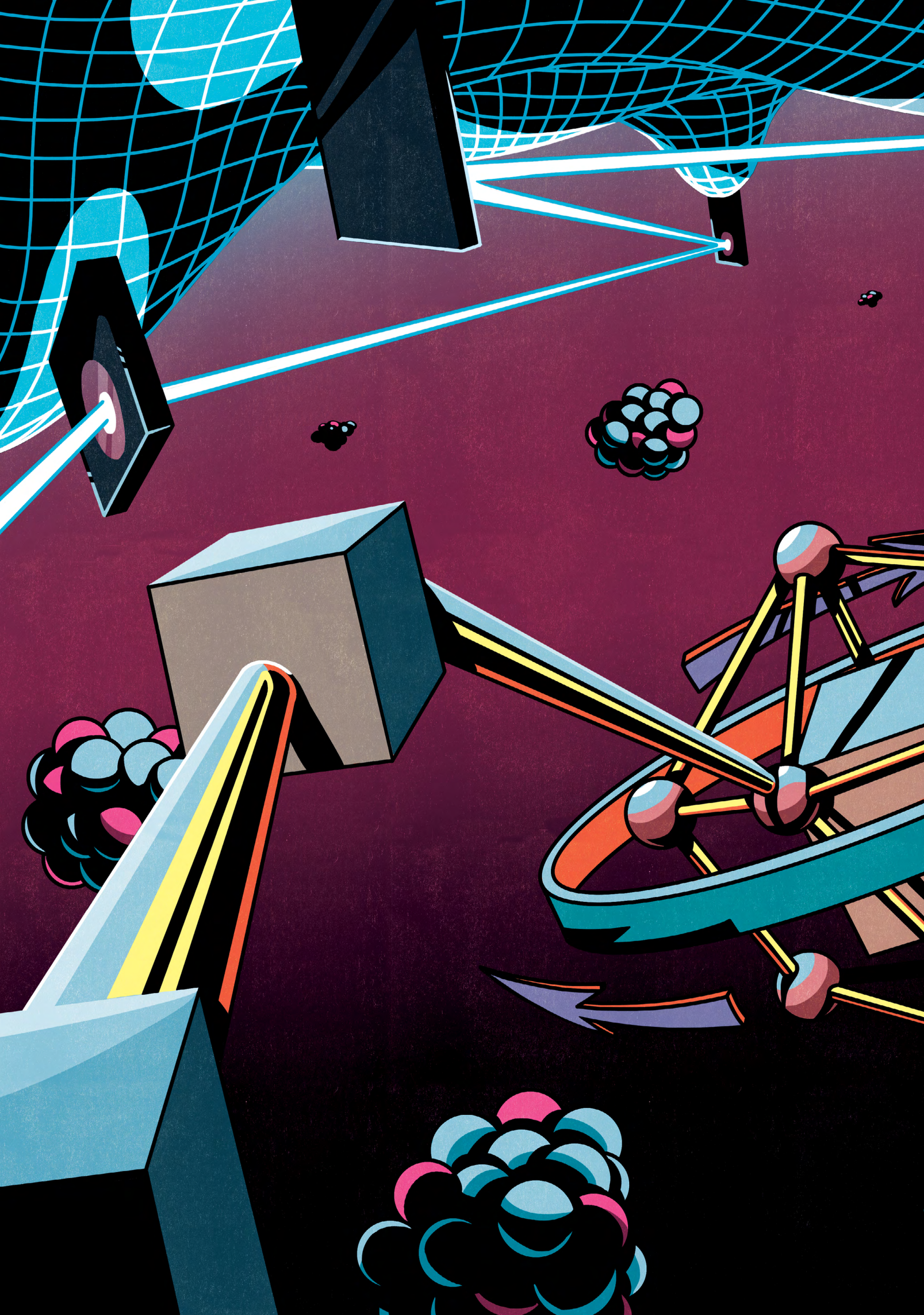
https://www.j2d.org/antarctique2d

Title

Science for all

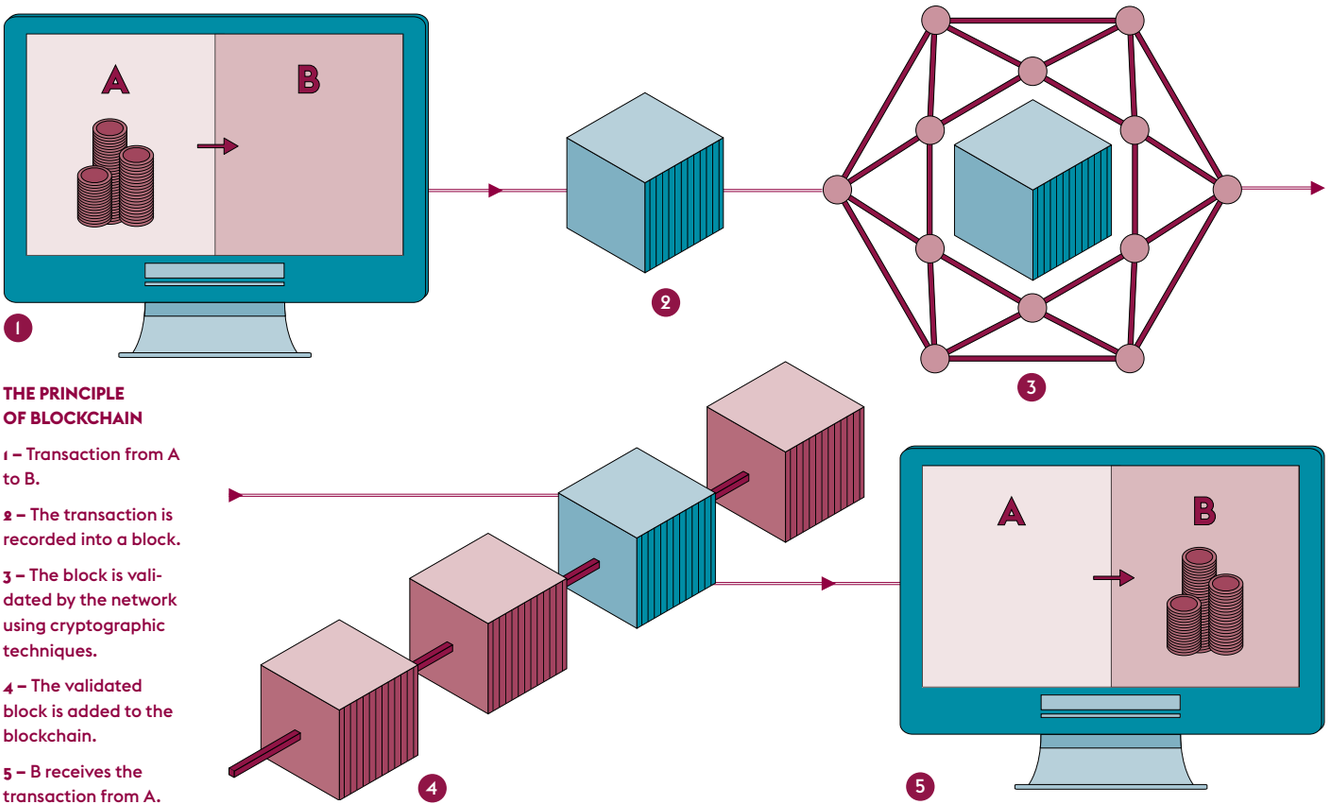
The aim of the *Sciences pour toutes et pour tous* (Science for All) project, funded by the Ministry of Territorial Cohesion, is to open the University up to secondary school students from priority education networks by promoting contact with researchers. "*One of the objectives is to introduce them to some current major scientific issues, the way research works and the diversity of the research jobs,*" explains Hélène Courvoisier, a biologist at Université Paris-Saclay and a member of the project. Together with other researchers and artists, she visits schools during half-day "Déclics" events (Dialogues Between Researchers and Students to Engage them in the Construction of Knowledge). "*The informal exchanges with passionate adults are very enriching for these students and, hopefully, will be a trigger for their future orientation.*" Three summer schools in June and July will aim to help female students rediscover computer science and mathematics and combat gender stereotypes in these subjects.

Illustrations right-hand page and page 22: **Maxime Mouysset**



Title

Unlocking the potential of blockchain



THE PRINCIPLE OF BLOCKCHAIN

1 – Transaction from A to B.

2 – The transaction is recorded into a block.

3 – The block is validated by the network using cryptographic techniques.

4 – The validated block is added to the blockchain.

5 – B receives the transaction from A.

Today, blockchain is being used more widely. This requires lifting a certain number of scientific, technological and legal barriers, which scientists at Université Paris-Saclay are currently working on.

Bitcoin (2008) and Ethereum (2015) are the most well-known, while Zcash (2016), Tezos (2018) and Algorand (2019) are the most recent. With millions of users worldwide, these various crypto-currency (token) exchange networks are based on blockchain technology. Blockchain is similar to a shared, transparent and secure database which operates in a decentralised manner and without a controlling intermediary. Similar to a distributed ledger, it contains the entire history of transactions carried out on a network by the parties involved. Transactions are grouped and recorded in blocks of data which are linked to each other. Each new block is first validated by the participants before being added to the chain using blockchain-specific techniques. In the end, each user has the same copy of the database.

While the general public still tend to largely associate blockchain with the transfer of assets, this technology for storing and sharing information is now used in other sectors (health, supply chain, intellectual property, governance, voting, energy, automotive, etc.) and is of increasing interest to companies. Originally intended to be public and open to all (still its most popular format), the technology has evolved into private formats, such as those developed by companies, with access limited to authorised users.

Once upon a time there was proof of work

While a range of parameters vary from one blockchain to another, the mechanism for validating new blocks of data, or a consensus protocol, is the key to ensuring that the system remains consistent. The method used when Bitcoin first emerged and which was widely adopted by subsequent public blockchains is proof of work, or PoW, based on the solution of algorithmic problems. This validation mechanism responds to a crypto-economic logic: the first user to solve the algorithm sees their efforts (and computing power) rewarded by the payment of tokens. In this scenario, it is more profitable for participants to try to secure the network rather than attack it. "*If a person has to make an effort to validate the blocks and is paid in return, they will be more likely to respect the protocol and not jeopardise the blockchain,*" points out Sara Tucci-Piergiovanni, head of laboratory and blockchain expert at the Software and Systems Engineering Department (DILS) at the CEA-List (Univ. Paris-Saclay, CEA). The more users a network has whose validation mechanism is based on PoW, the more secure it is.

However, even if blockchain is considered almost infallible and unfalsifiable, it is not immune to attacks, like the so-called 51% rule. It occurs when one user has enough computing power to dominate and take control of the blockchain. This type of attack is unlikely for large blockchains, but becomes possible with smaller ones.

One of the main problems with blockchains, whose consensus protocol is based on proof of work, is their energy consumption. "*The most optimistic of assessments suggest that validating a transaction with PoW is equivalent to consuming as much energy as that consumed by a four-person household per day in France,*" says Sara Tucci-Piergiovanni. On Bitcoin alone, the number of transactions averages 330,000 per day.

In addition to its energy and environmental costs, PoW also limits scaling up options. "*The most popular public blockchains, such as Bitcoin and Ethereum, are experiencing bottlenecks. Ten transactions take place per second at most, which is relatively low. More efficient consensus, data representation and transaction processing mechanisms must be found in order to scale up to several thousand transactions per second,*" points out Daniel Augot, a researcher at Inria Saclay and a member of the Ile-de-France academic research group BART (Blockchain Advanced Research & Technologies).

The challenge of proof

It is for these reasons that another method for achieving distributed consensus, which has emerged in recent years, is gaining ground in public blockchains. Known as proof of stake or PoS, the method does not consume so much energy. The PoS does not require users to use their computing power, but instead prove that they hold a certain amount of crypto-currency in the blockchain. "*The more assets the user has in the system, the more likely they are to be chosen as a block validator,*" explains Daniel Augot. As the user commits their money and the money invested is locked in, it is in the user's interest to contribute to the smooth running of the system. This mechanism is at the heart of the Cosmos, Cardano and Tezos blockchains, and Ethereum has committed itself to implementing the PoS model by the end of 2021.

"*With proof of stake, there is however a small chance that two validators will be chosen at the same time to validate a transaction and enter it into the next block. This can produce two competing blocks, one of which must be rejected. The rule when this occurs is to opt for the longest chain,*" points out Sara Tucci-Piergiovanni. A new algorithm developed and applied by some blockchain platforms such as Hyperledger and Tendermint avoids this temporary inconsistency. This consensus algorithm, known as byzantine fault tolerant (BFT), tolerates network communication faults and uses a list of validators known at the outset. For additional security, the most recent blockchains combine PoS and BFT. "*They include a committee of validators whose task is to approve each new block generated by a BFT algorithm. If a quorum of signatures is reached for a given block, then it is immediately accepted by the rest of the network. It starts again in the same way for a new block,*" explains Sara Tucci-Piergiovanni.

At CEA-List, researchers have recently analysed the BFT consensus protocol of the Tendermint blockchain. "*Certain flaws and vulnerabilities were found and have since been fixed,*" says Sara Tucci-Piergiovanni. This work also confirmed Tendermint's ability to tolerate up to one third of malicious participants without jeopardising the consistency of the system. The team is currently working on low power blockchains, such as Tezos, which use PoS and the BFT algorithm. "*The security and performance of these systems continue to improve.*"

Proving without showing

Guaranteeing the confidentiality of transactions when a public blockchain is, by definition, open, (meaning everyone can see everything), is one of the other cryptographic issues that remains to be resolved. The solution might just lie in the zero knowledge proof (ZKP) protocol, which is used by the blockchain Zcash. The ZKP makes it possible to prove that transaction's validity criteria have been met without having to explicitly show them, i.e. without providing evidence. Neither the sender, nor the recipient, nor the transaction amount are known. "*It is a bit like the game 'Where's Wally?' – to prove that the character has been found in the picture without showing him precisely, a much larger sheet of paper is superimposed and perforated at the character's exact location,*" explains Daniel Augot.

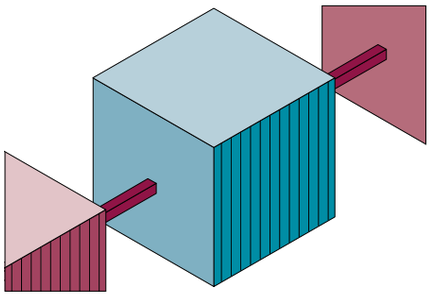
The other advantage of ZKP is that the proof provided is much shorter than the real proof. This makes validating a large number of transactions with a single proof possible. "*Zero knowledge proof excites people, especially in industry. It is seen as a solution for scaling up and major standardisation initiatives are being carried out on this technology,*" says Daniel Augot.

Auditing smart contracts

Smart contracts are another blockchain feature which are of great interest to industry. These computer programmes are quite small (between 30 and 100 lines of code) and once started, they automatically execute a set of predefined instructions within the network without the need for human intervention. Many of the challenges relate to their language and verification. "*The aim is to develop verification tools so that users, particularly those in industry, are able to describe their programme and its normal behaviour,*" explains François Bobot, a researcher from the Software and Systems Engineering Department (DILS) at CEA-List. These tools must be able to express the properties of the programme easily and verify them. "*The smart contract scene is very active. There are a lot of computer languages for coding them – new ones, as well as old ones which have been updated.*"

At CEA-List, François Bobot and his colleagues use the Why 3 platform to verify these programmes. The platform was developed by the Laboratory for Computer Science (LRI) which became the Formal Methods Laboratory (LMF – Univ. Paris-Saclay, CNRS, Inria, CentraleSupélec). "*Why 3 has a fairly powerful language and many tools to express the desired properties easily. It is used to transition towards the programming languages used by industry, like Solidity.*" The team uses formal methods, such as abstract interpretation, deductive verification and model checking. "*Using mathematical formulas, we try to describe the expected behaviour of the programme as precisely possible as in order to check that it respects its specification.*"

New areas of use



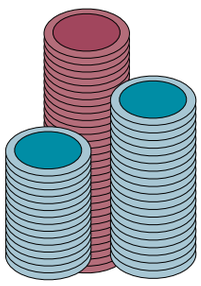
Today, blockchain is increasingly being used in areas like supply chains where traceability and product auditing is key. For example, BART and IRT System X are currently conducting a vehicle logbook project. The idea is to record in a blockchain all the operations carried out, from the numbering of spare parts in the factory to the arrival of the vehicle at the scrapyard. The goal is develop a passport for a product that conforms to a set of rules and criteria imposed by regulations. "*At the moment, there is no central supervisory authority capable of acting as a cross-border validator. And there is no other technology, apart from blockchain, which can meet this challenge,*" says Sara Tucci-Piergiovanni.

Recently, CEA-List has been working with TEO (The Energy Origin), the start-up incubated by Engie and Bureau Veritas, the world leader in inspection, certification and laboratory testing, to launch a green energy traceability application based on blockchain and the implementation of smart contracts. "*The aim is to ensure that the green energy credit lines produced in one location are used only once elsewhere,*" says François Bobot. With the start-up Connecting Food, CEA-List is trying to encourage stakeholders in the food industry to enter their certificates into blockchain for greater transparency.

The role of the legal system

Aside from technological issues, blockchain raises legal and regulatory questions which

legislators are only just beginning to address. And the task is not that simple. "*The technology is not stable, nor are its uses. It is difficult to provide a legal framework for an area that is constantly evolving,*" points out Mélanie Clément-Fontaine, a researcher of the Business Law and New Technologies Laboratory (DANTE – Univ. Paris-Saclay, UVSQ). Finding the right timing for legislation is not easy. "*If we intervene too early, the law will prevent the technology's development.*" The cross-border aspect of technology also makes it difficult to apply simple regulation.



"*This does not mean that there is a legal vacuum as there is an existing legal arsenal to draw on. The challenge is how to successfully adapt it to blockchain uses,*" suggests Mélanie Clément-Fontaine. The field of crypto-currencies, where the technology is most advanced, is the first field where the law has understandably become involved. "*It clarified how tokens are classified, which do not have the status of money but of digital assets.*" The PACTE law (Action Plan for Business Growth and Transformation), enacted in 2019, allows the creation of financial securities (shares) through blockchain. "*Thanks to this law, it is now possible to issue financial securities, which was previously reserved for banks,*" points out Véronique Magnier, a researcher at the Institute of Ethical Property Law (IDEP – Univ. Paris-Saclay). The law also added a principle of equivalence – a financial security on blockchain has the same scope as a security in a bank account. This principle challenges the supremacy of banks, which is something that the French competition regulator, the *Autorité de la concurrence*, is also monitoring. "*When players have their own crypto-currency, it creates an ecosystem which drives competition. The consumer is caught and locked into this system,*" points out Mélanie Clément-Fontaine.

Another issue, resolved by the 2016 Sapin II law, is the tax framework for transactions carried out in blockchain. The application of a flat-rate levy was the chosen solution. In regards to money laundering, the law has also intervened by passing a law in 2019 that removes the anonymity of users in the event of an inspection from tax and public authorities. "*The government's role is to ensure that individuals are protected when using this technology. It is mindful of respecting personal data, consumer rights and the prevention of scams or unlawful activities,*" says Mélanie Clément-Fontaine.

Shaking up corporate governance

The registration of financial securities in a blockchain opens up a whole field of possibilities in terms of corporate governance. Traditionally, holding shares in a company gives a person the right to vote at general meetings. Although French law has allowed remote voting since 2001, and in particular electronic voting, in practice it is not widely used as it is not considered secure enough. "*There have been many cases of fraud. Companies have remained very wary of this method of voting,*" says Véronique Magnier. However, the current health crisis has changed everything. The suspension of travel and face-to-face meetings has forced companies to develop blockchain-based voting platforms, the majority of which are private.

Blockchain also has the potential to ease the administrative burden on businesses. In France and abroad, companies are required by law to keep registers, including the register of share movements or the shareholders' register, the minutes of shareholders' and partners' meetings, the accounting books, etc. "*Transferring all of these records, which are typically kept in paper format, to a blockchain, would be revolutionary for company legal departments. However, this transfer would have to be planned in order to avoid any disruption of information.*"

The argument of legal evidence

In the field of intellectual property, blockchain is a good way to demonstrate the existence of prior art. "*People have rights and if someone challenges them, they have to prove the existence of a prior right,*" points out Véronique Magnier. As evidence is at the heart of the law during a trial, what type of evidence is blockchain similar to? French and European law allow for different types of evidence – documentary or written, witness accounts, circumstantial, confessions and oaths. Among forms of written evidence, the law recognises digital evidence and the value of digital writing. This evidence must meet a certain level of reliability. "*If there is a cryptographic protocol, the evidence is considered as submitted. However, as long as French or European legislators do not specify that blockchain evidence is equivalent to submitted evidence or simple evidence, we will remain in the dark.*" At present, this does not prevent certain lawyers from protecting their clients' intellectual property by using dedicated blockchain platforms. "*The question is how will a judge react to this type of evidence in a trial?*"

In the short term, efforts should be made to train lawyers and company staff. "*Today, companies do not necessarily have all the possible uses of blockchain in mind. People need training so that they can understand and be able to manage the technology,*" says Véronique Magnier. It is a technological shift which is at the root of many sociological questions as certain professions will probably disappear within companies. "*This will inevitably require a trade-off between human and artificial intelligence,*" warns the researcher.

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• Yackolley Amoussou-Guenou et al. Rational vs Byzantine Players in Consensus-based Blockchains. AAMAS 2020: 43-51.

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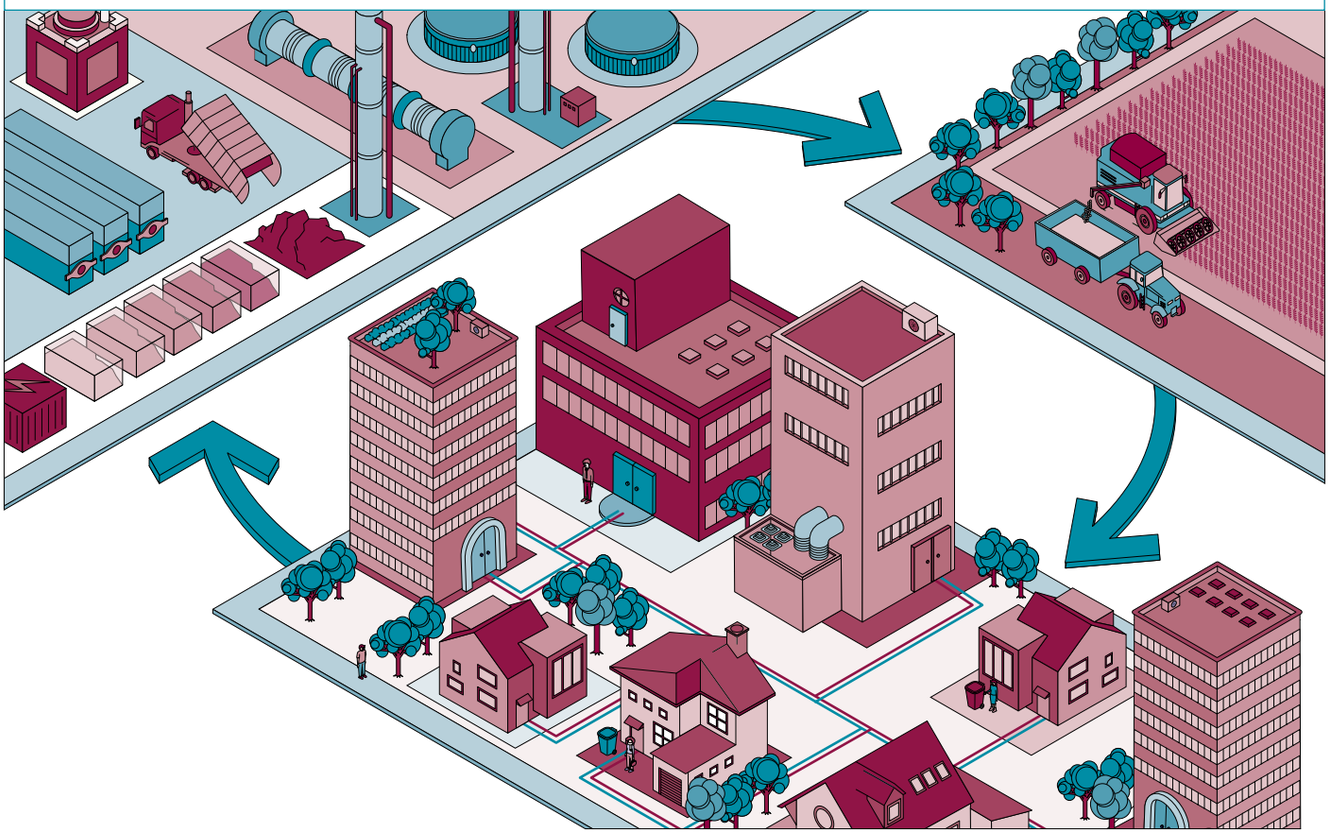
Keywords
Circular economy

Title

The shift towards a circular economy



Scientists at Université Paris-Saclay have been developing sustainable business models and efficient new circular processes to support mass production industries with their ecological transition.

With countries like France committing to carbon neutrality by 2050, people are following suit. Sustainable development is gradually taking root in people's minds and eco-friendly initiatives are on the increase. However, faced with the climate emergency and its consequences for the planet and its inhabitants, the global economy must be reassessed. This involves, among other things, increased restraint, an end to the overexploitation of the planet's limited resources and a reduction in carbon footprint. At the heart of this approach is the development of a circular economy for a sustainable transition which reconciles ecology with economic development.

Production from waste

Currently, the economy is largely based on a linear model. Natural resources are extracted to manufacture products (and their packaging) which are then sold, distributed, used and discarded at the end of their life. It is an energy-consuming model which generates waste and pollutants. The circular economy proposes reusing waste locally by transforming it into raw materials and reducing the environmental impact of consumption by placing material and energy flows in a continuous loop.

Over the past few years, several sustainable initiatives have been introduced on a large scale, such as the recovery of energy from waste incineration and the recycling of plastics, metals and glass. Nevertheless, these processes still need to be improved as most of the value of incinerated waste goes up in smoke and the quality of recycled plastic is not the same as the original. Actions which support the circular economy are also possible for ordinary citizens. This can be done by favouring a more responsible approach to consumption based on short supply chains and composting, or by simply extending the life of consumer products by exchanging services or goods, repairing used products and adopting good sorting habits for recyclable products.

As the saying goes, "*together we are stronger*". In order to be effective, the circular economy requires investment and commitment – especially from those at the forefront, i.e. mass production industries. In France, the construction sector produces about 30% of the country's greenhouse gas, the food industry is responsible for about 30% of household waste (mainly uneaten food) and the transport industry recycles very little of its commercial production. In contrast, responsible companies who make products from recycled materials, facilitate disassembly, reduce repair costs and recycle their own waste, greatly reduce their carbon footprint.

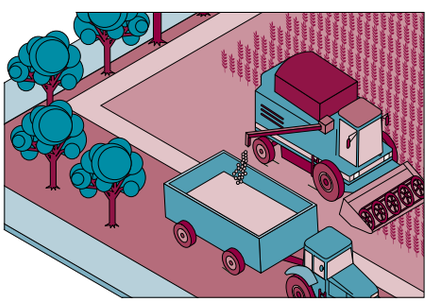
A worthwhile undertaking at a local level

The circular economy has many advantages. "*However, it is only worthwhile when it is implemented at a local level,*" explains André Torre, a researcher at the Science for Action and Development: Activities, Products, Regions Laboratory (SADAPT – Univ. Paris-Saclay, INRAE, AgroParisTech) and a specialist in regional sustainable development. If the concept of regional is broad, the reality is much less so. It is a matter of encouraging the local circulation of goods and services by bringing producers closer to consumers. "*Carrying out recycling*

abroad or consuming products from foreign organic farming isn't worthwhile as they involve a lot of time spent in transit and therefore result in greenhouse gas emissions," points out the researcher. Much more than mere geographical proximity, a closer relationship between different local stakeholders is crucial. "*Neighbouring businesses should have compatible operations in order to recycle their waste and reuse their energy locally.*"

Businesses are not the only ones who can benefit from focusing on a circular economy. By opening up a new market in the recycling sector, a circular economy helps to create jobs across the whole region. So, why is it not more widespread? The main obstacle at the moment is purely financial. With the exception of a few sectors that have already made the transition, such as food with short supply chains, biogas plants or heat networks, most companies find it difficult to change their production processes. One of the reasons for this is that they find it difficult to evaluate and value the benefits. Given this situation, government investment is needed to support businesses in their transition by offering financial incentives and simple, rapid assessment methods for sustainable investments.

Strengthening industrial circularity – a closer look at urban agriculture



Several scientists at Université Paris-Saclay are working to support companies in their efforts to become more sustainable. They are developing simplified analytical tools to help companies optimise the circularity of their industrial processes and reduce their carbon footprint. Several sustainable strategies which are feasible on an industrial scale are currently being considered in partnership with various industrial sectors.

Christine Aubry and Erica Dorr, who are urban agriculture specialists at the SADAPT laboratory, have developed strategies in collaboration with a mushroom farm located in the French department of Yvelines (78) to limit the environmental impact of their activity. "*Urban agriculture has been developing in France over the last ten years. It is an opportunity to implement the circular economy as it reuses urban waste locally,*" explain both researchers. "*The local aspect of the operation means that journeys are reduced to a minimum and producers and consumers can talk to each other more easily.*"

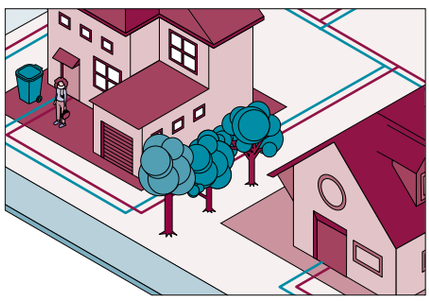
The mushroom farm is already well developed and generates a double circular economy in that, on the one hand, coffee grounds are reused as a growing medium for *Pleurotus ostreatus* (or oyster mushrooms) and, on the other, the mushroom compost is reused by farmers in the Île-de-France region to create fertiliser. Although this economy is already strong, the farmers would like to continue to reduce their emissions, which currently amount to 3kg of CO_2 per kilogram of mushrooms. By modelling different scenarios, the researchers have identified two strategies which will reduce their environmental impact by 45%. They involve reducing the pasteurisation time of the coffee grounds and improving sanitary practices to maximise the yield.

Apart from reusing organic urban waste, these analysis models also contribute to the development of alternatives to water consumption in the agri-food sector. "*The use of drinking water for watering crops would be reduced by reusing waste water. The sticking point at the moment is logistics and equipment. However, these issues are increasingly being addressed,*" says Christine Aubry.

These analysis models are nevertheless difficult to extend to all agricultural crops as each farm has its own expertise and particularities. In the case of outdoor crops, environmental conditions such as rainfall and temperature are not easily controlled and the parameters which can be influenced are very variable. It becomes quite difficult to model material flows and accurately assess the origin of impacts on the environment.

The potential of the second-hand car market

The automotive industry, however, offers greater stability for the development of technological-economic models. Bernard Yannou and his team at the Industrial Engineering Research Department (LGI – Univ. Paris-Saclay, CentraleSupélec) have also been using their skills and knowledge to explore the circular economy. In partnership with three companies specialising in the construction of heavy machinery (Manitou in France, Liebherr in Switzerland and John Deere in the United States), the team have developed a model for assessing the profitability of a second-hand market. Unlike light vehicles, the heavy machinery sector, which produces a massive amount of waste, is not subject to any recycling regulations. "*However, the volume of heavy machinery in circulation is exactly the same as for light vehicles,*" says Bernard Yannou in astonishment.



By buying back their used vehicles, companies could become key players in the second-hand market. Thanks to their expertise, they would be able to dismantle the machinery and resell or reuse the spare parts. "*Using the model we have developed, it is quick and easy to assess the condition of components, find out their value on the second-hand market and estimate the time and cost of the industrial processes involved in their reuse, such as disassembly, renovation and reconditioning. Next, consumer behaviour is simulated to find the perfect balance between circularity and overall profit on the two markets,*" explains the researcher.

This work has also revealed the importance of the traceability of goods. Companies are generally unable to locate their end-of-life vehicles, which makes it difficult to recover them. By modelling the recycling of platinum in particular – a metal which is as expensive as gold and contained in the catalytic converters of heavy machinery – scientists from the LGI have seen an exodus of material. "*Platinum is considered to be a critical material by the European Union. It is very difficult to recover, so it is becoming rarer and its price is increasing. According to our study, about 25% of losses are due to catalytic converters going outside of Europe,*" explains Bernard Yannou. The team from LGI have shown, through the use of a multi-model simulation, that the introduction of European economic directives on eco-design and traceability would reduce this loss by half.

Creating new sustainable processes – the potential of recycling printed circuit boards

While some scientists are trying to increase the circularity of existing industrial processes, others at the University are working to create new and scalable potential options. This is precisely what Jean-Christophe Gabriel from

the Nanoscience and Innovation for Materials, Biomedicine and Energy laboratory (NIMBE – Univ. Paris-Saclay, CEA, CNRS) is working on. In partnership with the Marcoule Institute for Separation Chemistry and Nanyang Technological University (Singapore), he has developed chemical separation methods to increase the recycling of e-waste.

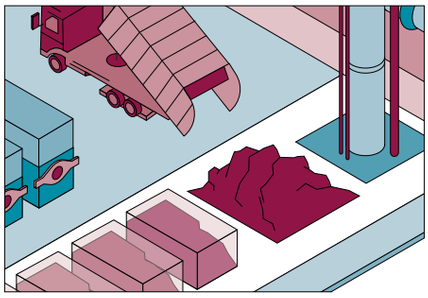
"*At the moment, just 30% of used printed circuit boards are recycled,*" points out the researcher. Traditional channels currently only recycle precious metals from printed circuit boards such as gold, silver and platinum, or those with high tonnage, such as iron, copper and aluminium. This is because the separation of chemical elements (nearly sixty per printed circuit) using thermal and chemical processes (liquid-liquid extraction), which are specific to each metal, is complicated. To tackle this, the team at NIMBE are exploring new process steps which can finely separate metals and recover rare earth metals, which are essential for new technologies. "*The challenge is to be economically viable despite the diversity of chemicals in the waste,*" says Jean-Christophe Gabriel.

Using selective sorting coupled with a microfluidic system and extensive chemical analysis, scientists have been able to evaluate more than 75 liquid-liquid extraction process steps using different formulations. "*This system reduces volumes and saves time. It also limits any increase in cost and waste.*" In addition, it means several kilograms of electronic components can be sorted per hour to selectively recover certain rare earth metals.

As this system also uses organic solvents (as do traditional processes), the team have developed a new extraction strategy based on supercritical CO_2. This non-toxic and easily recycled solvent has both the properties of a gas (to penetrate materials) and a liquid (to dissolve compounds). It successfully recycles both metals and plastics from printed circuit boards, which are contaminated with toxic additives such as dyes, polluting heavy metals and flame retardants. The team recently extracted the latter with an efficiency rate of about 40% per cycle, as the operation needs to be repeated until the desired purity is achieved. Unlike plastic recycling schemes, which fail to recover the full potential of polymers, this process is also able to improve their value on the market. "*The plastic can be purified by removing molecules that have not fully reacted. Recycled in this way, certain plastic waste can be reused in a higher value-added sector,*" says Jean-Christophe Gabriel.

Making better use of CO_2

While the creation of new circular processes helps to reduce CO_2 emissions, it also contributes to the recycling of the molecule. This is the approach proposed by Thibault Cantat, a chemist at the NIMBE laboratory. "*Producing fuels or chemical compounds requires the use of carbon products. Currently, the chemical industry relies on fossil fuels for more than 95% of its energy supply, but it would be a good idea to use renewable resources such as CO_2 and biomass,*" suggests the researcher.



For several years now, he and his team have been studying various CO_2 recovery synthesis methods which produce methanol, an important compound for the chemical industry. One of the most promising is based on CO_2 electrolysis. However, the reaction also produces an explosive gas which is difficult to handle. To avoid this, the team has developed a process which uses silicon, a naturally abundant compound which can be recycled and reused at the end of the reaction through a chemical cyclic process. By passing through an intermediary (formic acid), the silicon encourages the formation of methanol at the expense of dihydrogen. Thanks to this, the team can convert more than 75% of the formic acid – from CO_2 – into methanol. "*By fine tuning this, we could easily maximise the yield. On a European scale, methanol production could recycle 10 million tonnes of CO_2 per year,*" says Thibault Cantat. Further studies are underway to apply this process to other economic markets, such as the production of hydrocarbons, plastic monomers or medicines by combining formic acid with molecules from biomass.

The transition has started. Who can stop it now?

Publications

• E. Dorr, *et al.* Life cycle assessment of a circular, urban mushroom farm. *Journal of Cleaner Production*, 288, (2021).

• S. Dermine-Brullot, A. Torre. Quelle durabilité pour le développement territorial ? Réflexions sur les composantes spatiales de l'économie circulaire. *Natures Sciences Sociétés*, 28, (2), (2020).

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• C. Chauvier, *et al.* Catalytic Disproportionation of Formic Acid to Methanol by using Recyclable Silylformates. *Angewandte Chemie International Edition*, 59, (2020).

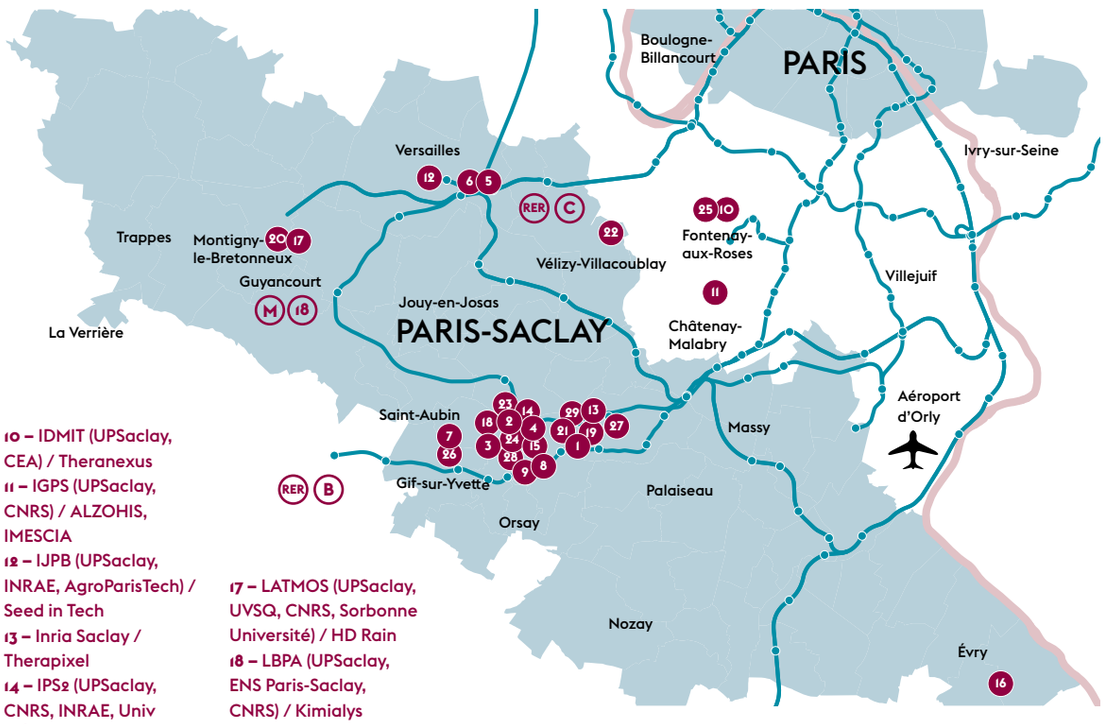
• D. Xia, *et al.* On-line spectroscopic study of brominated flame retardant extraction in supercritical CO_2. *Chemosphere*, 263, (2021).

Keywords
(Pre)development – Start-up – Support resources

Title

From labs to start-ups – promoting the research carried out at Université Paris-Saclay

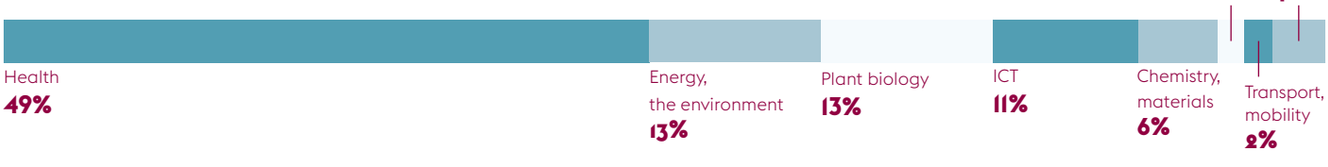
Laboratories are not just places of research. They are places of innovation too. Their work results in technology transfers which in turn lead to the creation of start-ups. This (pre)development process often benefits from several funding and support resources within the Paris-Saclay community. Here is a non-exhaustive overview of some of the start-ups born in the University's laboratories and some examples of the resources used at each stage of their journey.



SOURCE LABORATORY / START-UP(S) CREATED

1 – C2N (UPSaclay, CNRS, Univ.de Paris) / CRYOHEMT, KLEARIA, QUANDELA, Spin-ION Technologies
2 – Centre Borelli (UPSaclay, CNRS, ENS Paris-Saclay, Univ. de Paris, SSA) / Visionairy
3 – CVN (UPSaclay, CentraleSupélec) / Therapanacea
4 – EM2C (UPSaclay, CNRS, CentraleSupélec) / Spark
5 – END-ICAP (UPSaclay, UVSQ, Inserm) / EG427
6 – GEMAC (UPSaclay, UVSQ, CNRS) / EXOTRAIL
7 – I2BC (UPSaclay, CEA, CNRS) / LPS BIOSCIENCES
8 – ICMMO (UPSaclay, CNRS) / NOVECAL
9 – ICP (UPSaclay, CNRS) / ALYXAN, BICHROMATICS, Teratonics
10 – IDMIT (UPSaclay, CEA) / Theranexus
11 – IGPS (UPSaclay, CNRS) / ALZOHIS, IMESCIA
12 – IJPB (UPSaclay, INRAE, AgroParisTech) / Seed in Tech
13 – Inria Saclay / Therapixel
14 – IPS2 (UPSaclay, CNRS, INRAE, Univ d'Évry, Univ. de Paris) / BIOPHYTECH
15 – ISMO (UPSaclay, CNRS) / ABBELIGHT, VitaDX
16 – LAMBE (UPSaclay, Univ d'Évry, CNRS, Univ. Cergy-Pontoise) / DREAMPORE
17 – LATMOS (UPSaclay, UVSQ, CNRS, Sorbonne Université) / HD Rain
18 – LBPA (UPSaclay, ENS Paris-Saclay, CNRS) / Kimialys
19 – LCF (UPSaclay, IOGS, CNRS) / DAMAE MEDICAL, PASQAL
20 – LI-PARAD (UPSaclay, UVSQ) / PEXL
21 – LIST (UPSaclay, CEA) / ALKALEE, TRIDIMEO, WiN MS, WISEBIM
22 – LISV (UPSaclay, UVSQ) / OLEDCOMM
23 – LMF (UPSaclay, CNRS, ENS Paris-Saclay, CentraleSupélec, Inria) / Cryptosense
24 – LMT (UPSaclay, ENS Paris-Saclay, CNRS, Sorbonne Univ.) / EIKOSIM
25 – MIRCEN (UPSaclay, CEA) / BRAINVECTIS
26 – NIMBE (UPSaclay, CEA, CNRS) / NAWATECHNOLOGIES
27 – ONERA / AERACCESS, Blue Industry and Science, MORPHEE +
28 – SPI (UPSaclay, INRAE, CEA) et SCBM (UPSaclay, CEA) / CERES BRAIN Therapeutics
29 – UMPhy (UPSaclay, CNRS, Thales) / DAUMET

The main areas:



µDROPMIXER – innovation that goes beyond the academic world

µDROPMIXER was the winner of Université Paris-Saclay's Poc in Labs 2020 call for pre-maturation projects, which supports and finances the proof of concept of innovative projects. µDROPMIXER is a new microparticle mixer for the production of micromixtures. The patent-protected project is led by Étienne Herth, a research engineer at the Centre for Nanoscience and Nanotechnology (C2N – Univ. Paris-Saclay, CNRS). Étienne Herth was keen for medical, biological, chemical, genomic, agri-food, and other industries to benefit from the project, so in 2020 he submitted it to the University's Maturaction educational programme. The programme teaches students how to manage innovative projects and create Deep Tech start-ups through real-life case studies, enabling researchers to transform their research findings into industrial projects. Étienne Herth also participated in the Genesis Light programme led by Incuballiance, which raises awareness among researchers about business creation and shows them the economic feasibility of a project. "*By engaging with the socio-economic world and industry needs, I realised that there was a real need for innovative techniques and that it is just a question of going beyond the boundaries of the academic world to satisfy it. Genesis Light helps to reveal a project's ability to meet its market and Maturaction greatly facilitated this process.*"

https://www.universite-paris-saclay.fr/actualites/le-programme-maturaction-une-formation-la-creation-de-start-deeptech-inedite

SOUND – turning surfaces into speakers

The goal of the SOUND project is to locate and monitor vibrations on any surface, from a smartphone screen to a car dashboard, to make them multifunctional. The project is led by Christian Bolzmacher from the Systems and Technology Integration Laboratory (List – Univ. Paris-Saclay, CEA). "*We have developed spatio-temporal inverse filtering technology which turns a surface into a loudspeaker, with the possibility of creating multiple sound sources.*" To help develop the innovation's potential, the project was aided by the Poc in labs call for pre-maturation projects in 2019. This allowed the researcher to follow the Genesis Light entrepreneurship programme, carry out a market study and be supported by the Design Spot to develop the technology's use for the greatest number of people, particularly with regard to home automation. "*As a result, we have developed a prototype to showcase the functionalisation of many types of materials.*" The prototype is currently under construction.

BOSS – an alternative solution to pesticides

The BOSS project (Booster of Seeds and Seedlings) began at the Institut Jean-Pierre Bourgin ((IJPB - Univ. Paris-Saclay, INRAE, AgroParisTech). Its "priming" technology involves improving the germination quality of seeds through the use of biological molecules which stimulate their natural growth potential and resistance to stress. "*It is a little bit like a vitamin treatment,*" explains Loïc Rajjou, a university professor, researcher and the project's manager. In 2015/2016, pre-maturation funding from Poc in labs gave him the opportunity to transfer the work developed on model plants to cultivated plants. Thanks to the results obtained, at the end of 2018, he won a development programme which was funded and supported by SATT Paris-Saclay, the area's official Technology Transfer Accelerator Office. "*We were also able to recruit two young scientists, extend the technology to other species and scale it up to a pre-industrial scale, as well as file a patent.*" The team then put together an entry for the i-Lab BPIfrance competition with supporting advice from Incuballiance and AgroParisTech innovation. The technology can be accessed by key players in the seed industry via the Seed In Tech start-up, which is in the process of being set up.

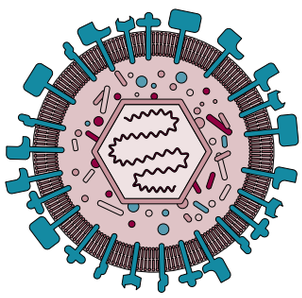
https://satt-paris-saclay.fr/vitrine-technologique/boss/

Spark – extracting hydrogen from gas without CO_2 emissions

The start-up Spark has developed a solution for hydrogen-consuming industries. The process uses cold plasma technology for electric cracking technology. "*When we extract the carbon, the process is CO_2 free and uses three times less electricity than an electrolyser,*" points out Erwan Panier, a Doctor at the Molecular and Macroscopic Energy & Combustion laboratory (EM2C – Univ. Paris-Saclay, CentraleSupélec, CNRS). He started the project in 2019 thanks to Université Paris-Saclay's *Doctor'preneuriales* programme, which aims to introduce PhD students to Deep Tech entrepreneurial techniques. He then turned to SATT Paris-Saclay's *Jeune docteur* project funding and support scheme. "*I was able to carry out an initial technical and market proof of concept, which led me to adapt and redirect the technology towards the most promising applications*." In 2020, he benefited from funding resulting from the call for development projects from SATT Paris-Saclay. Thanks to this, he was able to strengthen the R&D team and successfully scale up the technology to produce hydrogen directly on site.

http://spark-cleantech.eu/

EG427 – gene therapy for urinary disorders



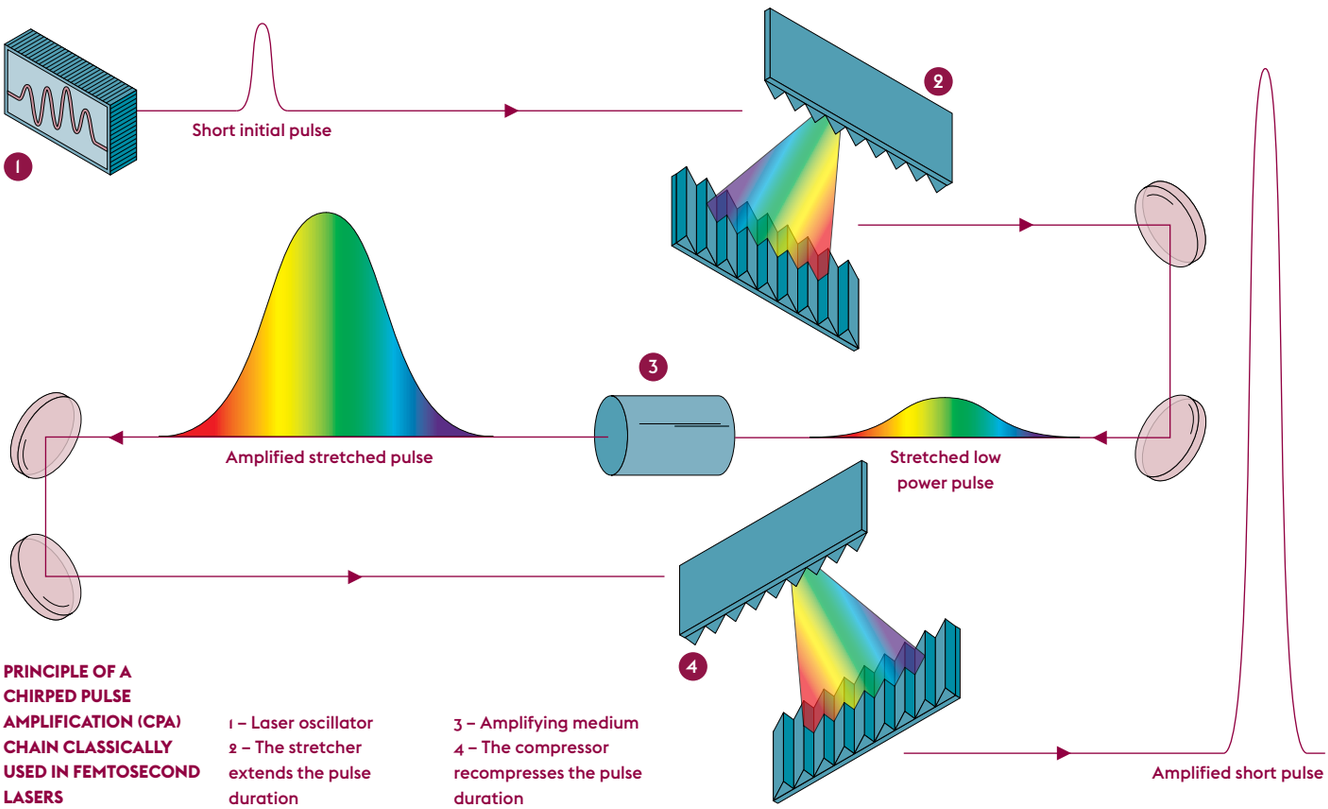
The EG427 start-up (formally known as Genelpis) has developed a treatment for neurological disorders in order to resolve bladder dysfunction related to spinal cord injury. The technology involves a gene therapy platform based on the use of defective vectors derived from the herpes simplex virus (HSV-1), which prevents abnormal bladder contractions. It is the fruit of the research carried out by François Giuliano, Pierre Denys and Alberto Epstein from the Neuromuscular Disability: Physiopathology, Applied Biotherapy and Pharmacology laboratory (END-ICAP – Univ. Paris-Saclay, UVSQ, Inserm) and the AP-HP. The team benefited from significant support through the ERA-NET Neuron European programme during its development phase, and from 2016, from SATT Paris-Saclay's development programme. This gave the team the opportunity to conduct pre-clinical studies, obtain proof of concept and file a patent. "*After transferring the technology to the start-up in 2019, and following a new round of studies, we raised €12 million in funding in January 2021 to build on this great start,*" says Philippe Chambon, the Deputy Managing Director of EG427.

https://www.eg427.com/s

Keywords
Femtosecond lasers

Title

When light is brief but intense



PRINCIPLE OF A CHIRPED PULSE AMPLIFICATION (CPA) CHAIN CLASSICALLY USED IN FEMTOSECOND LASERS

1 – Laser oscillator
2 – The stretcher extends the pulse duration
3 – Amplifying medium
4 – The compressor recompresses the pulse duration

Scientists at Université Paris-Saclay are shedding light on the phenomena and uses of femtosecond lasers. These devices, with their ultrashort pulses and ever-increasing power, use a unique kind of radiation.

Few inventions have had such a successful history as the laser. Conceived in theory in 1917 by Albert Einstein, the first amplified, coherent, monochromatic radiation device appeared in 1960, thanks to the work of the American physicist Theodore Maiman. Since then, the device has become widely popular and has undergone many improvements. It is now indispensable in fields as varied as medicine, telecommunications, imaging and micro-machining. New types of lasers have emerged. Their features, including the spectral width of emission, pulse duration and rate, energy, power and power density delivered, open up new horizons.

The goal is to generate very high intensity ultra-short pulses compatible with new applications and the study of biological, physical or chemical phenomena taking place on extremely short time scales, like those explored by researchers at Université Paris-Saclay. Popularised in the 1990s thanks to their use in eye surgery, femtosecond lasers are leading the way. They now deliver pulses of ten to several hundred femtoseconds (fs, 10^{-15} s) with units of power reaching a terawatt (TW, 10^{12} W) or even a petawatt (PW, 10^{15} W).

A high-performance laser amplification chain

Several lasers are available for use in the Interactions, Dynamics and Lasers Laboratory (LIDYL – Univ.Paris-Saclay, CEA, CNRS). Among these, those from the EquipEx ATTOLAB (classified as an 'equipped with excellence' facility) routinely produce perfectly controlled pulses of 15 mJ at a high frequency and with a duration of about 23 fs. This duration can be reduced to 17 fs by adjusting the settings.

"*The particularity of the ATTOLAB Orme platform managed by LIDYL is that it offers a dual-frequency (1 and 10 KHz) laser amplification chain (FAB 1-10) with infrared emissions and attosecond secondary sources (as, 10^{-18} s) emitting in the extreme XUV range,*" says Jean-François Hergott from the Support and Short Pulse Lasers team (SLIC). FAB 1-10 is the result of work started over ten years ago with the company Amplitudes Technologies, as part of the Impulse joint laboratory. "*The entire amplification chain has been designed for greater stability. The laser's surroundings have been improved and the facilities upgraded.*" The team focused in particular on stabilising the first stage of the chain using a more efficient regenerative cavity which is compatible with higher speeds, which in turn cause higher thermal loads. Combined with an acousto-optic tunable filter, the whole system improves optical efficiency and delivers three times more energy at output than a 'classic' arrangement. Another development has been the precise control of the position of the oscillation field in the time window for the amplified pulse.

The team is now continuing to reduce pulse length. "*A high-energy post-compression system has been developed. This is an intermediate step between the laser output and the generation of XUV radiation. In a hollow optical fibre drawn in a vacuum, the laser pulse is coupled with gas. After nonlinear interaction, pulses of 3.9 fs and 2.5 mJ are obtained.*" By connecting these pulses to the platform's XUV stations,

the team aims to generate unique attosecond pulses, with which they can study and control electron dynamics in matter.

Observing nanoscale objects on attosecond time scales

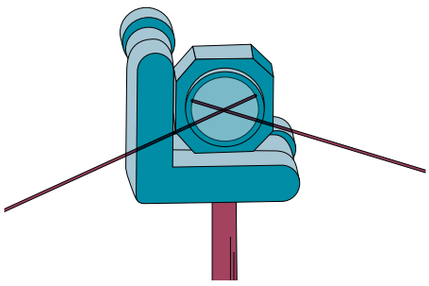
This system, known as strong field, is at the heart of the research carried out at LIDYL by Hamed Merdji and Willem Boutu. They are driven by the understanding of ultrafast phenomena at the nanoscale and are particularly interested in the new area of petahertz electronics. "*In electronics, today's processors operate at frequencies in the gigahertz (GHz, 10^6 Hz) range. The petahertz frequency (PHz, 10^{15} Hz) would make it possible to respond to new calculation and information storage problems. This requires new methods to track the movement of electrons in semiconductors at the nanoscale and attosecond time scales,*" points out Hamed Merdji.

The physicists rely in particular on coherent diffraction imaging (CDI) which consists of illuminating an object with coherent light to collect the diffraction pattern generated and then reconstruct the phase encoded on the hologram and the object's image, using inversion algorithms. "*The principle is similar to what we observe with sunlight when it passes through a hole in a leaf on a tree. The light rays are diffracted and spread out in several directions. The angle they take conveys information about the size of the hole. The smaller the hole, the larger the angle of diffraction. With a camera, the image of the passage of light is recorded and by using coherent light, the radiation phase is encoded, which conveys spatial information about the object.*"

In the work carried out, CDI uses coherent XUV or ultra-short X-ray radiation. "*If you want to observe nanoscale objects, you need light sources with a nanoscale wavelength.*" However, in the case of attosecond pulses, the extremely broad spectrum of these XUV light sources blurs the diffraction image obtained in CDI. "*Each of its wavelengths produces a diffraction image and they all overlap in an inconsistent way. As a result, the encoded information is lost.*"

To "disentangle" them, the team has developed a unique algorithm which uses an inversion system based on mathematical projections of the spectrum. The resulting "de-blurring" produces an average diffraction pattern which can be analysed by CDI reconstruction algorithms. The team validated its method using coherent X-rays from the NANOSCOPIUM beamline of the SOLEIL synchrotron. "*The theoretical spectral content of an attosecond pulse was experimentally reconstructed.*" In the near future, the plan is to apply the mathematical tool to a system involving a real attosecond source.

Functionalisation of transparent materials



At the Orsay Institute of Molecular Chemistry and Materials (ICMMO – Univ.Paris-Saclay, CNRS), the team led by Bertrand Poumellec and Matthieu Lancry promotes the use of femtosecond lasers as a unique tool for the in-depth modification of transparent materials (glass, optical fibre, film, solid or vitreous substrate, polymer and crystal) and for implementing a whole series of functions (micromechanical, optical, microfluidic, etc.), regardless of their shape and composition. Once they have been functionalised, the objects become sensitive to the environment and are used as sensors for temperature, pressure, deformation, concentration, etc. "*The laser reduces the number of manufacturing methods. lt avoids assembly and gluing, minimises errors and improves the lifetime of objects,*" explains Matthieu Lancry.

"*All materials, even transparent ones, are sensitive to light intensity,*" points out the researcher. With pulses of 0.1 µJ to a few µJ and of the order of TW/cm², the radiation no longer passes through the medium but is absorbed over a volume of a few µm³. With it, the local density and the refractive index of the material changes. "*Light is a bit like a hand which manages to sculpt a material without touching it,*" suggests Bertrand Poumellec.

Everything happens at the interface between the light beam and the plasma produced by the material. Phase transitions occur, such as the formation of nanobubbles (or nanopores) of about ten nanometres in diameter, or the creation of nanonetworks. While density changes are not very thermally stable, refractive index changes can withstand very high temperatures. "*It gives access to extreme environments, such as future generation nuclear power plants, aircraft engines and gas drilling sites, etc.*" explains Matthieu Lancry.

Controlling the size of all these changes is of paramount importance. "*For example, if the nanopores are too large, the signal spreads too far and is lost.*" Smaller pores, which optical components find easier to deal with, cause less optical and scattering problems, but are also less thermally stable. By adjusting the laser settings, the researchers are able to alter their size. "*The laser's writing speed and the repetition rate are used to accumulate more or less heat in the material.*" The challenge is to improve our understanding of writing and erasing mechanisms in order to stabilise the components in their future operating conditions. "*It is important for manufacturers to have components which will not deviate and will remain reliable throughout their lifetime.*"

In recent years, a new breakthrough has been achieved thanks to a model developed in the laboratory which predicts the erosion kinetics of nanopores according to their size and the material's chemical composition. This expertise puts the ICMMO team in a good position to propose new 'recipes' for materials and obtain even more thermally stable sensors. The compositions focus on mixtures of 95% silica (SiO_2) and 5% germanium oxide (GeO_2), SiO_2 and aluminium oxide (Al_2O_3), or SiO_2 and zirconium oxide (ZrO_2). "*We are starting to see an effect for mixtures with more than 30% Al_2O_3.*"

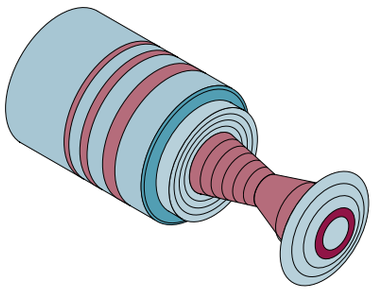
The team is currently finalising a model which predicts the formation of nanopores and are developing new optical fibres from glass, semi-crystalline and glass-ceramic compounds for temperature conditions over 1,500 °C.

Terahertz waves for remote spectroscopy

At the Matter in Extreme Conditions laboratory (LMCE – Univ.Paris-Saclay, CEA), Luc Bergé, Laurent Gremillet and colleagues are interested in the generation of terahertz (THz) electromagnetic waves by femtosecond laser. Using particle numerical simulations (PIC), the team speculatively reproduces the physical parameters of target irradiation experiments in order to improve the conversion efficiency of the laser pulse into THz radiation and obtain the most energetic THz source possible. The challenge is successfully differentiating between the different sources of THz emissions.

At intensities above 10^{14} W/cm², laser pulses almost instantaneously ionise the molecules of the irradiated target, transforming it into a plasma and inducing low-frequency electronic currents. These photocurrents are sources of THz emissions, which are even more effective as the oscillations of the laser electric field used are asymmetric. This is achieved by using multi-coloured laser pulses. When the laser intensity exceeds 10^{18} W/cm², a fraction of the target's electrons are accelerated to

near-light speeds and a new, relativistic interaction regime is established. These electrons are at the origin of many radiative processes, including the transition coherent radiation emitted when the electrons cross the interface between the target and the vacuum.



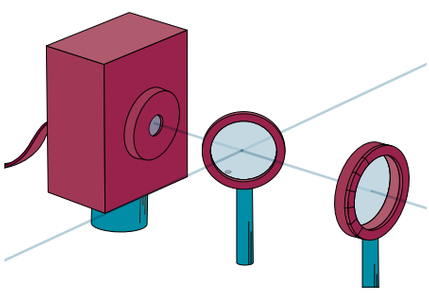
These electron acceleration mechanisms and the associated THz emission processes depend on the nature of the target. If it is transparent, such as a low-density gas, the laser propagates in volume and the acceleration of the electrons to energies in the GeV range occurs indirectly. "*The laser pulse ionises the gas and behind, a plasma wave develops in which the electrons are accelerated. When they escape from the plasma, there is radiation at the interface,*" explains Laurent Gremillet. If the target is solid, "*the laser is reflected and everything happens at the surface.*" The electrons reach lower energies, around a few MeV, but their number is greater. Nevertheless, both configurations lead to intense transition radiation in the THz range.

Until recently, THz emission had applications in spectroscopy and materials characterisation. But new needs are emerging in selective chemistry, tomography and medicine. Others are emerging in remote spectroscopy. The ALTESSE project, which began in 2015 in collaboration with the Franco-German Research Institute of Saint-Louis and the Centre for Intense Lasers and Applications, was intended to prove the feasibility of coherent THz spectroscopy of remote samples. "*The challenge was to control the way in which two-colour ultrafast lasers extract electrons and generate THz radiation that is sufficiently intense to reach the material to be analysed through the atmosphere, where water molecules absorb these waves,*" explains Luc Bergé. In a single laser shot, the team managed to collect numerous spectral signatures at a distance of 15 m and characterise some twenty powdered samples (amino acids, sugars, explosives, drugs) with spectroscopy. The next phase, ALTESSE 2, which will be completed in 2023, will focus on the femtosecond laser filamentation process, a non-linear optical phenomenon in which the laser beam, coupled to a plasma channel, propagates in a self-focused manner over a large distance. The team also plans to study new detection systems and propose a high-performance glass-based demonstrator for detecting explosives at more than 20 m to the French Defence Innovation Agency (AID).

Photoinjection of nanoparticles

Rachel Méallet-Renault, from the Orsay Institute of Molecular Science (ISMO – Univ. Paris-Saclay, CNRS), together with colleagues from the Nara Institute of Science and Technology (NAIST) in Japan, the Supramolecular and Macromolecular Photophysics and Photochemistry Laboratory (PPSM – Univ. Paris-Saclay, ENS Paris-Saclay, CNRS) and the Paris-Saclay Galien Institute (IGPS – Univ. Paris-Saclay, CNRS), conducted photoinjection experiments with luminescent nanoparticles (decorated with a chromophore from the BODIPY family) into living plant cells. The scientists studied the effects of a targeted 20 nJ femtosecond laser pulse on the cell membrane. "*The femtosecond laser causes photoporation. The deposited energy induces local heating and a cavitation bubble which deforms the membrane and allows the nanoparticles into the cell.*"

Using fluorescence imaging coupled with rapid video microscopy, the team followed the penetration and then the diffusion of nanoparticles in the cells in real time. This penetration is also observed when the laser irradiation targets a region close to the cell. While a low laser intensity threshold and a size limit of the nanoparticles are necessary to get them into the cell, the team did not observe any changes in pulse duration on diffusion.



"*It has been observed that nanoparticles are also found in the cells adjacent to the irradiated cell. This opens up new insights into cell-cell interactions. By following the path of the nanoparticles, we can obtain information on the viscosity of the cell and its potential metabolic changes.*" The researcher now plans to transfer the technique to bacteria. "*It can be used as an alternative to electroporation, which is frequently used but is very damaging for these cells in the presence of nanoparticles.*"

So, have you been convinced by the brilliance of lasers?

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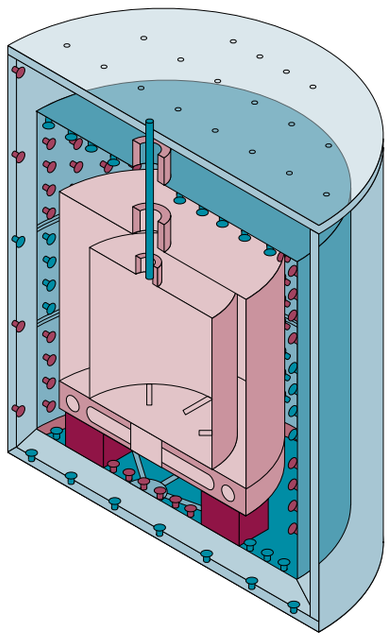
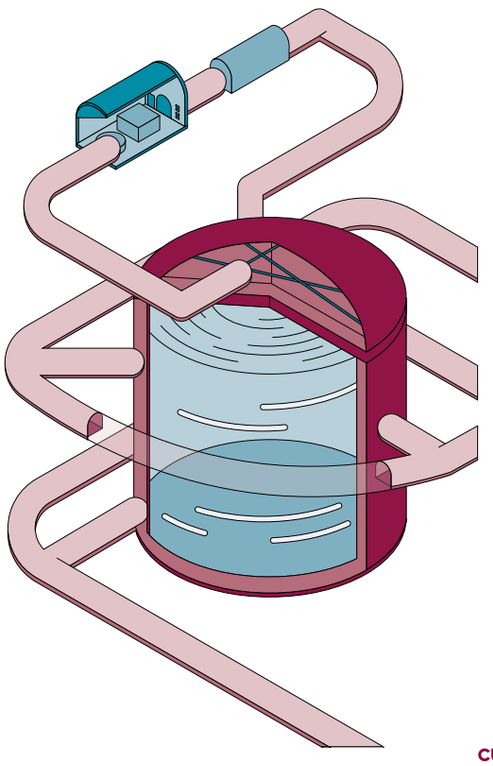
Keywords
Neutrinos – Standard Model – Particle physics

Title

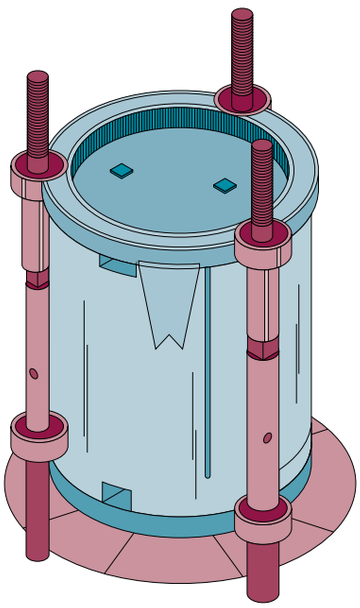
The neutrino: towards physics and beyond



DOUBLE CHOOZ
NEAR DETECTOR



HYPER-KAMIOKANDE
FAR DETECTOR



CUPID
SCINTILLATING
BOLOMETER

Thanks to large-scale experiments, physicists at Université Paris-Saclay are working to unravel the mysteries surrounding the neutrino and are looking ahead to a new model of particle physics.

Developed in the mid-1970s and extended since then, the Standard Model is the centrepiece used in particle physics to explain observable phenomena at this scale and to understand the structure of matter. Based on discoveries made over 100 years ago, this theoretical model organises and describes the elementary building blocks (fermions) that constitute matter, and the fundamental interaction modes that govern them. It distinguishes 12 fermions – six quarks and six leptons and their antiparticles of the same mass but opposite charge – divided into three families, and bosons that orchestrate three of the four fundamental forces of the universe – strong, weak and electromagnetic.

Although the majority of the experimental results still coincide with its theoretical principles, some imperfections are apparent. And for several years, researchers have been pursuing a new physics, beyond the standard model. In their quest, they are interested in the neutrino, an elementary lepton that is still very enigmatic but improved knowledge about it promises to revolutionise our perception of the universe.

With a neutral charge and a mass 465,000 times less than that of the electron, the neutrino fascinates by its ghostly singularity: it interacts very little with matter, one million billion times less than the electron, and only by the weak force. This explains why it has remained under the radar for a long time. Generated massively at the heart of the Sun, during cosmic cataclysms or by cosmic rays in the atmosphere, neutrinos travel without making a ripple and every second, 65 billion of them pass through every square inch of the Earth and its inhabitants, like a wall pass.

Neutrinos in three flavours

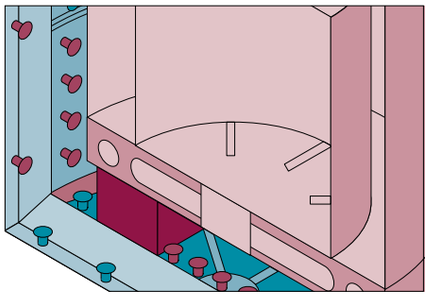
Considered as early as 1930 by the physicists Wolfgang Pauli and James Chadwick, their existence was proven in 1956 by the Americans Frederick Reines and Clyde Cowan, who observed them for the first time in the radiation emitted by a nuclear reactor: during nuclear fission, a uranium nucleus breaks into two smaller, unstable nuclei, which return to stability by emitting either photons – this is gamma radioactivity – or electrons and neutrinos – this is beta (β) decay with neutrino emission. "*These are antineutrinos, the antiparticles of neutrinos, of electronic type, or 'flavour', as they are emitted with their lepton partner, the electron,*" Matthieu Vivier explains, a researcher at the Particle Physics Division (DPhP – Univ. Paris-Saclay, CEA) of the Institute of Research into the Fundamental Laws of the Universe (IRFU).

Together with protons and neutrons – trios of up and down quarks – and electrons, electron neutrinos constitute the first family of fermions. In 1962, and again in 2001, experimental observations revealed two other neutrino flavours that add to two families of fermions: the muon neutrino, the companion of the muon, and the tau neutrino, the companion of the tau. A neutrino flavour is in fact a superposition of three mass states marked 1, 2 and 3.

But more surprisingly, the neutrino is capable of changing its flavour during its propagation. A phenomenon called neutrino oscillation and which "*relies on the hierarchy of mass states, which do not propagate at the same speed, and the mixing angles Θ_{12}, Θ_{23}, Θ_{13}, which govern*

the probability of a neutrino changing flavour," explains Fabien Cavalier, a researcher at the Irène-Joliot Curie Physics of Two Infinities Lab (IJCLab – Univ. Paris-Saclay, CNRS, Univ. de Paris). This oscillation is the focus of many international experiments.

Swinging from the reactor angle



Nuclear reactors are the medium of choice for its study. The fission rate is such that a reactor produces between 10^{20} and 10^{21} electron antineutrinos every second. There is hope for "some" interaction with the surrounding matter. To detect this, scientists use inverse β decay. "*It is the capture of an electron antineutrino by a proton. This produces a neutron and a positron, the antiparticle of the electron. If during the experiment we detect two concomitant signals characteristic of these two particles, this signals the reaction and distinguishes it from the ambient background noise due to natural radioactivity and cosmic rays,*" Matthieu Vivier explains.

This is the principle used by the Double Chooz experiment, set up in 2006 at the Chooz power plant in the Ardennes (France) and which recently delivered its last results before being dismantled. Double Chooz was designed to precisely measure the oscillation mode associated with the parameter Θ_{13}, which reflects a deficit of electron antineutrinos, which become muonic or tauic at a certain distance. "*In the case of reactor antineutrinos, whose energies reach the MeV, this oscillation mode develops at about 1 km,*" Matthieu Vivier comments, who worked on Double Chooz. Located 400 m from the reactor in an underground cavity, a first detector measured the number of electron antineutrinos emitted and a second detector 1,500 m away, measured those still present further away. "*In the end, about 5% of neutrinos change flavour.*"

Inside the detectors, transparent tanks filled with a sparkling liquid (a kind of mineral oil) rich in protons and to which a chemical compound had been added, were responsible for collecting the signal. "*When a neutrino passes through the liquid, it is captured by one of the protons present, and the neutron and positron then emitted deposit their energy in the liquid, which re-emits it in the form of scintillation light,*" Matthieu Vivier says. At Double Chooz, nearly 400 immersed photomultipliers recorded and then translated this light into electronic signals that scientists could interpret. They were able to measure the mixing angle Θ_{13} with an accuracy of about 10% and show that it is not zero.

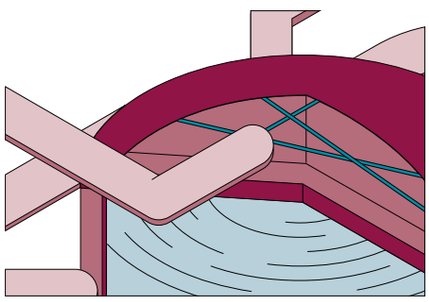
"*With Double Chooz, we also reviewed the calculations for predicting neutrino fluxes and realised that previous experiments had observed neutrino rates at very short distances from the reactors that were lower than predicted,*" Matthieu Vivier reports. An anomaly that gave rise to a postulate: the existence of a new oscillation mode and a fourth, sterile and non-reactive type of neutrino. This hypothesis was recently swept aside by the results of the STEREO experiment conducted a few dozen metres from the reactor of the Laue Langevin Institute in Grenoble. Operating on the same principle as Double Chooz, the detector is on the way to excluding the existence of a sterile neutrino, "*with a good degree of confidence*". "*To explain this anomaly, we would have to look at the theoretical models and check whether there is any calculation bias in the estimate of the neutrino fluxes emitted by the reactors,*" Matthieu Vivier says.

Detectors with new technologies

For the time being, he and his colleagues are participating in the design of a new experiment, Nucleus, which will be set up in Chooz, 50-100 m from the reactors. It aims to study another neutrino interaction process: coherent scattering. With a probability of occurrence almost 1,000 times greater than inverse β decay, it would open up the exploration of very low energy regimes, from 10 to 100 eV. "*Nucleus does not use the same detection techniques – there is no sparkling liquid – because the energies involved are far too low.*" The experiment uses bolometric detectors composed of cryostat-cooled sapphire and calcium tungstate crystals. "*When an antineutrino hits a nucleus in the crystal, the nucleus recoils under the 'shock' and a fraction of the energy is deposited in the crystal, which re-emits it as heat.*" The slightest increase in temperature is then measured by an ultrasensitive thermometer. "*This is a tungsten film placed at a transition temperature between a normal and superconducting regime. The measurement of a voltage change across the thermometer indicates a deposition of energy in the detector.*" The team also hopes to reduce the size of the detectors. Nucleus' will total 10 g. A real technological breakthrough.

Also at Chooz, the IJCLab plans to install a new concept of neutrino detectors. With the LiquidO project, developed by Anatael Cabrera and his colleagues, the idea is to dispense with transparent, sparkling liquid in favour of an opaque, glittering liquid. "*The detector is filled with tightly packed optical fibres that collect the emitted photons of light. The first results are very conclusive and prototyping is underway,*" says Fabien Cavalier.

The question of matter/ antimatter asymmetry



The IJCLab and Irfu teams are also heavily involved in the next generation of experiments to measure the oscillations of neutrinos produced by particle accelerators: DUNE in the United States and Hyper-Kamiokande, the big sister of the current T2K experiment in Japan. These experiments address another major flaw in the Standard Model: the matter/ antimatter asymmetry of the universe. "*The widely held assumption is that in the Big Bang, both matter and antimatter were created. So everything should have annihilated each other. In this case, how can we explain the fact that there is so much matter left in the Universe and that all the antimatter has disappeared?*" says Sandrine Emery-Schrenk, researcher at the DPhP.

This paradox has led the teams to analyse and compare the behaviour of particles and antiparticles, and to tackle another major paradigm: CPT symmetry. This combination of three components – charge (C), parity (P), time (T) – mathematically describes the behaviour of matter and antimatter. "*This is a strong theorem in particle physics. It says that if you reverse the charge and parity, an antiparticle going backwards in time would behave like a particle going forwards. Mathematically, the behaviours should follow the same equations*," Fabien Cavalier explains. Established for quarks, this CP symmetry violation is however not sufficient to explain the matter/ antimatter asymmetry, and DUNE and Hyper-Kamiokande will have to confirm the existence of a CP symmetry violation for neutrinos, widely suspected by the scientific community.

Accelerating particles to accelerate discovery

As in the case of neutrinos from nuclear reactors, these new experiments use two types of detectors, near and far. They are based on the results being accumulated by T2K and its distant detector Super-Kamiokande, located underground 295 km from the source, and which will begin its second phase at the end of 2022.

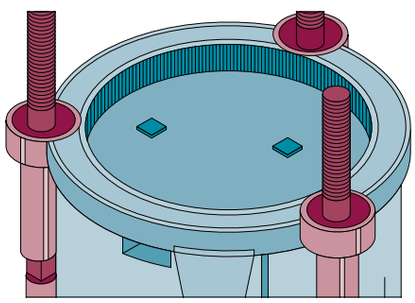
In principle, protons, accelerated to very high energies (30 GeV), strike a carbon target and break the nucleons of the material. This releases a cascade of particles, including pions selected in a tunnel with the help of magnetic horns. These decay into muon neutrinos or antineutrinos that are sent in a beam to the far detector, and it is their transformation into electron neutrinos and antineutrinos that is there measured. "*By adjusting the charge of the pions, we generate either a beam of neutrinos or a beam of antineutrinos,*" Sandrine Emery-Schrenk explains. At the finish line, a tank containing tons of perfectly transparent liquid water and adorned with photomultipliers records the blue light emitted by the passage of muons and electrons from the quasi-elastic interactions of neutrinos and traces them back to their flavour.

If matter is perfectly symmetrical, the probabilities of a neutrino and its antiparticle, the antineutrino, changing flavour on the way must be the same. However, the T2K results seem to indicate the opposite: the probability is much higher in the case of a neutrino than an antineutrino. The aim of T2K phase II and the future DUNE and Hyper-kamiokande experiments is to enrich the data sets and improve the statistics. "*The challenge is to bombard the target with enough protons to produce a more intense beam of neutrinos,*" Fabien Cavalier explains, who is involved with the IJCLab in the creation of the DUNE proton accelerator at Fermilab. "*Thanks to these much more powerful neutrino beams and more massive far-field detectors, we should be able to triple the amount of data collected by T2K phase II, and even more by Hyper-Kamiokande*", says Sandrine Emery-Schrenk, who is involved in the development of the T2K Phase II instrumentation, including the near detector that will also be useful for Hyper-Kamiokande and DUNE.

Scheduled to start up in 2026 and 2027 respectively and provide their first analyses by 2030, DUNE and Hyper-Kamiokande are gigantic in scale. If the technique used by Hyper-Kamiokande is similar to that of Super-Kamiokande, the volume of water in the far detector will be ten times greater. DUNE will contain 40,000 tonnes of liquid argon, not water. It will be located underground 1,300 km from Fermilab. With its four rectangular modules cooled to -185 °C and each containing nearly 18 000 tonnes of liquid argon, it will be the largest detector of its kind in the world.

"*Each module is a drift chamber with two anodes placed around a cathode at high electrical potential. When a neutrino hits an argon nucleus, it creates an electron or a muon. These charged particles will ionise the argon, and the ionised particles produced will drift between the anode and cathode and then be collected on a grid at the top or bottom of the module. The light emitted during ionisation will be detected by photomultipliers placed around the detector. The whole system will make it possible to reconstruct the trajectory of the charged particles and to reveal the neutrinos and their flavour,*" explains Fabien Cavalier, whose laboratory is responsible for the 800 m² of glass fibre cathode and the 100 or so stacks for lowering the electronics into the cryostats.

In search of a decisive disintegration



In their search for explanations for the matter/antimatter asymmetry, scientists are also fascinated by a very particular, rare and so far unobserved mode of decay: double β decay without neutrino emission. Great experiments are dedicated to it, as CUORE or NEMO, or in the future CUPID and SUPERNEMO, their continuation. "*If we could observe it, it would tell us that neutrinos are Majorana fermions,*" explains Claudia Nones, a researcher at DPhP. According to the Standard Model, for every particle there is its exact opposite, the antiparticle. If it turned out that the neutrino was both its own particle and its own antiparticle, it would elucidate the disappearance of antimatter from the universe.

But observing this decay is not easy: it occurs in a nucleus less than once every 10^{26} years! And only 35 natural isotopes are involved, few of which have been studied by scientists. To get away from natural radioactivity and increase their chances of seeing this decay, scientists descend into underground laboratories, such as the one in Modane in Savoie (France), where the rock forms a screen.

As a prelude to the CUPID experiment, scheduled to start in 2026 at the Gran Sasso national laboratory (Italy) and last for ten years, the CUPID-Mo experiment recently carried out in Modane is based on cryogenic scintillation bolometers. "*The crystals used contain an isotope of interest. When a particle passes through one of them, it releases energy and the crystal lattice starts to vibrate. This produces phonons which increase the temperature of the crystal. This increase is then detected by a thermometer glued to the crystal: to increase sensitivity, we work at temperatures of 10 to 20 mK,*" Claudia Nones explains. The bolometer is also a scintillator: when the particle hits the crystal, it emits light, which is recorded by a second type of bolometer. "*A thermal signal and a light output are obtained in coincidence, to better distinguish the original particle.*" While some experiments favour tellurium oxide (TeO_2) crystals – the ^{130}Te isotope being naturally very abundant (34% of natural tellurium), CUPID-Mo uses lithium molybdate (Li_2MoO_4) crystals, the ^{100}Mo isotope, although less abundant (10% of natural molybdene), being more promising.

The team managed to determine the half-life of the ^{100}Mo with the best limit in the world – 1.4×10^{24} years – and to initiate a change of scale with the best possible prospects. CUPID's cryogenic scintillation bolometers will house over a thousand Li_2MoO_4 crystals, with a maximised arrangement. "*We expect to see one event per year and per detector tonne*," Claudia Nones says.

New physics is not far off...

Publications

• The Double Chooz Collaboration. Double Chooz θ13 measurement via total neutron capture detection. *Nat. Phys.* 16, 558–564 (2020).

• The T2K Collaboration. Constraint on the matter–antimatter symmetry-violating phase in neutrino oscillations. *Nature* 580, 339–344 (2020).

• Abi, B. et al. Prospects for beyond the Standard Model physics searches at the Deep Underground Neutrino Experiment. *Eur. Phys.* J. C 81, 322 (2021).

• The CUPID collaboration, Characterization of cubic $Li_2{}^{100}MoO_4$ crystals for the CUPID experiment, *Eur. Phys. J.* C. 81, 104 (2021).

Journal
Medium

Title

MEASURING THE IMPACTS OF SHARED AND ELECTRIC AUTO-NOMOUS VEHICLES (SAEV) ON URBAN MOBILITY

Exploring the research into the impacts of SAEVs, using concepts from sustainability and technology assessment.

https://medium.com/digital-diplomacy/measuring-the-effects-of-shared-and-electric-autonomous-vehicles-saev-on-urban-mobility-417b404128e4

Journal
la Repubblica

Title

DALLA ZANZARA TIGRE AL RATTO NERO, QUANTO CI COSTA L'INVASIONE DELLE SPECIE ALIENE

Un team di ricercatori francesi ha calcolato i danni economici dovuti alla diffusione di specie esotiche come la zanzara tigre asiatica, le formiche rosse e i ratti neri. Perdite di decine di miliardi di dollari ogni anno. Solo nel 2017 si è arrivati a 162 miliardi.

https://www.repubblica.it/green-and-blue/2021/04/01/news/dalla_zanzara_tigre_ai_topi_neri_quanto_ci_costa_l_invasione_delle_specie_aliene-294642626/

Journal
Daily Mail

Title

NEARLY 14 TONS OF EXTRATERRESTRIAL "DUST" FROM PASSING COMETS AND ASTEROIDS LANDS ON EARTH EVERY DAY, STUDY REVEALS

Over 5,000 tons of microscopic 'micrometeorites' fall to the ground every year.
This is about 14 tons a day that comes from passing comets and asteroids.
The chief components are iron, nickel, magnesium and silicon.
Researchers measured the particles at the Concordia station in Antarctica.
The lack of snow and terrestrial dust makes the location ideal for collection.

https://www.dailymail.co.uk/wires/reuters/article-9172171/Frances-Macron-tells-isolated-students-look-one-another.html

Journal
THE STRAITS TIMES

Title

DINNER ON BOARD SPACE STATION: BEEF BURGUNDY OR LOBSTER?

Space agencies ensure astronauts can enjoy a quality meal at times amid hectic schedule.

https://www.straitstimes.com/world/dinner-on-board-space-station-beef-burgundy-or-lobster-o

Journal
ScienceDaily

Title

GREEN CHEMISTRY AND BIOFUEL: THE MECHANISM OF A KEY PHOTOENZYME DECRYPTED

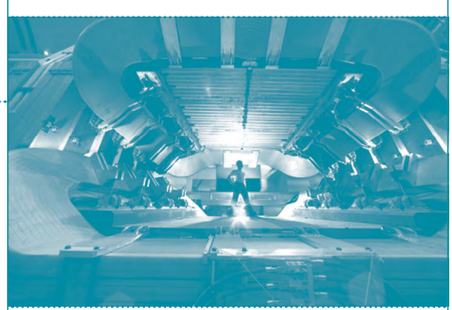
The functioning of the enzyme FAP, useful for producing biofuels and for green chemistry, has been decrypted. This result mobilized an international team of scientists, including many French researchers from the CEA, CNRS, Inserm, École Polytechnique, the universities of Grenoble Alpes, Paris-Saclay and Aix Marseille, as well as the European Synchrotron (ESRF) and synchrotron SOLEIL. The study is published in Science on April 09, 2021.

https://www.sciencedaily.com/releases/2021/04/210408153628.htm

Journal
SCIENTIFIC AMERICAN

Title

MUON RESULTS THROW PHYSICISTS' BEST THEORIES INTO CONFUSION



Experimental anomalies have sent researchers scrambling to concoct new explanations.

https://www.scientificamerican.com/article/muon-results-throw-physicists-best-theories-into-confusion/

Keywords
Soft traffic – New signage – COVID awareness

Title

A campus in keeping with its natural surroundings

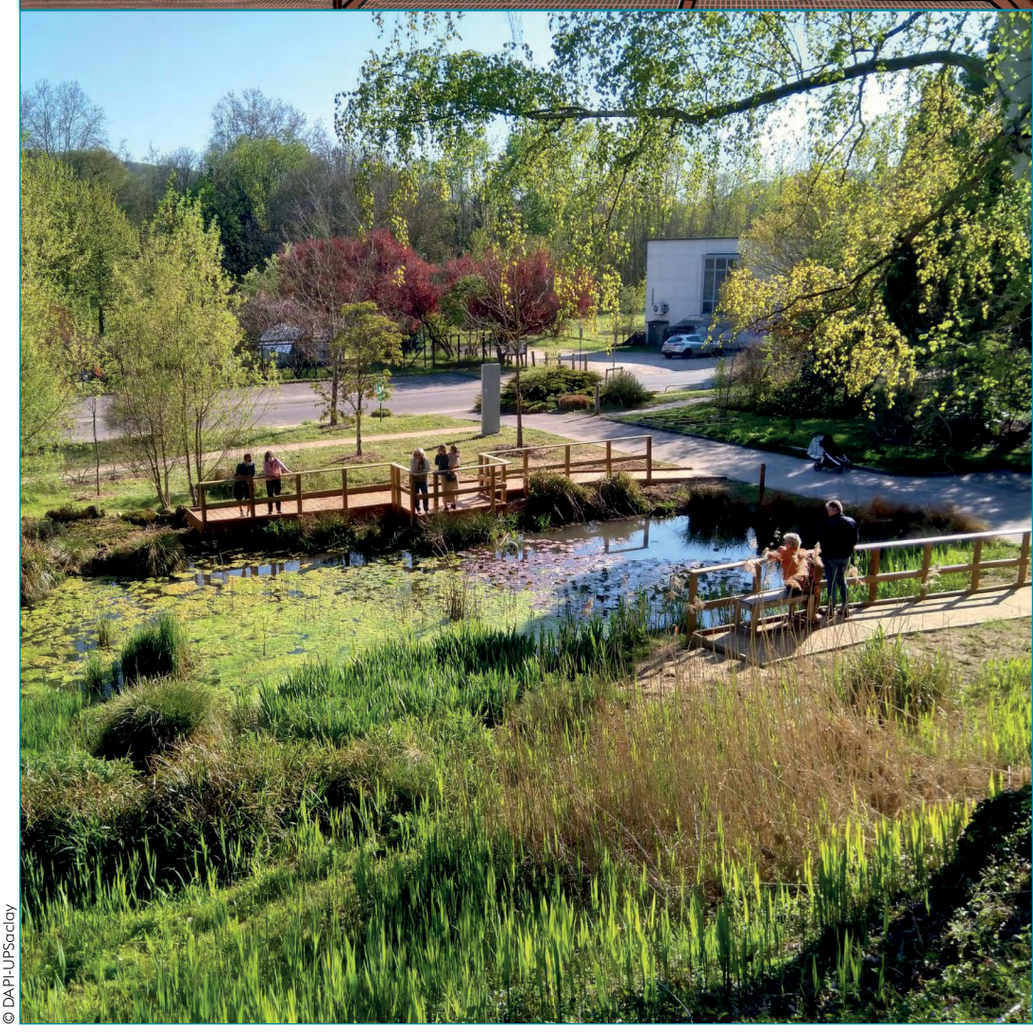
Numerous development and redevelopment projects will improve the campus at Université Paris-Saclay, helping it to blend in with its surroundings.

The University, the *Communauté Paris-Saclay* conurbation authority and the local planning and development authority, the *Établissement public d'aménagement Paris-Saclay* (EPAPS), all hope to enhance the value of the exceptional natural setting in which its facilities are located. This enhancement includes the (re)development of the soft mobility routes which cross the valley campus and the plateau de Saclay.

The work, which began in April 2021, will improve user experience and mainly impact routes which were already accessible to the public in the past, but have become neglected or poorly maintained. In total, over a kilometre of pathways around the buildings, with a 60-metre difference in height, through the woods and across the hillsides, will be redeveloped in an integrated way, respecting the natural characteristics of the valley. Some of the pedestrian paths linking university residences to facilities on campus are already accessible – in particular around the university equestrian centre in Orsay. Nonetheless, people will have to wait until the start of the academic year in 2021 to be able to re-use sections linking the plateau to the valley.

In the meantime, students craving some greenery can visit the University's botanical garden and explore its new features. The Environmental and Landscaping Services within the University's Department of Heritage and Property Development has made the most of the decline in footfall over the past few months to carry out maintenance and renovation work on the garden's features (pontoon, low wall, etc.). Since 2001, the site has been labelled the botanical garden of France and French-speaking countries and is home to a wide variety of both indigenous and exotic plants, as well as some endangered species. The garden not only has a conservation purpose, but also plays a scientific and educational role, with student and research groups visiting the garden to make their own observations.

Campus users and those living close by have not been forgotten either. A walk or bike ride along the restored banks of the Yvette river is now possible. The waterway, which cuts across the campus from east to west, underwent major ecological and flood control restoration work from 2019 to 2020. It is now the perfect place to enjoy a stroll and a special place for observing local wildlife.



© DAPI-UPSaclay

© Bruel Delmar

© VM – Université Paris-Saclay

Title

The plum colour adorns the campuses

© Christophe Peus

Université Paris-Saclay, together with its constituent faculties and institutes, *Grandes Écoles*, associate institutions and research partners, extends across a multitude of sites in the south-west of the Île-de-France region, including Paris. In order to ensure that these different places of study and research all are visually cohesive and show that they all belong to the same entity, these sites, have adopted the University's graphic charter. Banners, flags and street signs in the emblematic plum colour (Université Paris-Saclay's signature colour) now adorn the campuses in Orsay, Sceaux, Châtenay-Malabry and Cachan. The standardisation of signage started at the end of December 2019 to mark the creation of the University on 1 January 2020 and continues to this day.

Title

Students raised awareness about Covid-19

Faced with the financial pressures experienced by some of its students and as part of a drive to improve the management of the health crisis, at the end of January 2021, Université Paris-Saclay has been offering its students employment contracts to raise awareness about the risks linked to Covid-19 on campus. Recruited students were identified by their #TOUSANTICOVID branded clothing, which has also been given to Université Paris-Saclay's constituent faculties and institutes. Their role was to raise awareness about protective measures, testing and isolation in the event of symptoms and a positive test. Some 40 students were recruited at the height of the third wave, and only ten or so students were continuing in their role until the end of exams in June. We hope that this commendable initiative, which was managed by the University's student health services, the Department for Student Life and Equal Opportunities and the student support services of the constituent faculties and institutes, will not have to be renewed in September.

WE WERE THERE

MAY

Date	Location	Host
20 to 21	Online	French Tech Paris-Saclay, Île-de-France Region, EPAPS

Title

PARIS-SACLAY SPRING EVENT

Description

Université Paris-Saclay and its design centre, the Design Spot, took part in the third edition of this virtual event, which brought together key players in innovation, research, science and business development in the Paris-Saclay region. The aim was to show how, beyond the pandemic, France's largest shared innovation community is growing faster than ever. The specific focus for this event was to give centre stage to the 50 start-ups who are shining examples of the Paris-Saclay region and showcase their innovations in the very place where they have been created and developed.

https://paris-saclay-spring.com/

JUNE

Date	Location	Host
17	Online	Université Paris-Saclay

Title

20TH DOCTORAL SCHOOL DAY "THERAPEUTIC INNOVATION: FROM THE FUNDAMENTAL TO THE APPLIED"

Description

This day was a chance to present the doctoral school "Therapeutic innovation: from the fundamental to the applied" (ITFA) and its various research areas to a scientific audience made up of approximately 200 PhD students and researchers each year. These research areas include chemistry, immunology, protein engineering, microbiology, pharmacology, cell signalling and pharmaceutics. External speakers were invited to share their knowledge and expertise.

https://www.universite-paris-saclay.fr/evenements/journee-de-lecole-doctorale-innovation-therapeutique

Date	Location	Host
17	Online and at Gif-sur-Yvette	Université Paris-Saclay

Title

THOMAS PESQUET LIVE FROM SPACE

Description

On 17 June 2021, aboard the ISS, the French astronaut Thomas Pesquet passed over the University's campus. To mark the occasion, as part of an initiative with the ARISS (Amateur Radio on the ISS) organisation, the Collège Albert Camus de la Norville secondary school and Université Paris-Saclay were selected, alongside the amateur radio club F5KEE (Viry-Châtillon, Essonne), to make radio contact with Thomas Pesquet. This unique contact was hosted by Fred Courant from the French science TV programme, *l'Esprit Sorcier*, and was broadcast as part of a special programme on the University's YouTube channel.

https://www.universite-paris-saclay.fr/evenements/thomas-pesquet-en-direct-depuis-lespace

Date	Location	Host
28 to 30	Online	INRAE, AgroParisTech

Title

22ND EDITION OF THE NATIONAL COMPOSITE DAYS (JNC)

Description

The National Composite Days (JNC) is a biennial scientific conference which has been organised since 1978 by the Association for Composite Materials (AMAC – *Association pour les matériaux composites*). It provides periodic updates on the latest scientific and technological advances, and is also an opportunity for lecturers, researchers and manufacturers working in composites to meet and talk.

NOT TO BE MISSED

JULY

Date	Location	Host
3 to 4	Online	Université Paris-Saclay

Title

2ND EDITION OF THE "FROM THE BIG BANG TO BIG BANDS" FESTIVAL

Description

The second edition of the "From the Big Bang to Big Bands" festival invites you to enjoy a unique mix of music, cinema, astronomy, readings, reports, drawings and science fiction.

http://www.dubigbangauxbigbands.fr/

Date	Location	Host
20 to 23	Palaiseau	Inria, DATAIA, IRT SystemX, DFKI

Title

IDAI SUMMER SCHOOL 2021

Description

Inria, the DATAIA Institute, IRT SystemX and the German Research Center for Artificial Intelligence (DFKI) are organising the first European summer school on artificial intelligence (AI). This event is part of a national partnership between the institutions to support joint research in the field of AI. It will take place over 4 days in-person if health restrictions allow.

https://idessai.inria.fr/

SEPTEMBER

Date	Location	Host
18 to 19	Orsay	Université Paris-Saclay

Title

"LIVING BEINGS, VERTEBRATES – VISIBLE BIODIVERSITY" EXHIBITION

Description

The exhibition "Living beings, vertebrates – visible biodiversity" (*Au fil des êtres vivants, les vertébrés, une biodiversité visible*) at the Paris-Saclay Faculty of Sciences, is made up of short illustrated display panels (translated into English), and accompanied by stuffed animals. Workshops, games and events are also on offer during this event which is aimed at the general public, and young people in particular.

https://openagenda.com/universite-paris-saclay/events/au-fil-des-etres-vivants-les-vertebres-une-biodiversite-visible

NOVEMBER

Date	Location	Host
18 to 19	Orsay	Université Paris-Saclay

Title

CURIOSITAS ART & SCIENCE FESTIVAL

Description

CURIOSITas is an opportunity to discover works where art and science come together. On the agenda: interactive installations, shows, workshops and debates. The festival is for everyone: families and children, young people, students, scientists, artists and all those who want to learn about these original projects.

https://www.universite-paris-saclay.fr/evenements/festival-arts-sciences-curiositas

université PARIS-SACLAY

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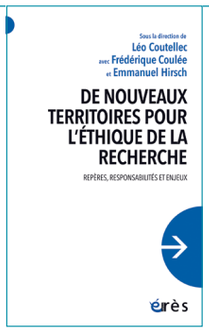
READING HIGHLIGHTS



New territories for research ethics

Léo Coutellec, lecturer in epistemology and ethics of contemporary sciences at the Faculty of Medicine of Université Paris-Saclay, Frédérique Coulée, professor of public law at the Jean Monnet Faculty (Law, Economics, Management) and Emmanuel Hirsch, professor of medical ethics at the Faculty of Medicine of Université Paris-Saclay, call for a redefinition of the contract between science and society, taking into account both the responsibilities involved and the vulnerabilities created by the impact of certain innovations.

Éditions Erès

The Conversation

More and more prisons: what for?

Christian Mouhanna and Annie Kensey, director and researcher at the Sociological Research Centre on Law and Penal Institutions (CESDIP - Université Paris-Saclay, UVSQ), review the announcement of the construction of new prisons and analyse the problem of prison overcrowding.

https://theconversation.com/toujours-plus-de-prisons-pour-quoi-faire-160645

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Thank you and enjoy reading!

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email .....

MAKING SUSTAINABLE DEVELOPMENT AN INTEGRAL PART OF UNIVERSITÉ PARIS-SACLAY – THE RESULTS OF A PARTICIPATORY INITIATIVE

Sustainable development is at the heart of Université Paris-Saclay's priorities. From September to December 2020, the University brought together its constituent faculties and institutes, *Grandes Écoles* and associate institutions to call on its student and academic communities, technical and administrative staff, to think collectively about sustainable development and gather their opinions via the collaborative platform, "Our projects for sustainable development at Université Paris-Saclay".
The initiative has enabled projects to emerge in the areas of Education, Research, Raising Awareness and Practices, which these communities would like to see implemented at the University, and to establish a broader picture of the priorities for sustainable development at the University.

For more information:
https://ds2021-universite-paris-saclay.fr/

The platform: a few facts and figures

754 contributors

838 propositions

59 projects put to vote

8 special edition newsletters on the "participatory initiative"

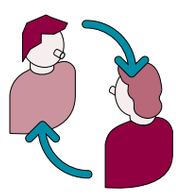
over **1,722** participants

600 hours spent on the platform

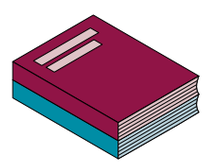
14 projects selected to start in 2021

The winning projects:

Education



Collaborations with committed players



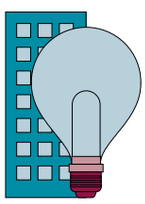
A shared sustainable development foundation for all courses

Participatory events

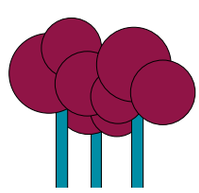
Research

Management of waste produced by research activities

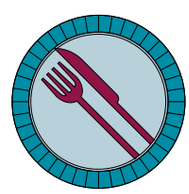
Practices



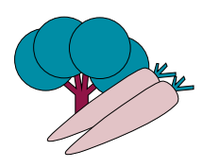
Improvement of the energy performance of buildings



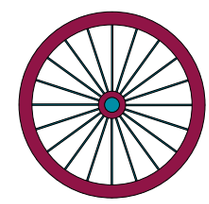
Curbing the urbanisation of land on the *plateau de Saclay*



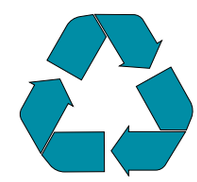
Using local products for catering



Taking it easy on meat!

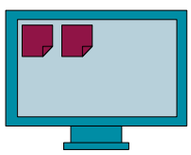


A soft mobility plan

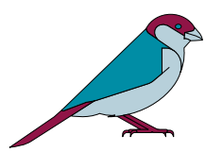


Waste collection and sorting

Raising awareness

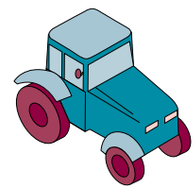


Awareness campaigns for staff



Participatory science projects

Regular awareness workshops



A market garden micro-farm

université PARIS-SACLAY