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THE MAGAZINE OF THE EUROPEAN PHYSICAL SOCIETY

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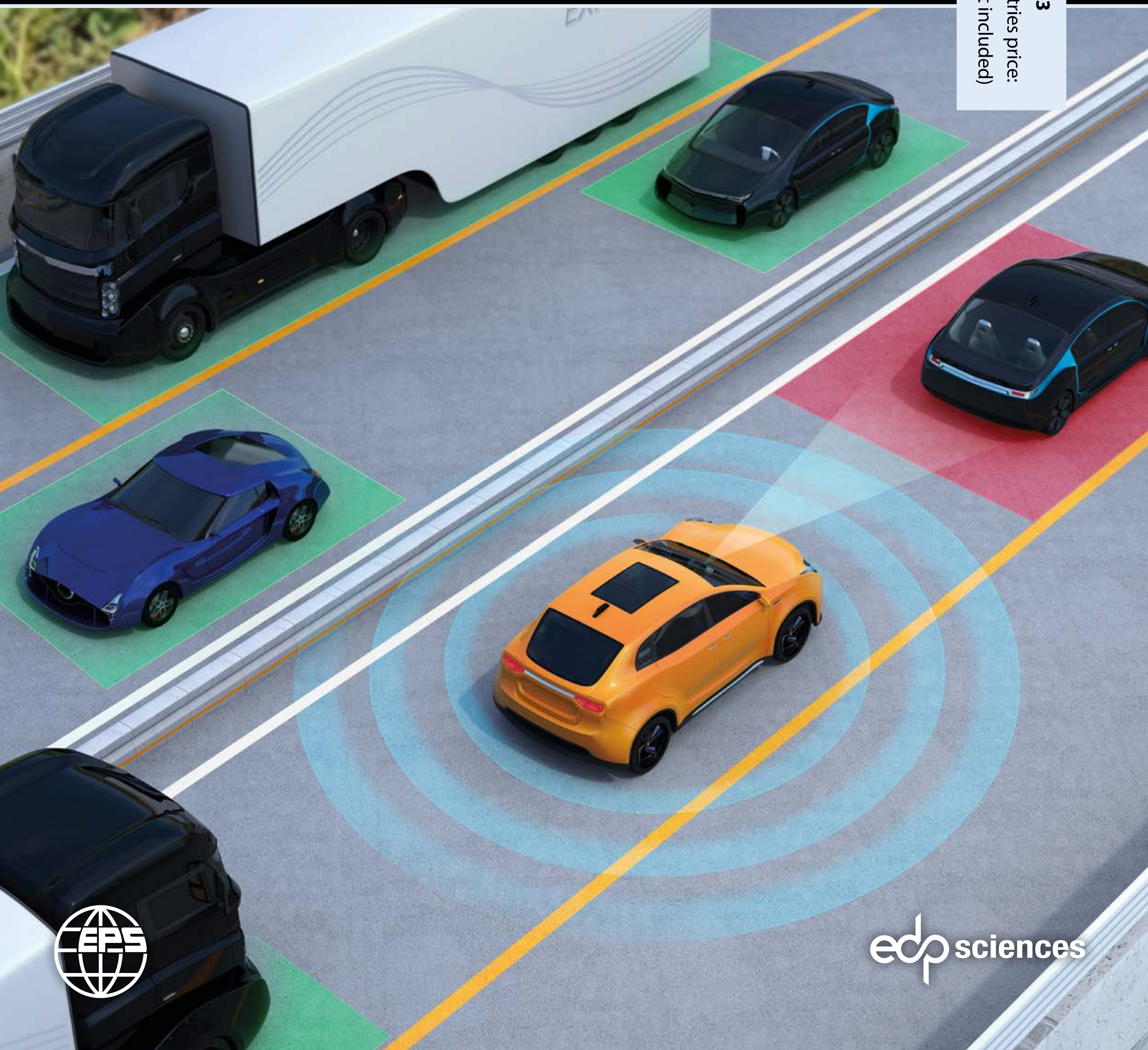

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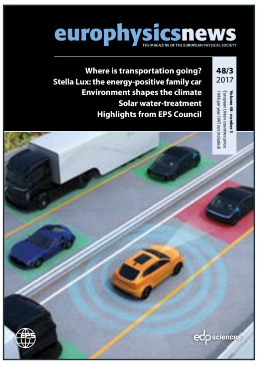

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Cover picture: © iStoclPhoto, see p.21 where is transportation going?

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Stella Lux: the energy-positive family car

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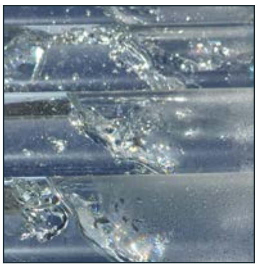
Environment shapes the climate



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Solar water-treatment

EPS EDITORIAL

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[EDITORIAL]

Challenging times for the EPS

The change of EPS Presidency is an opportunity to reflect on the mission of the EPS, and on the challenges which our society will be facing during the years ahead.

The first editorial which I contribute to *europhysics news*, as new President of the EPS, is a wonderful opportunity to pay tribute to my predecessor Christophe Rossel for his exceptional leadership. Chris has been an inspirational President who has advanced the cause of physics on many fronts, promoting new initiatives and perspectives, many of which were thoughtfully reflected in his editorials in previous issues. Chris is leaving a presidential footprint that will not be easy to fill for his successors. I am delighted and grateful that the EPS can continue to rely on his advice; I am equally grateful to the Executive Committee and the Secretariat for unfailing support, and for ensuring continuity in a period of transition.

Being President of the EPS is certainly an honour, but more importantly represents a unique challenge, responsibility, and opportunity. Let me use this occasion to sketch briefly my vision and priorities, which are neither new nor disruptive: they are firmly rooted in the EPS Strategic Plan, and in the continuity of the excellent work of previous Presidents and Executive Committees.

European unity is under pressure: notwithstanding the outcome of recent elections in the Netherlands and France, populist and anti-European movements continue their rise in many countries. The *Brexit* is only the most prominent example; while respecting the result of democratic votes, we must be conscious that a continued erosion of European cohesion will undermine fundamental values and best practices which all physicists take for granted today: free cross-border collaboration, unrestricted mobility of researchers and students, and access to European funding and infrastructures. These concerns are not unique to physics and must be addressed by the scientific community at large. The EPS, representing a science with a long tradition and highly developed culture of international collaboration, has a special responsibility to raise a strong voice when shaping European research policies.

The EPS point of presence in Brussels will have a key role to play in this respect. While still at an early stage, it must be developed and strengthened, for the EPS to act as a vocal advocate for physics education and research, in particular when shaping and implementing Framework Programs and roadmaps. If the pilot phase is successful, the Brussels presence will need to be expanded, and adequately resourced. The EPS is fortunate to have an Advisory Board on Science Policy composed of eminent experts, who stand ready to help sharpening our profile, not only in Brussels but wherever policy input is solicited from the EPS.

The EPS, representing a science with a long tradition and highly developed culture of international collaboration, has a special responsibility to raise a strong voice when shaping European research policies.

Looking beyond the European horizon, the EPS has an equally important role in promoting cooperation on even larger scales. Physicists have always been pioneers of transcontinental scientific cooperation, and many breakthrough discoveries of recent years have demonstrated the power and potential of global networks and collaborations. Future large research infrastructures and projects will require truly global efforts, combined with a coordinated division of labour, to pool resources and to avoid duplication of efforts. The EPS can support such efforts through strengthening contacts with societies and federations in other regions of the world, in the best interest of science in Europe.

To better promote our vision and actions, we will need to invest in communication, outreach, and broadening our base of members. Whereas most national physical societies in Europe are members today, there is a large untapped potential for enlarging the tiers of Associate and Individual Members. A vigorous initiative to enlist more Associate Members is in preparation and I plan to launch a similar initiative for Individual Members, in close coordination with our Member Societies. The EPS will speak most effectively when it can act not only as a federation of national societies but also as the direct voice of all players in the physics arena. The 50th anniversary, which the EPS can celebrate in 2018, will be an excellent incentive to reflect in greater depth on the future role and mission of our society.

Finally, when debating strategies and policies, we must never forget that the EPS is most and foremost a learned society. The work of our Divisions, Groups and Action Committees forms our scientific and organizational lifeblood, and their dedication and competence are our most important assets. No EPS President will be able to succeed without their support. ■

Rüdiger Voss,
EPS President

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Highlights from EPS Council

The annual Council Meeting of the European Physical Society was held on 31 March – 1 April 2017 at the Max Planck Institute for the Science of Light in Erlangen, Germany. The EPS Council is composed of representatives of the 42 EPS Member Societies and the chairpersons of the 12 Divisions, 6 Groups, and 6 Committees. Individual Members and Associate Members are each represented by 5 elected delegates.

The Council meets for a variety of reasons. There are extensive reports, covering the activities and finances of the previous year. (the annual report can be downloaded here: http://bit.ly/2rx9g4Z). Important projects discussed at this year's Council meeting included the setting up of the EPS office in Brussels (BE), and the correct level of interaction with European policy makers.

Council also approved the creation new Gravitation Physics Division. Mairi Sakellariadou has agreed to be the chairperson of the GPD, and a meeting to plan their activities will be held in June 2017.

Luc Bergé presented a plan to attract more Associate members to the EPS. Associate Members are important to the EPS because they expand the communities represented by the EPS to research organisations, and industries that rely on physics for the development. The plan introduces levels of engagement, allowing potential Associate Members to devote their contributions to the EPS for specific activites, *e.g.* for a prize or for projects for young researchers *etc.*

Council also discusses and approves strategic initiatives, and looks at the plans for longer term activities. An ambitious project was presented to Council 2017 by Carlos Hidalgo. The project, entitled "Physics for Society

▲ **(Left to right) TOP:** Eva Salvador and David Lee **BOTTOM:** Ophélia Fornari, Antigone Marino, winner of the EPS Achievement Award and Christophe Rossel

▲ Participants of the 2017 EPS Council meeting

in the Horizon 2050" will look at physics developments for understanding nature as global human enterprise, as well as physics developments to tackle major issues directly affecting the lives of citizens. EPS Divisions and Groups will be asked to contribute to the project in their various fields. An extensive document is planned for the end of 2018.

Council members were also asked to provide input into activities to celebrate the 50^{th} anniversary of EPS in 2018.

The EPS Council provides an opportunity to recognise individuals who have made significant contributions to the EPS. In 2017, the EPS Gero Thomas Medal was awarded to Jo Hermans, for his dedication to the EPS, for his role as Science Editor of Europhysics News and his numerous contributions to education and public understanding of physics. Antigone Marino received the EPS Achievement Award for her outstanding leadership skills and her active promotion and development of the EPS Young Minds Project. Eugenio Coccia, Luís Miguel de Oliveira e Silva, and Victor N. Zadkov were accepted as EPS fellows.

Council also serves to focus on issues of specific importance to the members of the EPS. This year, a panel discussion, was organised by Frances Saunders on "What is the role of science and scientists in addressing social, political and societal issues in an ethical manner? How can EPS contribute and operate?" F. Saunders introduced the topic. There are ethical questions in all stages of the research cycle, ranging from the cost/benefit analysis from the research activity to potential impact on society of the research results. Pere Puigdomènech, Centre for Research in Agricultural, ES reported on activities in the field of ethics from All European Academies (ALLEA). Christian Hauser, University of Zurich, CH explored the relationship between ethics and big data. Paul Hardaker, Institute of Physics, UK summarised the current situation of ethics in scientific publications.

As a learned society, the EPS relies heavily on the volunteer contributions by its members. Council is also a way to create a constructive dialogue with EPS members. The EPS Executive Committee decided that for 2017, EPS Members would be invited to submit projects for new activities for the EPS. If retained, the projects would receive funding from the EPS. This lead to a lively discussion of the 16 projects that were received.

Rüdiger Voss, who was elected as EPS President-elect in October 2016 formally began his 2 year term as President. Council warmly thanked Christophe Rossel, the outgoing President for his hard work and dedication. C. Rossel will remain in the Executive Committee as Vice-President until the end of March, 2018.

Finally EPS Council is also a place to meet new colleagues and old friends. Face to face interaction is efficient, and permits the free flow of information from many people simultaneously. The Council participants came away with a positive vision of the EPS, ready and willing to devote time and energy to developing the EPS. I would like to thank Gerd Leuchs and his team for hosting us in Erlangen, and for the excellent organisation. ■

▼ Rüdiger Voss and Christophe Rossel

OBITUARY

Alexei Abrikosov (1928-2017)

Nobel Prize Winner Professor Alexei Abrikosov passed away on the 29th of March 2017 at the age of 88 years at his home in the USA. His theory of the Abrikosov's vortex lattice in type-II superconductors in magnetic field is among the outstanding contributions of the Landau school of theoretical physics to the quantum era of science. His book co-authored with Lev Gor'kov and Igor Dzyaloshinski "Methods of quantum field theory in statistical physics" remains one of the major handbooks for theoretical physicists all over the world, and a long-lasting memory of him.

Abrikosov was one of the most brilliant students of Lev Landau, whom he respected all his life as a Teacher. While still only 19, he successfully passed Landau's 'Theoretical Minimum' exams, a year later in 1948 graduated from the Moscow State University with Honours and became a PhD student of Landau at the Peter Kapitza Institute for Physical Problems in Moscow. One year later he successfully defended his PhD thesis on the theory of plasma. In 1955, being 27 years old, Abrikosov obtained his Habilitation, based on the work in quantum electrodynamics. He started his research career in Lev Landau's theory group at the Kapitza Institute in 1951. There he made the discovery which brought him the Nobel Prize in 2003.

In 1951-1952 Abrikosov, together with the experimentalist Nikolay Zavaritskii, tested the Ginzburg-Landau theory of superconductivity with the experimental data on the critical magnetic fields of thin superconducting films. As a result, the concept of the type II superconductors was formulated. Subsequently, developing the theory of bulk type II superconductors, Abrikosov came to the fundamental idea that a magnetic field partially penetrates into the superconductor in the form of quantum current vortex filaments. The vortices form an ordered lattice-like structure, now known as the Abrikosov's vortex lattice. Landau agreed with a publication of Abrikosov's paper only in several years, after he learned about Feynman's work on the vortex formation in rotating superfluid helium. Thus, the seminal paper of Abrikosov, which brought him the Nobel Prize and today is one of the most frequently cited in the world scientific literature, was published only in 1957. Ten years later the existence of the vortex lattice was confirmed experimentally by the magnetic decoration method.

Besides the type II superconductivity Abrikosov delivered other key contributions to the physics of superconductivity: the theory of superconductors in high-frequency electromagnetic field (with Gor'kov and Khalatnikov), the theory of superconducting alloys and theoretical discovery of the phenomenon of gapless superconductivity in superconductors with magnetic impurities (with Lev Gor'kov). Together with L. Gor'kov and I. Dzyaloshinskii, Abrikosov made the outstanding contribution to the development of the diagrammatic technique and its extension to kinetics and transport phenomena at finite temperatures. *The monograph Methods of Quantum Field Theory in Statistical Physics* became a desktop must book for theoreticians. Abrikosov significantly developed the Kondo problem (Abrikosov-Suhl resonance), the theory of semimetals of the bismuth type and zero-gap semiconductors, predicted the existence of the excitonic insulator in magnetic fields, and gave impetus to the development of the theory of quasi-one-dimensional systems.

Abrikosov had a great impact on the formation of the next generation of the Landau theoretical physics school. He devoted much time and energy to the organization of numerous national workshops and summer schools for young researchers in the Soviet Union. He was co-founder of the Landau Institute of Theoretical Physics in Chernogolovka, where he headed the sector of the theory of solids since 1965. Abrikosov was elected in 1964 a correspondent-member, in 1987 a full member of the Soviet Academy of Sciences, and in 1988 - the Director of the Institute for High Pressure Physics of the Academy of Sciences (now RAS). In parallel, he was enthusiastically teaching and guiding research in different universities: Moscow State University, Lobachevsky University of Nizhny Novgorod, Moscow Institute of Physics and Technology. In 1976-1991 he chaired the Department of Theoretical Physics at Moscow Institute of Steel and Alloys (Technological University). In 1987 Abrikosov published the famous monograph *Fundamentals of the Theory of Metals*, based on his lecture courses in physics of normal metals and superconductors.

In 1991 Abrikosov became an Argonne Distinguished Scientist and groupleader of the Condensed Matter Theory group in the Materials Science Division of the Argonne National Laboratory.

Collaboration with experimentalists in Argonne and at Chicago University led Abrikosov in 1998 to the idea of quantum linear magnetoresistance phenomenon, indications of which were observed by P. Kapitza in 1928. Abrikosov also worked in the field of high-temperature superconductivity and suggested his own version of the theory of this phenomenon.

Abrikosov's legacy in physics is marked by a number of prestigious international prizes and awards, among them: the Fritz London Memorial Prize (1972); the Lenin Prize (1966) and the John Bardeen Prize (1991), both jointly received with V. Ginzburg and L. Gor'kov. In 2003, he became a laureate of the Nobel Prize in Physics jointly with V.L. Ginzburg and A.J. Leggett *"for pioneering contributions to the theory of superconductors and superfluids"*.

Alexei Abrikosov will be remembered as a great scientist whose work has impacted different domains of physics and laid the foundation of our understanding of superconductivity. He was a very bright person with humour, courage and dignity along the difficult periods of his eventful life. ■

Authors:
Sergei Mukhin, Head of Theoretical Physics and Quantum Technologies Department of the National University of Science and Technology 'MISIS', Moscow, Russia
Andrey Varlamov , Research Director of the Institute for Superconductivity and Innovative Materials of the Italian National Research Council, Italy
Alexander Buzdin, Full Professor of exceptional class of the University of Bordeaux, and Condensed Matter Theory Group Leader at Laboratoire Ondes et Matière d'Aquitaine, Talence, France

PIONEERING SESAME LIGHT SOURCE OFFICIALLY OPENED

The laboratory's official opening ushers in a new era of research covering fields ranging from medicine and biology, through materials science, physics and chemistry to healthcare, the environment, agriculture and archaeology.

Speaking at the opening ceremony, the President of the SESAME Council, Professor Sir Chris Llewellyn Smith said: *"Today sees the fulfilment of many hopes and dreams. The hope that a group of initially inexperienced young people could build SESAME and make it work - they have: three weeks ago SESAME reached its full design energy. The hope that, nurtured by SESAME's training programme, large numbers of scientists in the region would become interested in using SESAME – they have: 55 proposals to use the first two beamlines have already been submitted. And the hope that the diverse Members could work together harmoniously. As well as being a day for celebration, the opening is an occasion to look forward to the science that SESAME will produce, using photons provided by what will soon be the world's first accelerator powered solely by renewable energy."*

SESAME, which stands for Synchrotron-light for Experimental Science and Applications in the Middle East, is a particle accelerator-based facility that uses electromagnetic radiation emitted by circulating electron beams to study a range of properties of matter. Its initial research programme is about to get underway: three beamlines will be operational this year, and a fourth in 2019. Among the subjects likely to be studied in early experiments are pollution in the Jordan River valley with a view to improving public health in the area, as well as studies aimed at identifying new drugs for cancer therapy, and cultural heritage studies ranging from bioarcheology – the study of our ancestors – to investigations of ancient manuscripts. Professor Khaled Toukan the Director of SESAME, said *"In building SESAME we had to overcome major financial, technological and political challenges, but – with the help and encouragement of many supporters in Jordan and around the world – the staff, the Directors and the Council did a superb job. Today we are at the end of the beginning. Many challenges lie ahead – including building up the user community, and constructing additional beamlines and supporting facilities. However, I am confident that - with the help of all of you here today, including especially Rolf Heuer, who will take over from Chris Llewellyn Smith as President of the Council tomorrow (and like Chris and his predecessor Herwig Schopper is a former Director General of CERN) - these challenges will be met."*

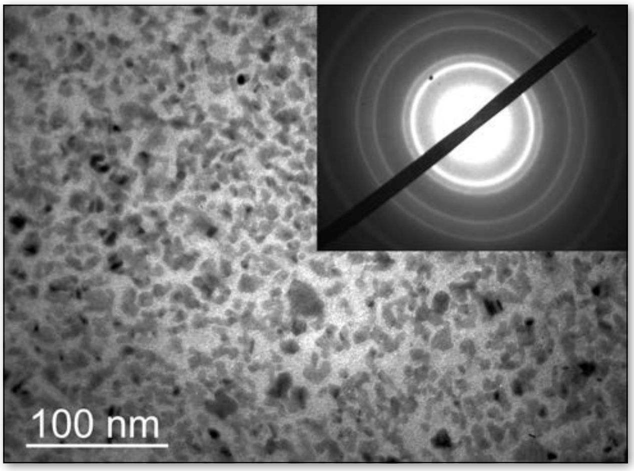
The opening ceremony was an occasion for representatives of SESAME's Members and Observers to come together to celebrate the establishment of a competitive regional facility, building regional capacity in science and technology. ■

Highlights from European journals

MATERIAL SCIENCE

Smart multi-layered magnetic material acts as an electric switch

New study reveals characteristic of islands of magnetic metals between vacuum gaps, displaying tunnelling electric current



▲ The structure of ultrathin films of a cobalt nickel alloy

The nanometric-size islands of magnetic metal sporadically spread between vacuum gaps display unique conductive properties under a magnetic field. In a study recently published, the authors found that the vacuum gaps impede the direct magnetic alignment between the adjacent islands — which depends on the external magnetic field — while allowing electron tunneling between them. Such externally controlled conducting behaviour opens the door for applications in electronics with magnetic field sensors – which are used to read data on hard disk drives – , biosensors and microelectromechanical systems (MEMS), as well as in spintronics with magnetic devices used to increase memory density. They found that the maximum values of the electric conductivity under an external magnetic field are obtained when the islands have a width of between 3 nm and 5 nm, with vacuum barriers of between 1 nm and 3 nm between them. However, they also observed that the tunnelling of electrons between the islands depends on the relative orientation of the direction of magnetisation in the adjacent islands and on the external magnetic field. ■

■ **A.M. Chornous**, **Yu.O. Shkurdoda**, **V.B. Loboda**, **Yu.M. Shabelnyk** and **V.O. Kravchenko**,
'Influence of the surface morphology on the magnetoresistance of ultrathin films of ferromagnetic metals and their alloys', *Eur. Phys. J. Plus* **132**, 58 (2017)

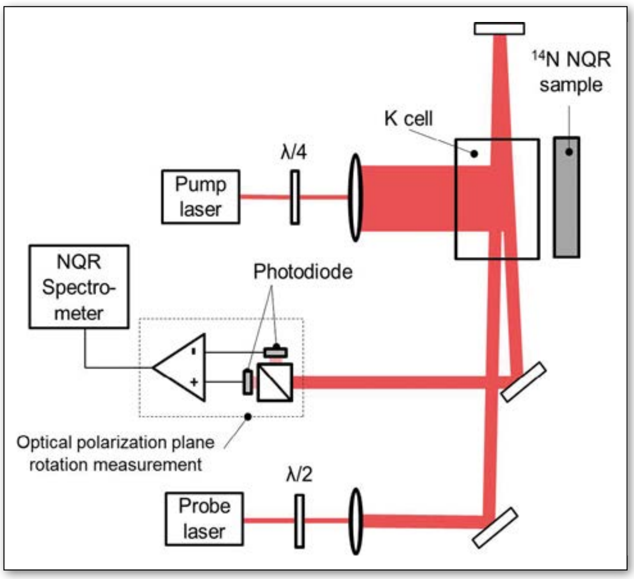
APPLIED PHYSICS

Optical detection of low frequency NQR signals

Nuclear quadrupole resonance (NQR) is a branch of radiofrequency (RF) spectroscopy. It became a promising tool in detecting illicit substances like explosives, narcotics and counterfeit medicines. Many of these substances contain ^{14}N nuclei and are detectable by the NQR spectrometer. Practically all ^{14}N NQR frequencies are in the range below 5 MHz and correspondingly the spectrometer sensitivity is low. One of possible improvements is a combination of the very sensitive potassium (K) pumped optical magnetometer (KPOM) and the pulsed NQR spectrometer. The linearly polarized probe laser beam detects the magnetic part of the low frequency ^{14}N RF signal. This results in a rotation of the probe beam polarization plane after the beam leaves the K-cell. This rotation is measured and is proportional to the NQR signal. Combination of the classic RF excitation of the sample ^{14}N nuclei and a subsequent optical detection of the sample response leads to a S/N improvement of up to a factor of 10 as it was demonstrated in the case study of some difficult-to-detect illicit substances. An efficient magnetic shielding may be necessary. ■

■ **S. Begus**, **J. Pirnat**, **V. Jazbinsek** and **Z. Trontelj**,
'Optical detection of low frequency NQR signals: a step forward from conventional NQR', *J. Phys. D: Appl. Phys.* **50**, 095601 (2017)

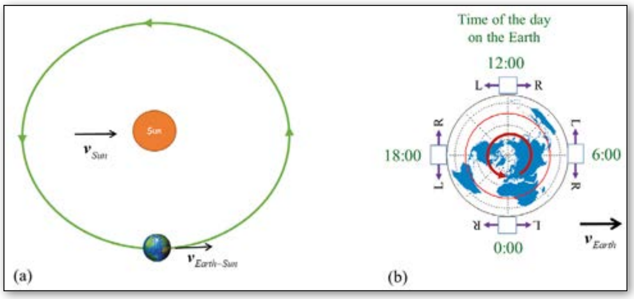
▼ Optical detection of NQR signal.



RELATIVITY

Does the universe have a rest frame?

Experiment aims at resolving divergence between special relativity and standard model of cosmology



▲ A simplified diagram showing the basic idea of the experimental design.

Physics is sometimes closer to philosophy when it comes to understanding the universe. The author attempts to elucidate whether the universe has a resting frame. The results have recently been published. To answer this tricky question, he has developed an experiment to precisely evaluate particle mass. This is designed to test the special theory of relativity that assumes the absence of a rest frame, otherwise it would be possible to determine which inertial frame is stationary and which frame is moving. This assumption, however, appears to diverge from the standard model of cosmology, which assumes that what we see as a vacuum is not an empty space. The assumption is that the energy of our universe comes from the quantum fluctuation in the vacuum. In this study, the author set out to precisely measure the masses of two charged particles moving in opposite directions. The conventional thinking assumes that the inertial frame applies equally to both particles. If that's the case, no detectable mass difference between these two particles is likely to arise. However, if the contrary is true, and there is a rest frame in the universe, the author expects to see mass difference that is dependent on the orientation of the laboratory frame. ■

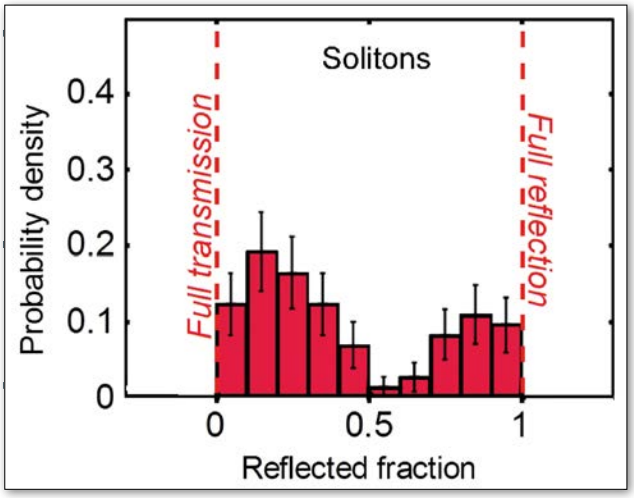
■ **D. C. Chang**,
'Is there a rest frame in the universe? A proposed experimental test based on a precise measurement of particle mass', *Eur. Phys. J. Plus* **132**, 140 (2017)

ATOMIC AND MOLECULAR PHYSICS

Nonlinear scattering of atomic bright solitons in disorder

Atomic bright solitons are self-trapping Bose-Einstein condensates. They exist in one-dimension because of attractive interactions. We observe nonlinear scattering of 39K atomic bright solitons launched in a one-dimensional disordered potential. The atoms from solitons behave collectively, *i.e.* are either mostly reflected or transmitted in contrast to non interacting atoms, which behave as independent quantum particles. This is the first observation of a non-linear behaviour with atomic bright solitons beyond their self-trapped nature. It requires the soliton interaction energy to be of the order of its center-of-mass kinetic energy. Our observations are reproduced in a mean-field framework by Gross-Pitaevskii simulations, while mesoscopic quantum superpositions of the soliton being fully reflected and fully transmitted are not expected for our parameters. We discuss the conditions for observing such superpositions, which would find applications in atom interferometry beyond the standard quantum limit. ■

■ **A. Boissé**, **G. Berthet**, **L. Fouché**, **G. Salomon**, **A. Aspect**, **S. Lepoutre** and **T. Bourdel**,
'Nonlinear scattering of atomic bright solitons in disorder', *EPL* **117**, 10007 (2017)



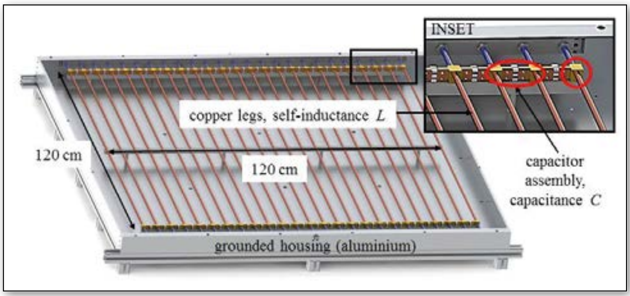
▲ Histogram of the atom reflected fraction when a soliton is scattered in a disordered potential. The atoms tend to be collectively either transmitted or reflected in contrast to the observation for non-interacting atoms. The non-linear scattering behaviour appears as a double peak structure in the histogram.

PLASMA PHYSICS

Flat inductive plasma for large area plasma processing

Low temperature plasma generated by a resonant network antenna.

Plasma processing over large areas (> 1 m^2) is of fundamental importance for the industrial production of solar cells, flat panel displays, packaging, surface treatment, large area electronics, *etc.* Magnetic induction by RF oscillating currents in parallel legs is often used to drive the plasma in large inductive sources. In this work, the novel plasma source is a multiple *LC* resonant network antenna as shown in the figure.



▲ Schematic of the $1.2 \times 1.2\ m^2$ planar antenna. Capacitors join the ends of copper leg inductors to form a LC resonant network.

An electromagnetic model describes the antenna-plasma coupled system as a multi-conductor transmission line. Inspired by the "complex image" model for power transmission lines, this theory is used for the first time to calculate the induced image currents in the plasma. This approach could be applied generally to ICP antennas for large area plasma processing. ■

▮ **Ph. Guittienne**, **R. Jacquier**, **A. A. Howling** and **I. Furno**,
'Electromagnetic, complex image model of a large area RF resonant antenna as inductive plasma source', *Plasma Sources Sci. Technol.* **26**, 035010 (2017).

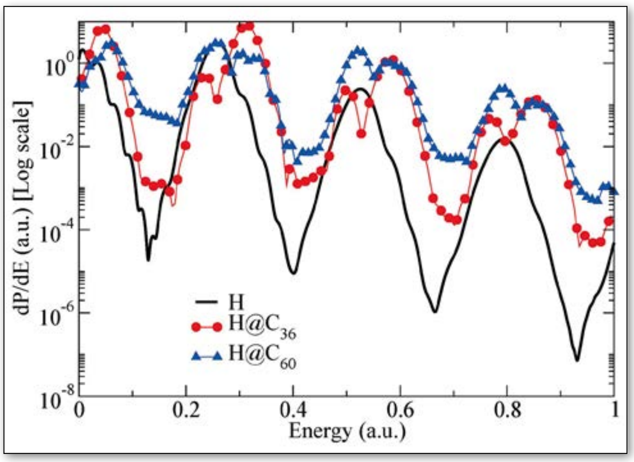
ATOMIC AND MOLECULAR PHYSICS

Ionisation mechanisms of captive atoms struck by light matter

Physicists elucidate the effects of light rays falling onto hydrogen atoms trapped in a carbon atom cage

Light interacting with hydrogen atoms enclosed in hollow cages composed of carbon atoms—referred to as fullerene material—produces ionisation. This phenomenon, which has been the subject of intense theoretical scrutiny, is particularly interesting because the light rays can have dramatic effects in inducing small external energy potentials. Specifically, they alter the structural and dynamic properties of the atoms confined within the fullerene molecule. The authors have just published a study explaining the theory behind the ionisation. Applications of this process include drug delivery, quantum computation, photovoltaics and hydrogen storage. ■

▼ Ejected electron spectrum of the bare and caged hydrogen atom subjected to an external light pulse.

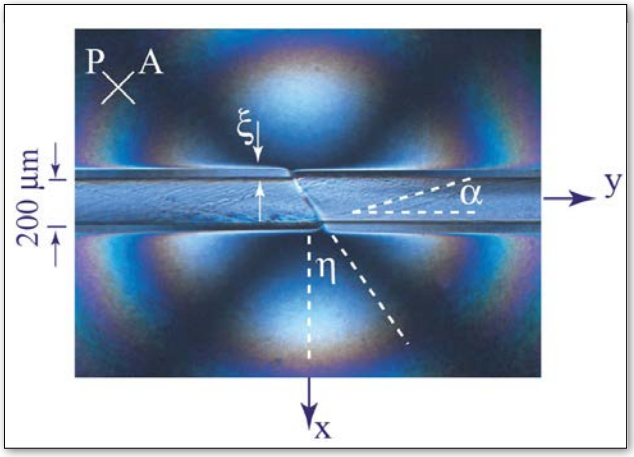


▮ **A. L. Frapiccini**, **G. Gasaneo** and **D. M. Mitnik**,
'Generalized Sturmians in the time-dependent frame: effect of a fullerene confining potential', *Eur. Phys. J. D* **71**, 40 (2017).

MATERIAL SCIENCE

Molecular scale transporter with a twist, powered by liquid crystal defects

Delivery of biochemical substances is now possible using a novel application of liquid crystal defects, forming a loop enclosing the substance travelling alongside twisted fibres



▲ Twisting effect, called chirogyral, dictated by the handedness of the fibre in a vertical magnetic field.

Defects that break the symmetry of otherwise orderly material are called topological defects. In solid crystals, they are called dislocations because they interrupt the regularly structured atom lattice. In contrast, topological defects called disclinations take the form of loops in liquid crystals of the nematic variety, whose elongated molecules look like a shoal of fish. New experiments supported by a theoretical model show how defects forming loops around twisted plastic fibres dipped in liquid crystal could be used for the transport of biochemical substances, when controlled by electric and magnetic fields. These findings, published recently, have potential applications in electro-optical micromechanical and microfluidic systems. The loops have the ability to move alongside a translational motion when a magnetic field is applied in a direction oblique to the fibre. This means that by applying such a field, it is possible to control the transport of molecules trapped inside the loops, moving alongside the fibres. ■

■ **M. Dazza**, **R. Cabeça**, **S. Čopar**, **M. H. Godinho** and **P. Pieranski**,
'Action of fields on captive disclination loops',
Eur. Phys. J. E **40**, 28 (2017)

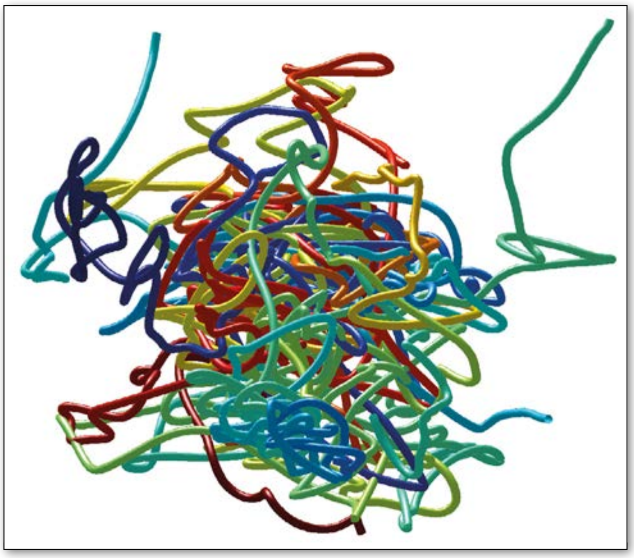
BIOPHYSICS

Speed-dependent attraction governs what goes on **at the heart of midge swarms**

New study reveals swarm cohesion stems from an adaptive behaviour, where the faster individual midges fly, the stronger the gravitational-like force they experience

Ever wondered what makes the collective behaviour in insect swarms possible? The authors modelled the effect of the attraction force, which resembles Newton's gravity force, acting towards the centre of a midge swarm to give cohesion to their group movement. In a recently published work, their model reveals that the gravity-like attraction towards the heart of the swarm increases with an individual's flight speed. The authors confirmed the existence of such an attractive force with experimental data. They chose to focus on insect swarms, rather than bird flocks or fish shoals, because interactions between neighbouring individuals appear not to play a key role. This makes insect swarms easier to model. Instead of building a model describing the microscale movement of individuals and confronting it with experimental data, the authors built a model of swarm behaviour that is consistent with experimental observations, in terms of swarm density, of individual midges' speed and acceleration. ■

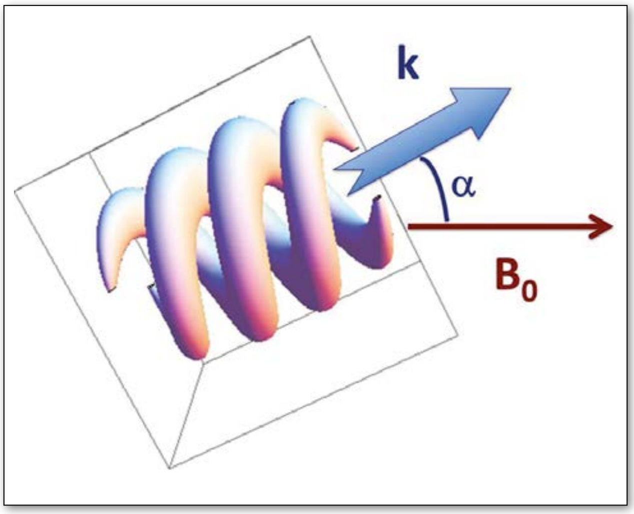
▾ Trajectories of individual midges within a swarm recorded using high-speed cameras.



■ **A. M. Reynolds**, **M. Sinhuber** and **N. T. Ouellette**,
'Are midge swarms bound together by an effective velocity-dependent gravity?', *Eur. Phys. J. E* **40**, 46 (2017)

PLASMA PHYSICS

Twisted waves in a magnetoplasma



▴ Twisted wave propagating in a magnetized plasma along an arbitrary direction.

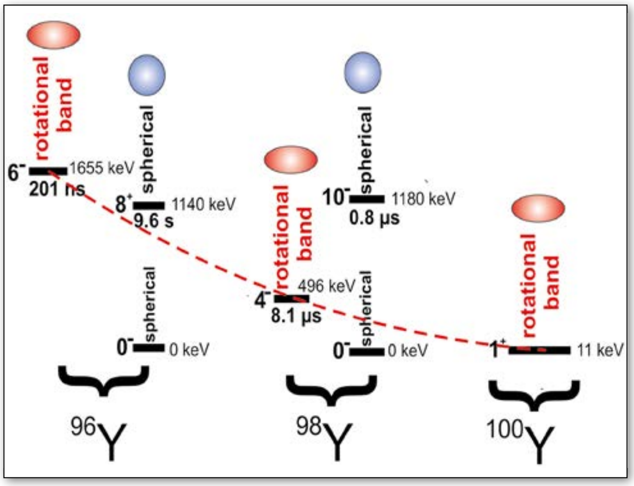
In recent years, the properties of twisted light beams have been widely explored. In particular, it was realized that twisted laser beams are able to excite twisted density perturbations in a plasma, and that these density perturbations are indeed new forms of twisted waves. Each twisted wave solution is characterized by a topological charge. A further step in the understanding of twisted light was recently made, by studying twisted wave solutions in a magnetized plasma. This leads to a variety of twisted wave solutions, both electrostatic and electromagnetic, depending on the angle of propagation with respect to the static magnetic field. These waves can also be seen as quasi-particles, carrying an intrinsic angular momentum, which is determined by the value of their topological charge.

Furthermore, the kinetic description of a gas of such quasi-particles can also be established. This leads to a generalized concept of plasma turbulence, made of a gas of several types of twisted quasi-particles. An example of application was considered, where two twisted modes with different topological charge interact with each other, exchanging energy and angular momentum inside the plasma. ■

■ **J. T. Mendonça** and **J. P. S. Bizarro**,
'Twisted waves in a magnetized plasma', *Plasma Phys. Control. Fusion* **59**, 054003 (2017)

NUCLEAR PHYSICS

Appearance of deformation in the yttrium isotopic chain



▲ Evolution of deformation across Y isotopic chain.

In the isotopes of rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr) and niobium (Nb) (*i.e.*, with Z=37-41), a sudden change of the nuclear structure occurs when the number of neutrons reaches N=60. While the nuclei with N<60 exhibit spherical shape in their ground states, the isotopes with N≥60 are significantly deformed. This phenomenon is considered the most dramatic shape change in the nuclear chart. A question was raised of whether the deformed structures appear just at N=60 or they reside also in the lighter isotopes. Indeed, deformed rotational bands built on the excited isomeric states are placed in ^{95}Rb, ^{96}Sr, ^{98}Y, $^{98-99}$Zr, *i.e.*, at N=58 and 59, however, nothing was known about location of such collective excitations at N<58. In our work, it was possible to significantly develop the level scheme of $^{96}Y_{57}$ via gamma-coincidence spectroscopy technique. During the analysis, a new 201(30)-ns isomeric state at 1655 keV excitation energy was located and the existence of a rotational band built on it was suggested. This result points to the presence of deformed structures already at N=57 which, with the increasing number of neutrons, gradually decrease in energy, to become dominant at N≥60. ■

■ **Ł.W. Iskra** and **35 co-authors**,
'New isomer in ^{96}Y marking the onset of deformation at N = 57', *EPL* **117**, 12001 (2017)

PLASMA PHYSICS

Reading between the lines of highly turbulent plasmas

Study shows how to identify highly turbulent plasma signatures in the broadening of the shapes of lines emitted by ions and atoms within

Plasma, the ionised state of matter found in stars, is still not fully understood, largely due to its instability. Astrophysicists have long-since sought to develop models that can account for the turbulent motions inside plasma, based on observing line shapes emitted by atoms and ions in the plasma. Turbulences are typically detected through the observation of broadened lines due to the Doppler effect, similar to the principle behind radar. In a new study published recently, the authors develop an iterative simulation model that accurately predicts, for the first time, the changes to the line shape in the presence of strong plasma turbulence. Ultimately, the authors aim to provide a system for assessing plasma turbulence that is valid for both a stellar atmosphere and the ITER tokamak designed to generate fusion energy. ■

■ **R. Stamm**, **I. Hannachi**, **M. Meireni**, **H. Capes**, **L. Godbert-Mouret**, **M. Koubiti**, **J. Rosato**, **Y. Marandet**, **M. Dimitrijević** and **Z. Simić**,
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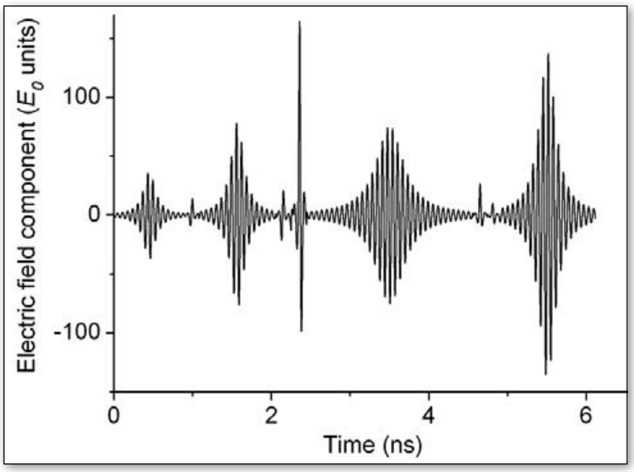
▼ A short sequence of solitons.



STELLA LUX: THE ENERGY-POSITIVE FAMILY CAR

Tom Selten – Eindhoven University of Technology, the Netherlands
DOI: https://doi.org/10.1051/epn/2017301

A family car that runs purely on solar energy, and that charges your home batteries when not on the road. In other words: a car that is Energy-positive. Can such a car be built? The answer is 'Yes!', as was shown by an enthusiastic group of students at Eindhoven University of Technology.

Imagine yourself driving an electric vehicle from your home to work. The morning sun is shining vaguely, and hundreds of cars are entering the highway. It's business as usual, and a traffic jam is beginning to form. You decide to evaluate your car's battery status while slowly progressing through the heavy traffic. Right now, you can see the battery is charging.

During the night the car has been standing in front of the house, and in the morning sun it has been wirelessly transferring energy to your house to meet your energy demand. At the same time, the car has been keeping track of your daily routines to make sure the batteries are sufficiently charged to drive wherever you want to go to.

The era of energy-independent vehicles has begun.

Why did they build this car?

Four years ago, a group of enthusiastic students decided to do something different. Normally you would expect a student to finish his or her studies by following the curriculum, especially in times where the Dutch government has decided to penalize students who take too long to graduate. But, something much more important has caused some students to rebel. They were triggered by a devastating fact: a recent study has shown that 4 billion people will reach the same level of prosperity as the people living in today's Western world. It seems like an impossible challenge to provide them with the high-quality individual transport which we enjoy today while still taking care of our lovely planet. Now, the trick is to let the car take care of its own energy needs. And that's what the students decided to devote 2 years of their lives to; against the status quo but with an unbelievable motivation.

> **"Stella Lux is the result of an optimized aerodynamic shape combined with the precision science of designing a highly efficient solar energy source."**

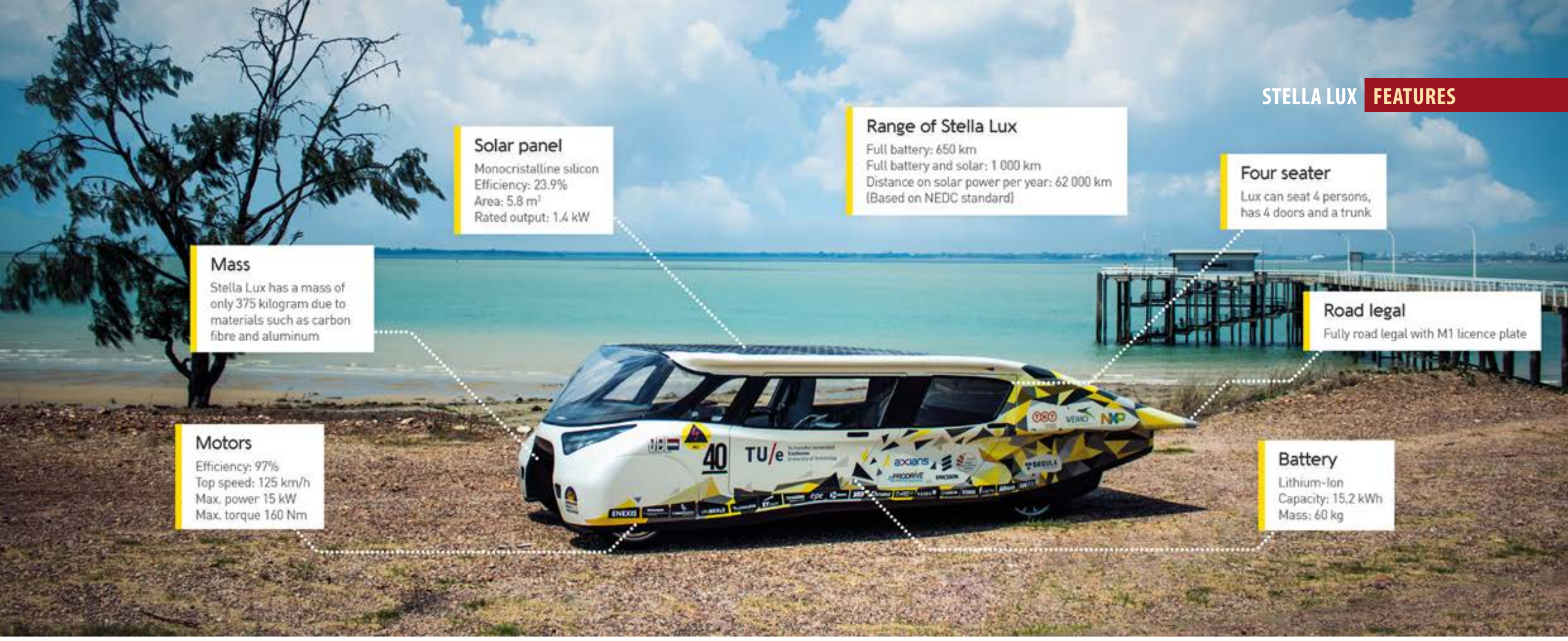
Current Situation

Today's cars rely on external resources, be it nature (oil, biogas) or space used by renewable sources elsewhere (solar panels, wind). When cars harvest the energy themselves, we unlock the freedom of mobility without feeling guilty about using it at the expense of others. With today's technology, it is possible to cut the line between the car and its energy source, and make it fully independent. Since it combines production, buffering, distribution and charging in one car, it is the most efficient family car in the world. A car that is always ready for a trip: an energy-independent vehicle. It can seat 4 persons and has a pretty large trunk for suitcases, so it is a true family car (see Fig. 1).

Designing an energy-efficient car

The principle of an energy-independent vehicle is very easy to understand. You minimize the energy consumed by the car while at the same time maximizing the energy yield. This is sometimes a trade-off which becomes self-evident when looking at Stella Lux. In order to increase the yield we extended the roof a little bit as can be seen in the pictures. By protruding the roof, two extra arrays of solar cells can be placed, which increases the energy yield (see Fig. 2).

The energy use at constant speed is completely determined by the resistance, in newtons, which the car has to overcome to maintain that speed; remember that 1 N = 1 J/m or, more conveniently, 1 kJ/km.



▲ **FIG. 2:** Stella Lux in Australia, where it became the winner in the Cruiser Class of the World Solar Challenge.

There are two types of resistance to be considered:

1) Air resistance or aerodynamic drag F_d. Since the flow profile around the car is turbulent, the aerodynamic drag is given by (*cf.* Bernoulli's law):

$$F_d = ½\, \rho V^2 C_d\, A \qquad (1)$$

where ρ is the air density, V the speed, C_d the drag coefficient and A the frontal area.

2) Rolling resistance or mechanical drag. This is primarily caused by the tires and can be written as

$$F_r = C_r\, N_f \approx C_r\, [1 + V/Q]\, mg \qquad (2)$$

where C_r is the rolling resistance coefficient, N_f is the normal force, $Q \approx 161$ km/h is a practical parameter to account for the (small) speed dependence of the rolling resistance, m the mass and g the acceleration due to gravity.

Note that the power, given by $P = F{*}V$, is proportional to V^3 for the aerodynamic drag (eq. (1)). Since this is the dominant resistance at high speed, it is very important to design an aerodynamic shape by decreasing the frontal area and the drag coefficient if one wants the vehicle to reach high speeds. Obviously, this also serves to decrease the energy use.

So the first concern in the design is to have a small aerodynamic drag. Secondly, the mass of the vehicle should be minimized (see eq. (2)). In every design decision, the mass of the car should be considered. And finally, low-rolling-resistance tires are very important to minimize the mechanical drag.

Not surprisingly, these three aspects were of major concern during the design phase of Stella Lux. The car is optimized based on these three aspects.

◀ **FIG. 1:** The Stella Lux is a true family car: it can seat four people and has a trunk for luggage. It is licensed for driving on the public highway. Photos: TU Eindhoven, Bart van Overbeeke.

Materials: How did they build it?

The most crucial parts for Stella Lux to be an energy-independent vehicle are the solar roof, the batteries, the lightweight design and the use of very energy efficient motors and low-friction tires.

a) Solar roof

The solar cells are the most crucial component in powering the vehicle. A total of 381 monocrystalline silicon cells are combined to form a highly efficient (1.5 kW peak) solar array with a total surface of 5.84 square meters (see Factsheet).

Even when it is cloudy, the sunlight capture is maximized by using a non-reflective surface, made up of tiny prisms, which have been layered over the array. These prisms bend the diffracted light to ensure that it arrives perpendicular to the solar cells, increasing the solar yield under all conditions. The solar array has demonstrated a maximum efficiency up to 23.9%, which is very high in comparison with standard solar panels.

b) Battery

The *custom-designed battery pack* contains *1224 Lithium-Ion 3450 mAh battery cells*, giving a total storage capacity of 15.2 kWh. The battery pack stores the energy produced by Stella Lux' solar array. To keep Stella Lux suitable for driving at night, it is possible to charge from the grid as well.

The battery pack uses intelligent load balancing technologies to ensure extremely efficient conversion of the stored energy. The battery monitoring system continuously checks the state of charge.

With the combination of direct solar energy and the battery pack, the maximum daily range of the car is up to 1000 km in summer but varies with the time of the year (see Fig. 3).

c) Lightweight design

A carbon fibre monocoque was used to build the car body. These really thin fibres are woven together much like textile threads. They are very strong, stiff yet lightweight. The monocoque has been designed to carry most of the body weight. It has an integrated roll cage for increased safety, meeting all the stringent safety requirements. The total body-mass is *75 kg*.

A car's energy consumption is closely linked to its shape, so it is of key importance to minimize air resistance (*cf.* eq. (1)). Stella Lux is the result of an optimized aerodynamic shape combined with the precision science of designing a highly efficient solar energy source.

Special features of the shape include the converging tail at the base of the car – for optimum aerodynamics – and the protruded roof – to accommodate additional solar cells. A tunnel under the vehicle further reduces air resistance (see Fig. 1).

d) In-wheel motors and low-friction tires

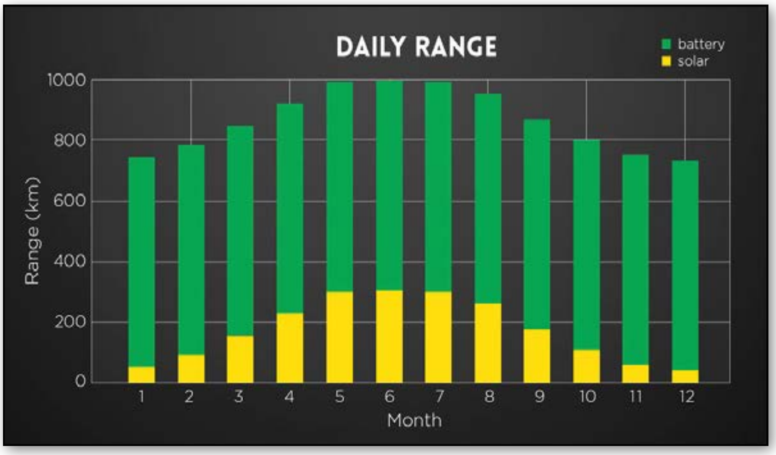
The *in-wheel motors* convert the supplied electrical energy into forward motion. Placing the motors directly in the wheels means that no transmission or gearbox is needed, resulting in an energy efficiency of 96%. The total powertrain – consisting of the battery and motor – has a measured efficiency of 92%.

In-wheel motors allow for *regenerative braking*. In conventional cars, the kinetic energy absorbed by the brakes is converted into waste heat. Instead, Stella Lux can capture a large part of this braking energy. By providing torque in the opposite direction, the motors become generators and recharge the batteries.

Stella Lux' special *low-friction* tires also contribute to minimizing energy consumption. The coefficient of rolling resistance for the tires on Stella Lux is around *4 times lower* than that of conventional tires.

Conclusion

The Stella Lux proves that an energy-positive family car offers a viable future scenario. One has to keep in mind that the performance of solar cells and batteries are bound to improve in the future. If costumers are willing to sacrifice some comfort and are satisfied with moderate speeds, sustainable personal transportation is within reach. ■



▲ FIG. 3: Maximum daily range of the Stella Lux car throughout the year in The Netherlands.

About the Author

Tom Selten is affiliated with the University of Technology Eindhoven. As a student Industrial Engineering, he decided to join Solar Team Eindhoven. Meanwhile, Tom Selten retired from his team and is currently a master student Innovation Management at the UT Eindhoven.

FACTSHEET STELLA LUX		
Seats	4	
Doors	5	
Length	4523	(mm)
Width	1756	(mm)
Height	1122	(mm)
Mass	375	(kg)
Battery capacity	15	(kWh)
Equivalent usage	390	(km/l)
Motor efficiency	97	(%)
Range sunny day in the Netherlands according to NEDC*	1000	(km)
Range sunny day in Australia according to NEDC*	1100	(km)
Range by night	plus/minus 650	(km)
Top speed	125	(km/h)
Amount of solar cells	381	cells
Type of solar cells	Monocrystalline Silicon	
Solar array	5,8	m^2
Number of battery cells	1224	cells
Type of battery cells	Lithium Ion	

* New European Driving Cycle

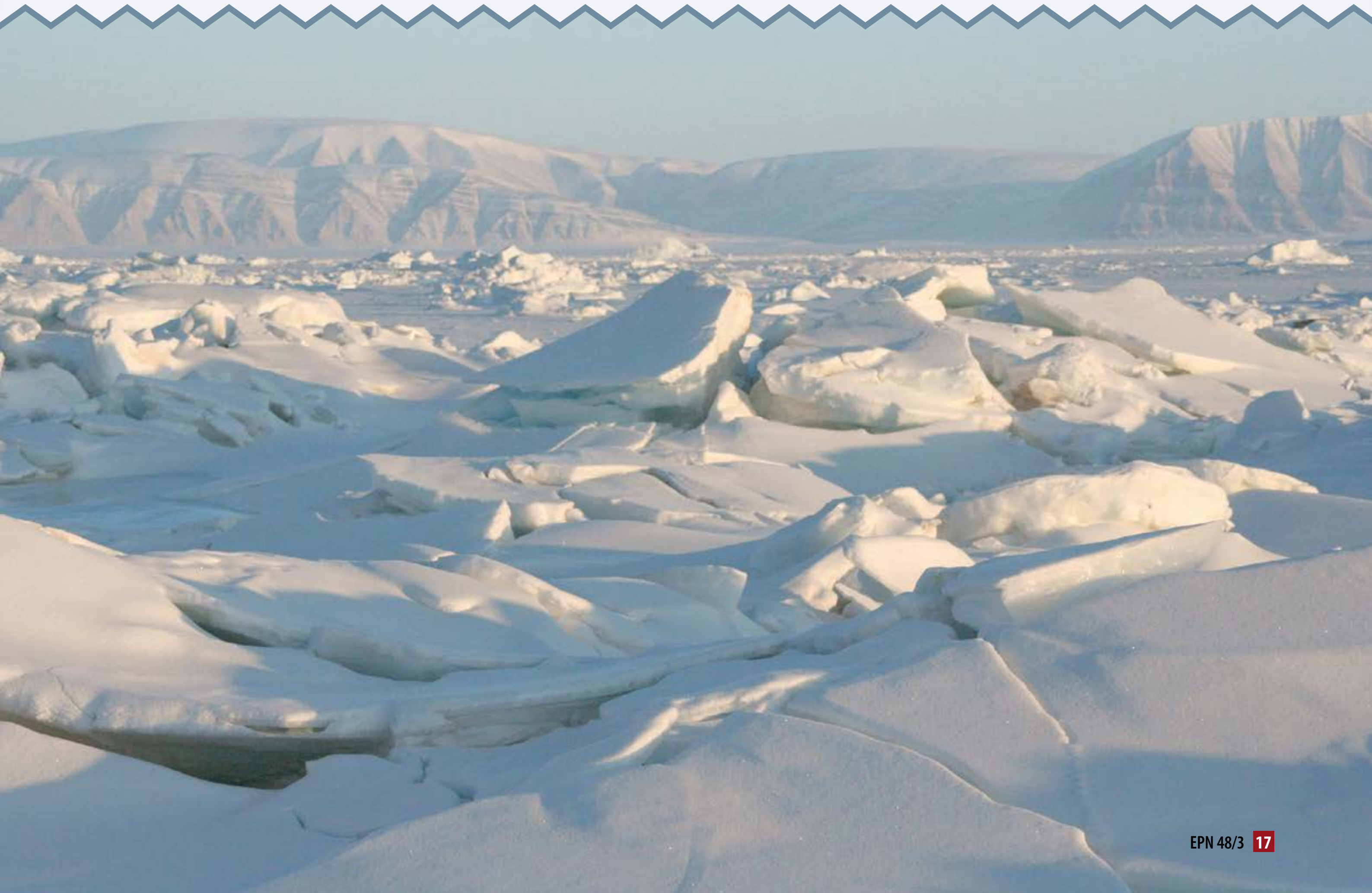
A BRIEF TOUR OF THE CLIMATE MACHINE
2 - ENVIRONMENT SHAPES THE CLIMATE[1]

Jean Poitou – DOI: https://doi.org/10.1051/epn/2017302
Laboratoire des Sciences du Climat et de l'Environnement (LSCE)*, Saclay, France

As explained in a paper in the preceding issue of EPN [2], the bulk of the climate system is a thermal machine by which the two fluids of the Eearth envelope transport energy from low to high latitudes. The present paper emphasizes the role of interactions in the fashioning of the climate.

Photo credit: courtesy Andy Mahoney, NSIDC

* Retired from LSCCE



Climate – environment interactions

Earth climate depends on the radiation budget: everything that may modify the energy flux (absorbed or escaping) will disturb the Earth climate.

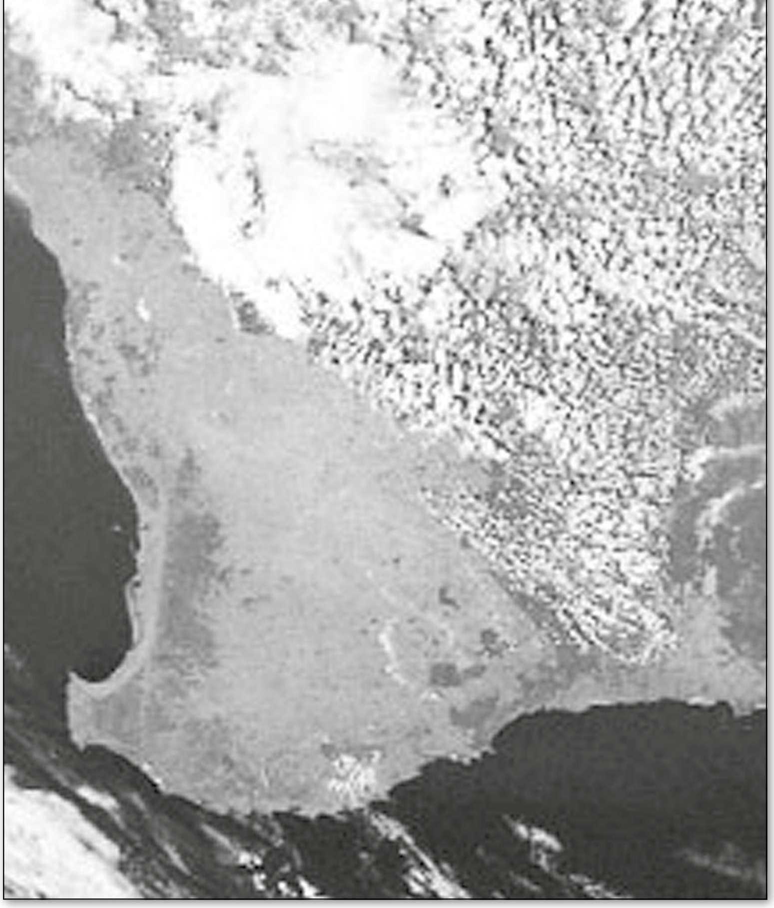
- The incoming energy flux hitting the surface depends first on the sunlight that reaches the Earth. This flux may vary due to variations in solar activity. At time scales of tens of millenniums, it also varies with the sun-earth distance that fluctuates with the Earth astronomical parameters: obliquity, eccentricity, precession of the orbit.
- In the visible and near-infrared parts of the light spectrum, the atmosphere is essentially transparent to solar radiation. The bulk of the absorption is due to aerosols such as black carbon. But the solar radiation is also scattered by atmospheric molecules and aerosol particles, and reflected by clouds. The importance and lifetime of clouds depend on aerosols.
- The reflecting power (albedo) of the surface depends on its nature. A snow or ice covered area has a high albedo value, 60 to 90%. However, the presence of vegetation reduces strongly the albedo that can become very small (10%) for dark equatorial forests. The ocean albedo is also very small. The global albedo (30%) is higher than the surface albedo thanks to clouds.
- In the thermal infrared domain *i.e.* that of the flux leaving Earth into space, the atmosphere acts strongly on the radiation. Clouds and aerosols again play a role in the reflection, scattering and absorption processes. But the major contribution is the absorption by greenhouse gasses (see box 1: ingredients of the greenhouse effect) without which life would not exist on Earth.

Continents stand in the way of the ocean circulation. They influence both horizontal and vertical atmospheric circulations: in the presence of mountains, the air is forced to rise and thus to cool, which can lead to water vapour condensation and rainfall, an effect that is particularly marked in Asia where the Himalaya contributes strongly to the strength of the wet monsoon.

Feedbacks

Climate determines the various compartments of the Earth environment: cryosphere, vegetation and fauna types, erosion … It determines water evaporation, cloud covering, rainfall patterns, lifting of natural aerosols (forest and savannah fires, mineral dust from bare soils). But the changes that are inflicted by climate evolutions to the environment react in turn on the climate and enhance or inhibit these evolutions as will be shown on a few examples.

- The increase in surface temperature leads to an increase of the radiated energy (Stefan-Boltzmann) which lowers the warming. Similarly, due to the vertical gradient of atmospheric temperature, local air warming results in a convective air rise; the rising warm air will be replaced by descending cooler air. These are examples of negative feedbacks.



▲ FIG. 1: Satellite view of south-west Australia on January 3, 1999. The limit between cloudy and clear sky areas is also the limit between forest and crops. (source UCAR – NCAL – EOL ; Geostationary Meteorological Satellite –5 visible channel imagery over southwest Australia for 3 January 1999, http://www.nsstc.uah.edu/~nair/BUFEX05/study_area.html)

BOX 1: INGREDIENTS OF THE GREENHOUSE EFFECT

What do we call greenhouse effect?

In the absence of atmosphere, an Earth having the same albedo of 30% as our Earth and receiving the same solar flux of 1360 $W.m^{-2}$ would have an average temperature of 255K (-18°C) according to Stefan-Boltzmann law. The average ground temperature of the Earth is 15°C. Calculations of energy transfer in the atmosphere show that this difference between radiative temperature and ground temperature is due to the combined action of various processes including, on one hand, vertical heat transport through the atmosphere, convection, radiation, and on the other hand, scattering, absorption and emission of infrared radiation by atmospheric molecules [3]. The overall phenomenon called greenhouse effect is possible only in an atmosphere with a temperature decreasing with altitude [4]. It involves the vertical structure of the atmosphere and the fact that photons emitted at low altitude are absorbed before they can leave atmosphere. The photons leaving the Earth are emitted in the atmosphere, which consequently cannot be treated like a thin window pane. The name "greenhouse effect" is related to the fact that the atmosphere confines heat thus increasing low altitude temperature similarly to the greenhouse window pane which confines heat inside the greenhouse (albeit by a different process).

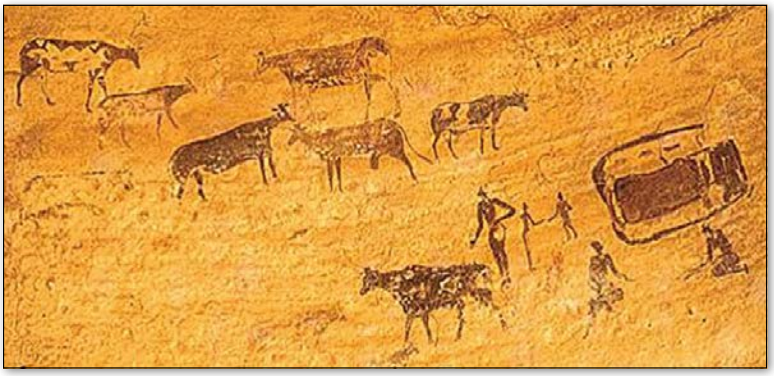
Greenhouse effect cannot be overlooked for the understanding of the climate of the Earth but also of the other planets and their passed convulsions [5]. The carbon cycle plays there a role which is necessary to understand the climate evolutions that paleoclimatologists identify by their imprints.

- The beginning of a glacial era involves several positive feedbacks (see box 2).
- There are also more complex cases: warming increases water evaporation. According to Clausius-Clapeyron the atmosphere will possibly contain more water vapour, that will enhance the greenhouse effect and thus the warming. But there will also be more clouds. If these additional clouds are low clouds, they will reduce the warming (parasol effect); however, if these are high cirrus clouds, warming will be enhanced.
- An interesting circumstance is that of the vegetation. Its presence reduces the ground albedo enhancing the solar radiation absorption. But its main climate role is to diminish the greenhouse effect by the large amounts of carbon it stores. Vegetation acts also by evapotranspiration [6]: the humidity that forest delivers to the atmosphere (Figure 1) favours regional rainfalls, a phenomenon which contributed to the "green Sahara" 6000 years ago (Figure 2). A stronger evapotranspiration has also a cooling effect on the surface.

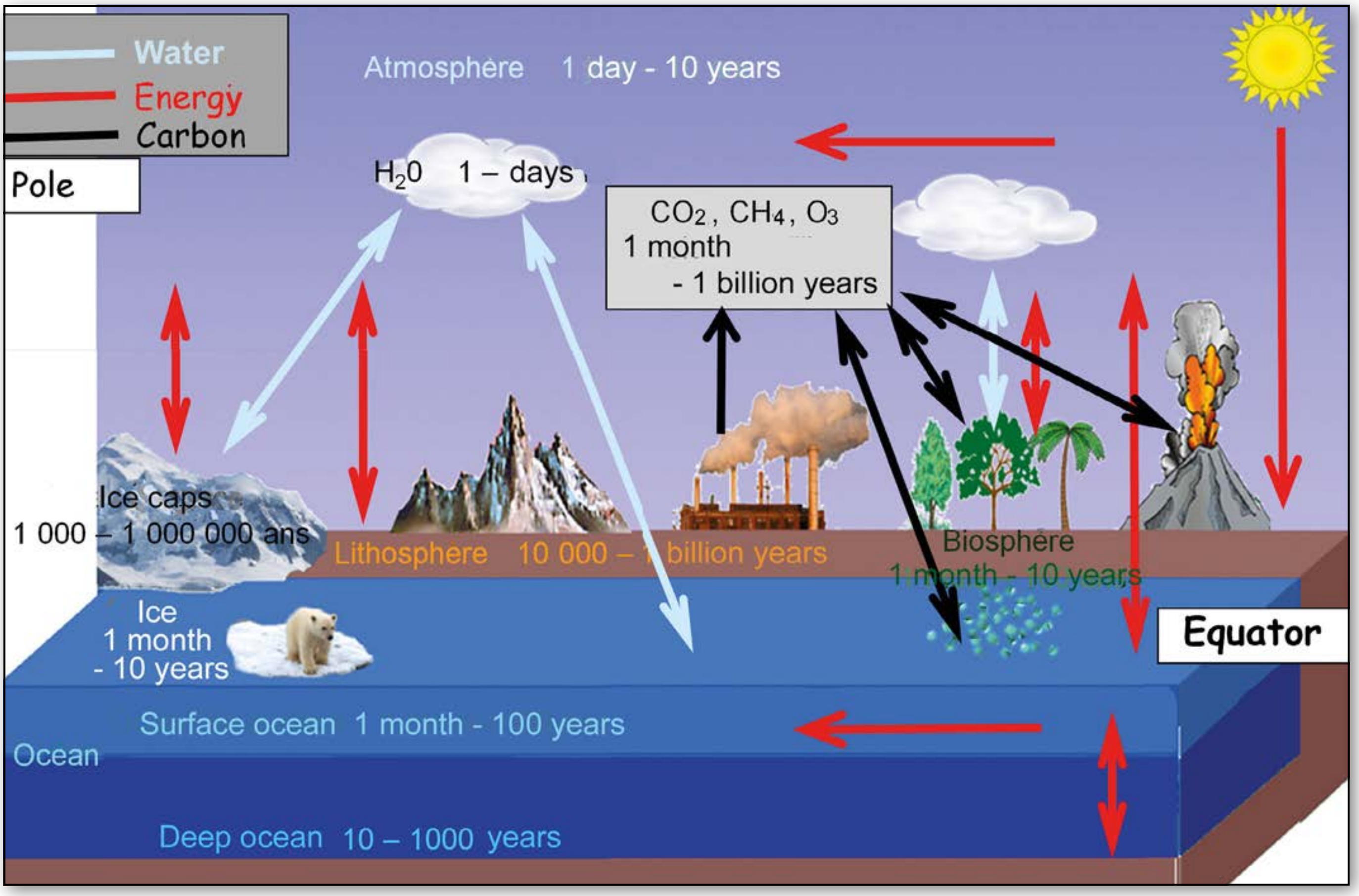
Climate modelling

Let us close this brief tour of the climate machine with an introduction to the role of modelling. The first climate models strived to describe how the atmosphere functions in terms of the physics laws of transport. These include fluid mechanics (Navier-Stokes) in a rotating frame, conservation laws (mass, energy, momentum) and thermodynamics; forces in play are pressure gradient, gravity, Coriolis and friction forces. This atmospheric component of the models is also that of meteorological forecasts. In these models, the environment (sea surface temperature, ground status) was considered as passive. Such models cannot account correctly for the energy redistribution by the atmosphere and the ocean.

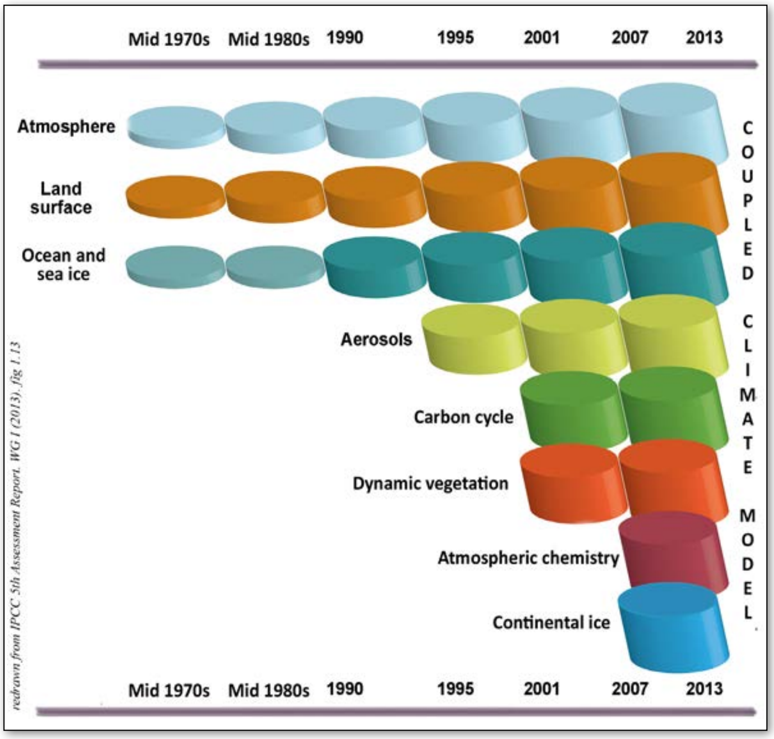
An oceanic circulation model was thus coupled to the atmospheric circulation model. A difficult problem to achieve this coupling is due to the various lengths of time typical of the processes involved in the two fluids as indicated on Figure 3. As we saw above, the climate acts on the environment which reacts on the climate. A realistic modelling has to take into account all environment components. It is no more a climate model but an Earth system model (Figure 4) which is used nowadays to describe the climate evolution.



▲ **FIG. 2:** Rock paintings in Tassili, showing livestock in the green Sahara 6000 years ago.



▼ **FIG. 3:** Exchange processes of energy, water vapour and greenhouse gasses have very different characteristic times ranging from a day to a billion years.



▲FIG. 4: Evolution over time of climate models. The number of components increases simultaneously as they use more refined descriptions (illustrated by growing cylinders). Current models aim at describing the whole "Earth system". Notice that ice caps are not routinely included yet in the models.

BOX 2: QUATERNARY GLACIATIONS OWE MUCH TO BACKUPS

For 3 millions years, Earth has experienced alternating interglacial eras (like the present period) with one ice cap on Antarctic and one ice cap on Greenland, and glacial eras with two additional enormous caps, one over Northern Europe and one over North America. A glaciation is initiated by specific seasonal conditions: rather mild winters at high northern latitudes with mild temperatures in the tropics so that the atmosphere is wet enough for bringing copious snowfalls; sufficiently cool summers so that the snow accumulated in winter does not completely melt. This requires that the winter solstice is close to perihelion and the summer solstice close to aphelion, with a not too small Earth orbit eccentricity and a strong obliquity. Snow thus stays all year long at high latitudes, which increases the albedo, reduces sun light absorption and causes a cooling. Due to the colder climate, boreal forest is replaced by toundra, a low vegetation yielding a higher albedo in these snow covered areas, thus reducing again solar radiation absorption and increasing the cooling. The colder sea water absorbs significantly more CO_2 which is taken and stored at the ocean bottom by the thermohaline circulation; its atmospheric concentration drops, which reduces strongly the greenhouse effect. At the same time, the microorganism activity at high latitudes decreases, which decreases the methane production. All these processes amplify the cooling. Such processes enabled the accumulation of 42 millions km^3 of ice over northern Europe and America 21,000 years ago, lowering the sea level by 120 m.

Such a model requires very large computer resources (computing capacity and time) that make it unusable for cases that require numerous simulations to elucidate specific processes in the present and passed climates. Thus Earth system models are complemented by a hierarchy of more theoretical or simplified models which play a decisive role in the understanding of the general atmosphere and ocean circulation and its interactions with the environment, or to decipher the natural variability of our climate. They play a key role in evaluating feedbacks and climate response to various perturbations of the global radiation budget. They are essential to understand the large changes of the past that are known from natural climate archives. They allow to give meaning to present changes by evaluating the share of natural spontaneous climate variability and of human influence. They are essential too to anticipate future risks. ■

About the Author

Jean Poitou.
Physicist, climatologist. Former deputy director of LSCE. Active in climate related NGOs and in introducing climate science to secondary school pupils.

Read more on this subject

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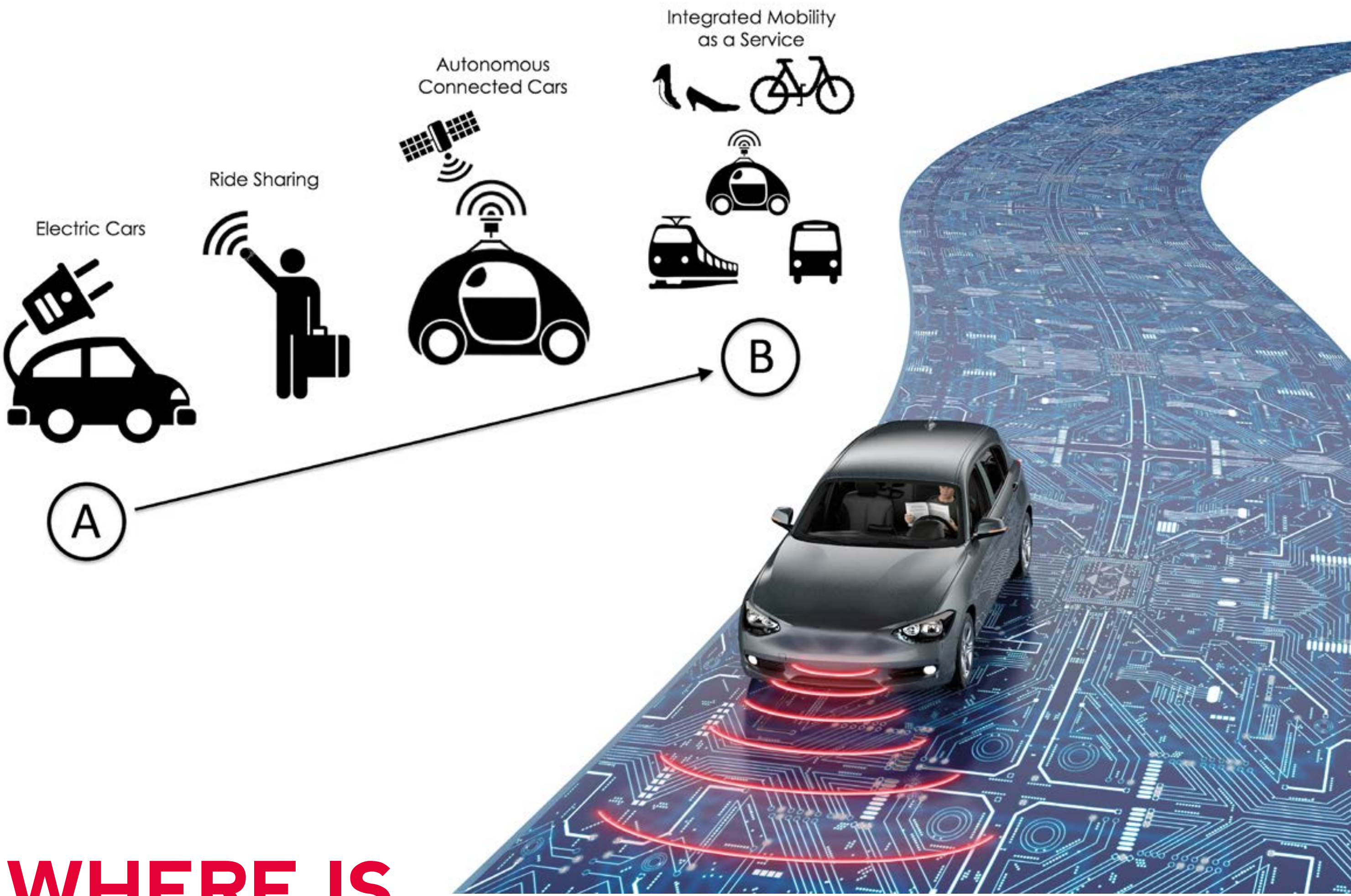

WHERE IS TRANSPORTATION GOING?

George Crabtree[1], Elizabeth Kocs[2] and Bryan Tillman[3] – DOI: https://doi.org/10.1051/epn/2017303
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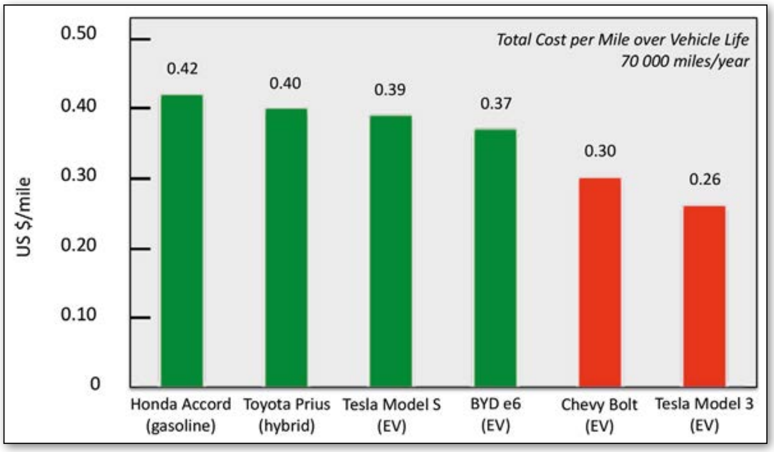
The Roman Empire introduced roads and transportation to promote culture, business and growth. It's time for the next step.

Disruptive innovation often occurs via the convergence of several creative advances. The smart phone, for example, arose from the emergence of lightweight lithium-ion batteries, Moore's Law in digital electronics and cell phone towers for wireless communication. Transportation is ready for such a disruptive leap, arising from electric vehicles, charging/electrical infrastructure, ride sharing, self-driving cars, and big data. The technology for these advances is already in place; completing the transformation requires only their integration into new paradigms for mobility and public acceptance by consumers and businesses.

Electric vehicles are the technological foundation of the new mobility. The price of batteries has declined dramatically in the last decade [1, 2] and continues to fall faster than expected (see Box). This and the learning curve for manufacturing electric cars has decreased the purchase price of electric vehicles from approximately \$100k in 2008 to \$35k in 2017 for a car with 200-mile (300 km) range. The operating costs of electric cars are significantly lower than for gasoline cars – driving a mile on electricity costs about half as much as driving on gasoline – and electric motors have a single moving part, the rotor, compared to hundreds of moving parts in a gasoline engine. Fewer moving parts dramatically reduces maintenance

▲ In twenty years, the technology, practice and business model of transportation will evolve from personal car ownership to mobility as a service, combining several modes of transportation for a single trip (Source: authors + ©iStockphoto))



▲ **FIG. 1: The lower fuel and maintenance costs of electric vehicles more than make up for their higher purchase price if the cars are driven 70 000 miles annually, as is typical of taxi and ride-sharing fleets. (Source: Vehicle Electrification Economics, Rocky Mountain Institute, October 13, 2015)**

costs while increasing longevity. For high-mileage cars, such as taxis and ridesharing vehicles, the total purchase plus operating cost of electric cars is already significantly cheaper than gasoline cars, as shown in Fig. 1 [3].

Ride sharing provides the mechanism for exploiting the low cost of high-mileage electric cars. The average personally owned car is vastly underused – parked about 95% of the time at home or at work, providing mobility only 5% of the time and usually carrying only a single occupant, the driver. Personally owned vehicles are driven 12 000 – 15 000 miles annually, compared to 70 000 miles for the average taxi. The dramatic rise of ride sharing services such as Uber and Lyft threatens to create a "new normal", replacing many low-mileage, underutilized personally owned cars with a few highly utilized, high-mileage fleet cars [4]. These cars will be overwhelmingly electric, taking advantage of the lower operating and maintenance costs of electric vehicles.

▼ **FIG. 2: Parking cars and trucks in urban areas is time consuming, expensive and requires precious land that could be devoted to more productive uses. (Source: public domain)**

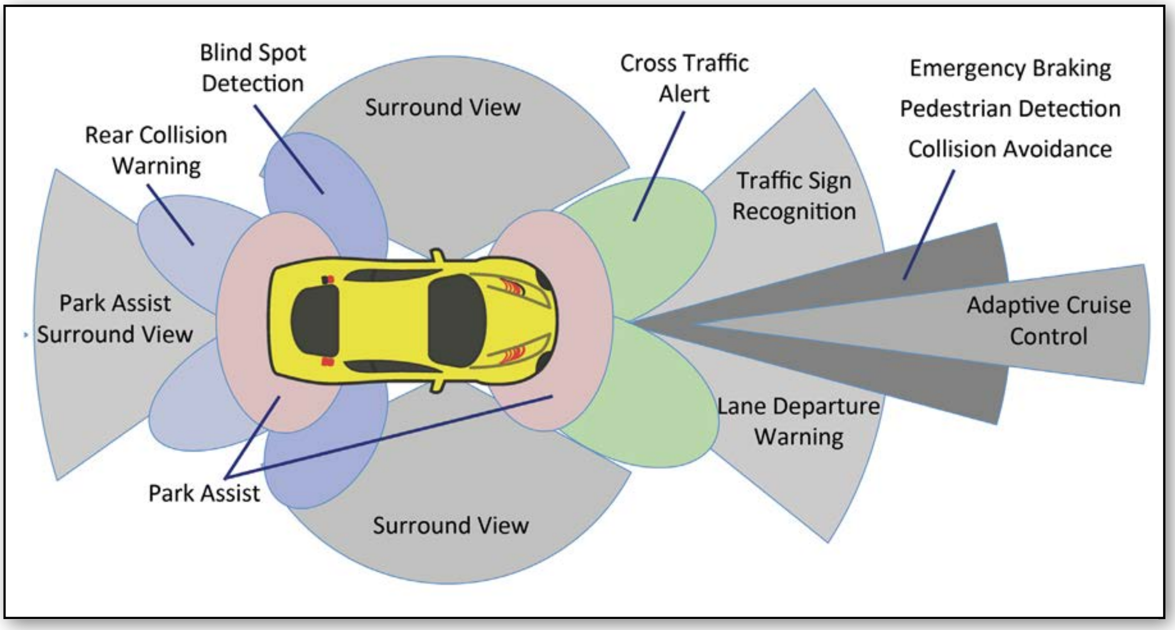
Ride sharing eliminates parking, an expensive and time consuming necessity for personally owned vehicles, and frees land in urban areas devoted to parking lots and garages for more productive uses (Fig. 2). Ride sharing also increases traveler flexibility, allowing seamless connection with other cost-effective and convenient mobility options such as walking, biking and public transit.

Self-driving cars are the next cog in the mobility transformation. Self-driving had its humble origins in electronic cruise control in the 1970s, and has grown steadily since to take over more and more driving functions as sensors and digital decision making matured, as shown in Fig. 3. Autonomous parallel parking is now widely available [5] removing the stress from this famously tricky maneuver. Many self-driving buses are now in place in restricted environments such as corporate campuses and private parks [6, 7] and far more sophisticated driving function is now within technological reach [8]. Google, Tesla, Toyota, Bosch, BMW and Daimler now have several million miles of experience with self-driving cars; they and others are racing to commercialize self-driving hardware and software [9]. The US has issued a set of proposed federal guidelines for self-driving vehicles; Europe and Japan are preparing similar international standards. The revised version of these guidelines will become the first self-driving rules of the road. Pittsburgh and Singapore have rolled out fleets of self-driving ride share cars on public streets [10]; these pilot programs are ready for replication, with refinement, in other cities.

Big data promises an even grander mobility transition. As revolutionary as self-driving is, it is only the near edge of the autonomous vehicle horizon. We can easily equip every car with a global positioning system (GPS) that reports its location, speed and direction, and this information can be collected wirelessly in a "transportation cloud". Such a data base empowers connected vehicles that share congestion, weather and road construction information and communicate recommended driving behaviour to autonomous or human-driven cars to minimize traffic, speed travel times, and reduce traffic accidents. This level of coordination is well within reach of big-data software using known methods.

Benefits

The new mobility brings far more benefit to the individual driver than simply being freed from making driving decisions. Statistical learning can predict when to make a given trip to encounter minimal congestion, re-route in real time to accommodate last minute itinerary changes and reduce delays, and adjust driving style for weather conditions such as rain, snow or slippery roads. At-risk groups such as the elderly, people with disabilities, and



◂ **FIG. 3:** Self-driving cars "see" lane markings, pedestrians, bikes, other vehicles, and objects in their path with many kinds of sensors. (Source: Authors)

children will have more mobility options and increased social well-being [11].

On the societal level, self-driving cars eliminate driver error, a major cause of accidents. Machines do not get tired, become distracted by texting, phone calls or in-car conversations, and they do not drive while physically impaired. The economic cost of traffic accidents is enormous - over $240B directly and over $800B in total harm in the US, according to the US National Highway Traffic Safety Administration. Fewer accidents mean lower medical costs, lower insurance rates and higher productivity through lower travel times. Sophisticated crash avoidance systems are already seeing lower insurance premiums, a trend that will accelerate as self-driving matures. Freight transport may see larger benefits than personal transport, including reduction in the number of drivers and rest stops on long hauls and the aerodynamic benefits of platooning, as shown in Fig. 4.

Self-driving vehicles increase the capacity of our surface transportation network for people and freight. Reducing congestion increases economic efficiency, and rolling out electric vehicle infrastructure such as fast charging stations and connected autonomous vehicles creates jobs and promotes economic growth.

Public health will see significant benefits from the new mobility. In dense urban areas tailpipe emissions from gasoline vehicles affect large numbers of people, while electricity generation is located away from cities where its pollution reaches far fewer people. The conversion of coal generation to gas and renewable wind and solar means that grid electricity gets cleaner every year, while the pollution of gasoline cars remains unchanged over the life of the car, a decade or more. Electric vehicles are a remarkably effective route to fewer lost workdays due to pollution-related illnesses, fewer asthma attacks, and fewer premature deaths.

Implementation

One of the beauties of the new mobility is that it can be implemented in stages. We are already seeing significant numbers of electric cars on the road, the charging infrastructure to support them, and a growing proliferation of ride-sharing services. Self-driving cars are rapidly approaching early adopter status, and vehicle connectivity via in-car GPS is a natural extension of the fusion of information and driving, as shown in Fig. 5. Each of these advances is within technological and economic reach; each brings mobility advantages, and their combination brings benefits well beyond the sum of the parts.

Imagine the year 2035, where transportation has adopted the technological, societal and generational trends that are now maturing [12]. Mobility is a service, less about car ownership as a personal statement and more about convenience and utility. The sharing economy allows open access and greater choice to riders and drivers, and financial benefit to both. The cloud and statistical learning personalize your daily mobility needs. Cities accommodate people at higher density with higher efficiency, less congestion and space devoted to parking. Emerging millennial culture becomes a dominant theme.

In less than twenty years, transportation will be transformed, in large part due to improved technology, both

▾ **FIG. 4:** Self-driving vehicles can platoon, following each other much more closely than human drivers can do. Platooning reduces aerodynamic drag, uses road space efficiently, and allows flexible convoy configuration. Platooning applies equally well to cars as to trucks. (Source: Institut fur Kraftfahrzeuge (ika), RWTH Aachen University)

incrementally and disruptively, and at the same time, cars and the business models that support them will evolve to meet the demands of future users [13].

Is a future like this so far-fetched? Autopilot was developed in 1912 and remains a staple for airline pilots and maritime captains. Sales of unmanned military aircraft and commercial drones are rapidly outnumbering piloted airplanes. Automation is increasingly utilized for safety, precision and efficiency including robotic surgery since the mid-1980's, and automated industrial machinery since the mid-1940s. Although we don't know exactly what the future holds for transportation, we do know that technology, connectedness, the Internet and evolving societal expectations will dramatically transform its character. ■

Acknowledgement

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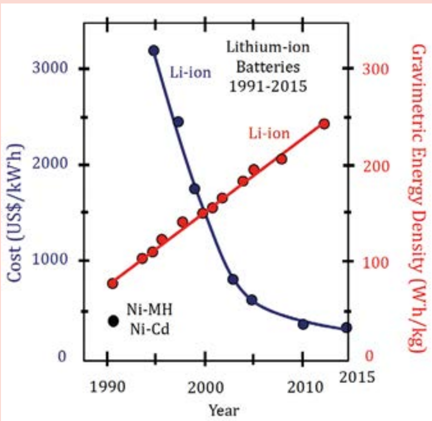
George, Elizabeth and Bryan teach the course Sustainable Mobility at University of Illinois at Chicago.

BOX: BATTERIES AT THE THRESHOLD

The battery is the dominant feature of electric vehicles. Its energy determines driving range, its power determines charging time and acceleration, its mass determines the energy required for driving, and its cost determines the price of the car. The ultimate success of electric cars depends on how much better batteries can become and how soon they can get there.

Dramatic improvements in the performance and cost of lithium-ion batteries (see figure) drove the personal electronics revolution. At their launch in 1991, lithium-ion batteries beat the next best batteries by a factor of two in gravimetric energy density (Wh/kg), and continued to improve steadily over the next 25 years by another factor of three. This factor of six in energy density enabled portable laptops, tablets and smart phones – imagine how limited, and less popular, these devices would be if they were six times larger and six times heavier. The cost reduction of lithium-ion batteries has been even more impressive than their performance increase, coming down more than a factor of ten since launch, and continuing to fall each year faster than projected.

Batteries for electric cars have more stringent criteria for mass-market acceptance than batteries for personal electronics. The batteries must be much larger to achieve acceptable driving range, much cheaper to make electric cars widely affordable, much faster charging to compete with gasoline car refueling, much longer lasting to match



▲ At their launch in 1991, lithium-ion batteries had twice the gravimetric energy density of Ni-metal hydride and Ni-Cd batteries, the best available at the time, and their energy density has improved an additional factor of three since. Cost has fallen even more impressively, by more than a factor of ten, and continues to decrease each year faster than projected. (Figure adapted with permission from (2).)

the lifetime of a car and much lighter to reduce the energy required for driving. Of these requirements, cost is the least challenging. As the figure shows, cost improves much faster than performance, and can be further reduced by improvements in manufacturing, such as those in gigafactories that promise to lower cost by an additional 30%. In contrast, the challenges of charging time, lifetime and weight reduction require fundamental science and technology advances in battery design that are beyond manufacturing and will be harder and slower to achieve.

Will lithium-ion batteries drive a transformation of mobility from gasoline to electric vehicles comparable to the personal electronics revolution? It seems clear that lithium-ion electric vehicles are here to stay and will compete with gasoline vehicles in high-mileage applications. For electric cars to replace gasoline cars across the board the way smart phones displaced land phones may require the next generation battery whose performance is several times better than lithium-ion, just as the performance of lithium-ion batteries is now several times better than its predecessors.

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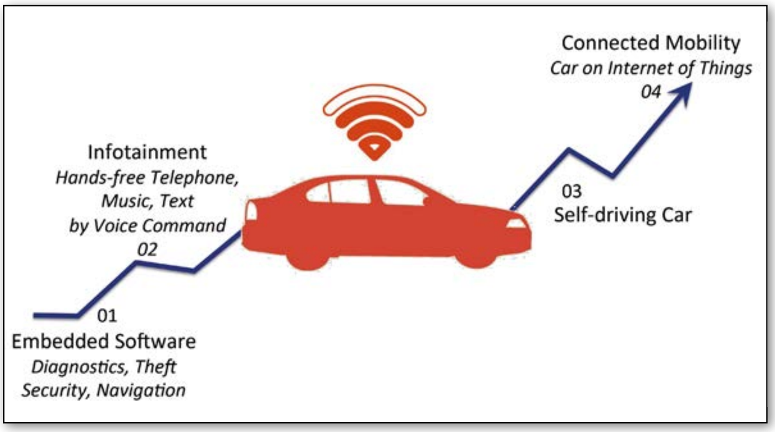

▲ **FIG. 5:** The evolution of the connected car, incorporating information into the driving experience in increasingly sophisticated ways. (Source: Authors).

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[Letter to the Editors]

Dear Editors,

In europhysicsnews 48/1, 2017, I read on page 30 that "nuclear energy is currently the only ready to use large-scale backup option for power production in an environment that is increasingly dominated by intermittent wind and solar power production". I consider this statement a political statement, not a scientific one, and I therefore dislike it.

History has taught us with Kytshtym (1957), Windscale (1957), Harrisburg (1979), Chernobyl (1986), Sellafield (2005), and Fukushima (2013) that nuclear power is no honest "option" if we hope for a longtime (centuries) survival of mankind on this planet. When you consult the internet concerning "Fukushima", you learn what I mean.

So why does "solar power" need a "backup option"? In Germany, during the 1980s, our president of the physical society Werner Buckel tried to convert us from nuclear to solar, but failed for political reasons: the Sahara was not considered a politically safe region.

Rudolf Kippenhahn, in his 1990 book "Der Stern, von dem wir leben", proved its feasibility on page 297. Similar words were expressed by our top physicist Freeman Dyson in 1999, in his monograph "The Sun, the Genome, and the Internet", on page 67. And an even more quantitative feasibility proof was published in Scientific American in December 2005 on pp.84-91, by William H. Hannum, Gerald E. Marsh, and George S. Stanford. Yet more recently, in 2013, Christoph Buchal, Patrick Wittenberg, and Dieter Oesterwind published 115 practical pages for German speaking people under the title "STROM".

We need no "backup option", I conclude, if we like life on Earth. ■

Wolfgang Kundt, Bonn University.

CAN SOLAR WATER-TREATMENT REALLY HELP IN THE FIGHT AGAINST WATER SHORTAGES?

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In the face of increasing global population, rising industrialization and the inescapable reality of climate change, the demand for access to clean, safe water has never been greater. Solar wastewater remediation technologies and solar water-treatment have the potential to contribute significantly towards affordable and sustainable solutions to this seemingly intractable problem. They do this by using solar energy to treat water from sources that previously would have been considered unsuitable for further use. In this article we reveal the basic principles surrounding the design and application of solar remediation reactors for urban wastewater treatment and reuse and then show how even simpler technologies are being used in low-income communities to provide affordable and safe potable water.

Solar technologies in urban wastewater treatment and reuse

Despite the fact that wastewater reuse is a strategy that is gaining wider acceptance and is rapidly expanding, there is still a number of issues to be tackled with respect to the presence of contaminants of emerging concern (CEC, *i.e.* chemical contaminants) in treated wastewater and their potential biological effects. The need to look beyond the conventional contaminants when assessing the hazards of wastewater reuse to ecosystems and to human health is now recognised as *a priorit*y issue in all policy areas at the EU level and beyond. CEC include pharmaceuticals and personal care products compounds, disinfection by-products, *etc.*, as well as their transformation products (TPs) originating during treatment through biotic/abiotic processes [1]. Moreover, the presence of antibiotic-resistant bacteria and resistance genes (ARB&ARG) in wastewater is another issue that should not be overlooked during wastewater reuse [2].

Conventional activated sludge currently applied in urban wastewater treatment plants (UWTPs) is inefficient in eliminating CEC, with their removal being highly variable [3]. Membrane bioreactors have been shown to be effective in removing only CEC susceptible to biodegradation. While the pores in microfiltration and ultrafiltration are too large to reject CEC, the lower pore sizes used in nanofiltration and also reverse osmosis, have been shown to effectively reject significant amounts of CEC. However, membrane technologies generate a residual stream, thereby creating a need for further proper management. Adsorption using activated carbon (AC) has been effectively used for the removal of CEC, but after reaching its maximum adsorption capacity, AC should be regenerated and further reused [4].

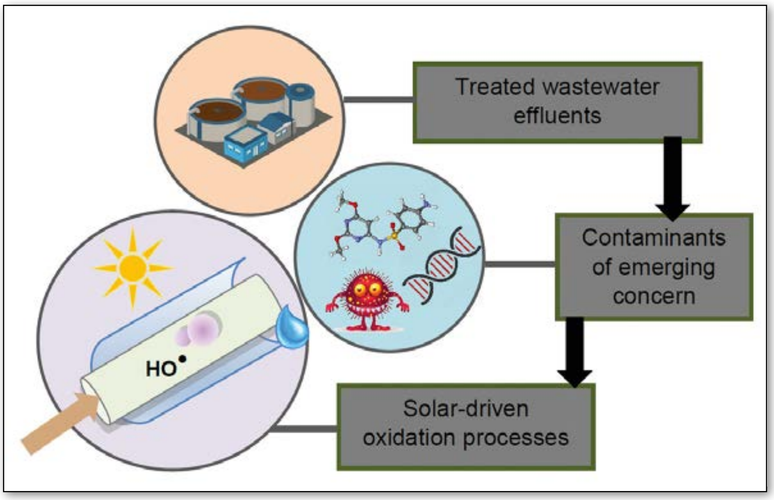
As an alternative, among the advanced oxidation processes, homogeneous solar-driven oxidation processes have experienced popularity over the past few decades in pilot-scale applications for the removal of CEC, including ARB&ARG, present in urban wastewater due to their environmentally friendly application and the prospect of operating under natural solar irradiation hence, lowering the operation cost considerably. Their high efficiency in degrading recalcitrant CEC, while also providing disinfection of the wastewater, is illustrated by the number of studies published in the scientific literature [5]. The optimization of the catalyst and oxidant doses during solar photo-Fenton (which can be summarised briefly as two reactions, *i.e.* first hydrogen peroxide reacts with Fe^{2+} forming hydroxyl radicals HO· , Fe^{3+} and HO^-; and second, in the presence of UV-visible radiation, $Fe3^+$ ions produced in the previous reaction are photo-catalytically converted to Fe^{2+} with the formation of an additional hydroxyl radical leading to hydroxyl radical generation from hydrogen peroxide) renders the process capable of rapidly removing CEC. The majority of the studies revealed that pH 2.8 is the optimum pH for the photo-Fenton process, while some others showed a positive trend for broadening the process operation pH up to mild neutral conditions, removing thus the burden of the economic limitation of the process associated with the chemical cost for pH rectification. Also, solar/H_2O_2 oxidation upon its proper optimization was shown to be effective in removing CEC and ARB from urban wastewater [6]. It is noteworthy that a number of TPs may be formed during the application of solar-driven oxidation, while in some cases bacteria have the potential to recover from sub-lethal oxidative stress and induce repair mechanisms. Nonetheless, these can be overcome by conducting prolonged oxidation.

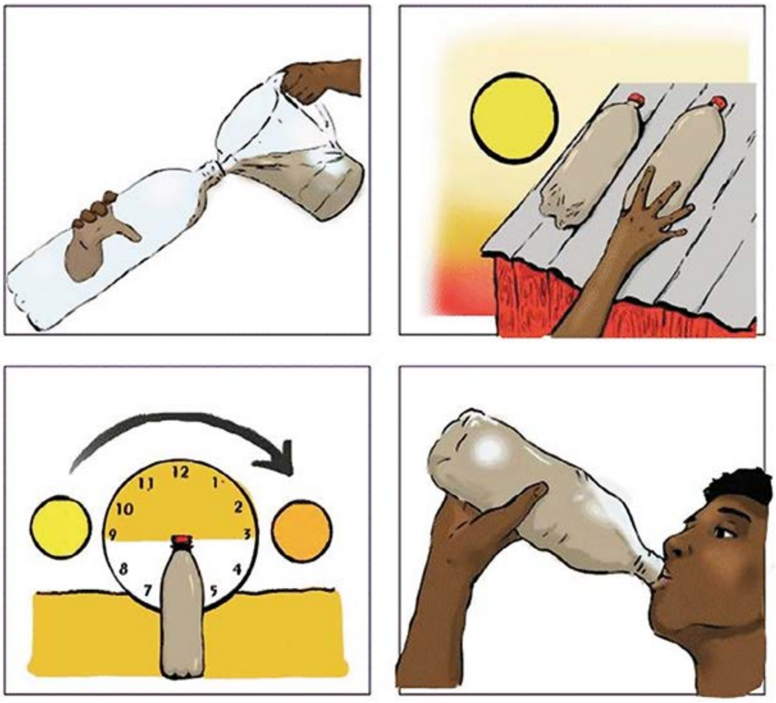
In summary, solar-driven oxidation technologies, upon their optimization, are promising treatment strategies for the removal of CEC, including ARB&ARG, from urban wastewater. Important aspects, such as oxidation time, should be taken into consideration during the application of such processes, in order to ensure both effective removal of CEC and cause permanent damage to susceptible bacteria. Nonetheless, there is a number of knowledge gaps and open questions related to the potential effects that the wastewater reuse practice might induce with regard to the CEC and their TPs. Knowledge on the risks that relate to low-dose exposure of CEC to non-target organisms, crop uptake and the additive and synergistic behaviour of various CEC/TPs in mixtures is only now starting to shape. The European COST Action ES1403 NEREUS http://www.nereus-cost.eu and the H2020-MSCA-ITN-2015/675530 (ANSWER) project http://www.answer-itn.eu address various of these important issues.

Solar Water Disinfection

Solar water disinfection, or SODIS as it is more commonly known, is a water treatment technique used in many low-income countries to make biologically-contaminated water safe for drinking. SODIS is often used by rural communities in those parts of the world with abundant sunlight and without realistic hope of access

▼ FIG. 1: Solar-driven oxidation can be successful in the removal of contaminants of emerging concern present in urban wastewater (Diagram shows a wastewater treatment plant, where the treated effluents are contaminated among others by contaminants of emerging concern. As an alternative to standard technologies, solar AOPs generating hydroxyl radicals are proposed to oxidise these contaminants).





▲ FIG. 2: Solar Water Disinfection instructional poster which was designed for use in areas of low literacy.

▼ FIG. 3: Ugandan primary school children bring their water to school to be solar disinfected.

to municipally treated distributed water. The technique is deceptively simple. Water is collected from the usual source and then stored in transparent containers, such as glass or plastic bottles, which are then placed in direct sunlight for a minimum of 6 hours. The microbes which cause waterborne diseases are inactivated by the small amount of solar UV-A light, which is transmitted through the container wall. In addition, DNA repair processes which the microbes use to repair the damage caused by the incident photonic energy, are inhibited by the elevated water temperatures (up to 55 °C), which are generated within the bottles thanks to a mini-Greenhouse Effect.

Since its resurgence in the early 1990s, SODIS has been demonstrated to be effective against all of the most important waterborne pathogens and especially those associated with diarrhoeal diseases such as dysentery, salmonella, cholera, gastro-enteritis, hepatitis A, *etc.* [7]. Outside of the solar simulation laboratory, human studies conducted in cooperation with rural communities in Sub-Saharan Africa have shown that children who use SODIS-treated water have lower rates of diarrhoeal disease with incidence of dysentery observed to reduce by between 25%- 50%. One retrospective [8] showed that Maasai children that had been using SODIS in a rural area of Kenya that experienced an epidemic of cholera in 1997, were seven-times less likely to experience a case of cholera than those households that have been relying on usual practices.

The benefits of such solar-based water treatments extend far beyond reduction in childhood disease rates. Studies in Kenya in 2011 [9] showed that children using SODIS-treated water were on average 0.8 cm taller at the end of the 12-month study than children relying on untreated water. Pupil absences in rural Ugandan primary schools children was observed to reduce from 0.9 to 0.2 days per semester [10]. Finally, the use of water treatment, such as SODIS, improves family finances since care-givers are free to participate in income-generating practices, while funds previously used for medicine and patient transport to clinics, become available for other purposes.

Although solar water disinfection is used to provide safe water to marginalised and vulnerable communities in more than 50 low-income countries across the globe, major obstacles to further uptake remain, such as the small treated volume (2L max) afforded by most transparent bottles. The EU Horizon 2020 WATERSPOUTT project (see www.waterspoutt.eu) is addressing this issue by designing and piloting a variety of affordable large volume solar based water treatment technologies.

Simple solar technologies for low-income communities

If we examine SODIS technology critically some technical limitations are quickly evident. The small volume of water bottles (typically 2-3 L) limit the total volume to be treated although the user can use as many bottles as they wish. Process efficiency depends on a range of environmental parameters including solar irradiance (which, in turn, depends on latitude, time of day, and atmospheric conditions), organic loading turbidity of the water, and the load and nature of the microbial contamination, which affects the time required to reach a certain disinfection level as different microorganisms have different sensitivities to solar disinfection. There are also some questions about the safety of using plastic bottles exposed to sunlight for prolonged times regarding potential leaching of chemical derivates [11]. Furthermore, SODIS is user dependent in terms of the treatment time and there is no quality assurance for the process. Compliance with the recommended protocol can also be a major issue [9].

Recent research has revealed a number of ways to overcome these technical drawbacks or to enhance the conventional SODIS process. These enhancements centre on one or more of the following considerations: (1) maximizing the solar energy collection in the polluted water, (2) accelerating the microbial inactivation efficacy, especially when resistant waterborne pathogens are present; (3) increasing the total volume of treated water provided by a solar system for a given solar exposure time; (4) automating the solar technology to avoid user- and weather-dependence; and (5) finding a compromise between cost, durability and efficiency of the technology.

In this sense, the main design developments in recent years are low-cost solar reactors for SODIS deployment [12]. These systems favour the collection of global solar UV radiation, using compound parabolic collectors (CPCs). CPCs are low-concentration collectors which were used initially for thermal applications and combine some characteristics of parabolic trough concentrators and flat stationary systems. Due to their shape, CPC mirrors collect solar radiation in static conditions with a high collection rate of solar diffuse-radiation. They use non-imaging optics to concentrate solar radiation into a diffuse focus and distribute solar radiation homogeneously into the photo-reactor (where the water is to be disinfected). Hence CPCs permit a highly efficient use of the solar photon flux in the water by utilising both diffuse and direct solar radiation even on cloudy days. CPCs are static collectors, which maintain a constant concentration factor (CF = 1) for all values of sun zenith angle within the acceptance angle limit. Solar CPC mirrors are usually manufactured from anodized aluminium to improve UV collection, as its reflectivity in the UV spectrum is high, ranging from 87% to 92% depending on surface aging. This material is also highly resistant to the environmental conditions. These characteristics make CPC-based solar reactors more efficient and less-dependent on ambient weather conditions for water disinfection. Another advantage of solar exposure in CPC reactors is the increased water temperatures achieved. These thermal effects accelerate the solar disinfection performance by the enhanced mild heat (*i.e.* up to 50-60°C) provided during solar exposure using these collectors [13,14]. The use of solar flow CPC reactors allows us to maximize the solar dose and can include UV feedback sensors for automated control [15]. Current research on SODIS-based reactors for drinking water disinfection carried out within WATERSPOUTT

◂ **FIG. 4:** Solar CPC reactor for solar water disinfection. CPC shape with ray tracing at different solar times (left) and photo of a CPC mirror (right).

▾ **FIG. 5:** View of several solar CPC reactors with different design concepts installed at Plataforma Solar de Almería, Spain.

H2020 project will help the deployment of solar water disinfection for low-income and vulnerable communities, with the expectation of providing low-cost and effective solutions to disinfect fresh or collected water (*i.e.* harvested rainwater) to improve water quality at household level.

Concluding remarks and future directions

In summary, solar applications for the treatment and remediation of water from a wide variety of sources and for numerous end-use purposes, is a topic of great interest and exciting developments. Water is a fundamental component of life and is an essential requirement in industry. As global warming progresses, and access to water becomes a greater source of conflict it is encouraging to think that solar treatment can provide a solution to both the technological and socio-political challenges that lay ahead. ■

About The Authors:

Pilar Fernández-Ibáñez is Lecturer at Ulster University (UK, 2017), after being Senior Researcher at Plataforma Solar de Almería of CIEMAT (Spain, 2003-2016) and head of the Solar Treatment of Water Unit. Pilar is an expert on solar technologies for water purification with wide experience in advanced oxidation processes for the removal of microbiological pathogens and hazardous chemical contaminants from water, using solar reactors. Her research focuses on real field applications of solar technologies for drinking water, wastewater disinfection and irrigation reuse of treated wastewater. Pilar has participated in 16 EU research projects in this area, has 120 peer-reviewed scientific publications and 150 conference publications.

Kevin G. McGuigan is an Associate Professor of Medical Physics at the Royal College of Surgeons in Ireland. He received his BSc from Maynooth University (1985) and both his PhD (1989) and his DSc (2013) from Dublin City University. His research specializes in running field studies to evaluate solar water-treatment technologies in low-income countries and he has completed such studies in Uganda, Kenya, Zimbabwe, S. Africa and Cambodia. He currently coordinates the €3.6M EU Horizon 2020 WATERSPOUTT Project (contract 688928, see http://www.waterspoutt.eu) in which 18 partner organisations across European and African countries are developing new solar water-treatment technologies which will be piloted in Malawi, Ethiopia, Uganda and S. Africa. He has published more than 60 peer-reviewed papers and is a fellow of the Institute of Physics and the Royal Society of Chemistry.

Despo Fatta-Kassinos is an Associate Professor at the Department of Civil and Environmental Engineering, and the Director of Nireas-International Water Research Center, of the University of Cyprus. Her research focuses on the understanding of the fate and behaviour of contaminants of emerging concern during advanced biological and chemical oxidation wastewater treatment. She serves as Editor of the Journal of Environmental Chemical Engineering (Elsevier), and she is the Chair of the COST Action ES1403 (NEREUS), and the project coordinator of the ANSWER project (H2020-MSCA-ITN-2015/675530 with a budget of €3.7M). She has over 120 peer-reviewed scientific publications, 100 conference publications, and she has co-edited various environmental books published by Springer.

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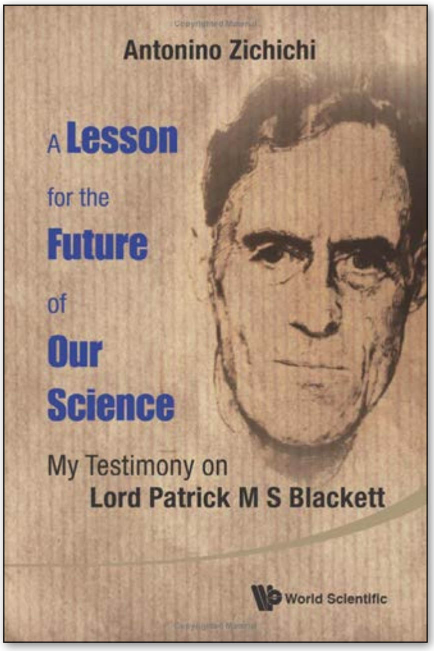
A LESSON FOR THE FUTURE OF OUR SCIENCE

MY TESTIMONY ON LORD PATRICK M.S. BLACKETT

P.M.S. Blackett was an extraordinary man who led an extraordinary life: a Nobel Prize winning physicist for his work on cosmic rays; Chief Scientific Advisor to the Admiralty during the Second World War; President of the Royal Society, a natural-born leader who played a major part in the creation of the European Organization for Nuclear Research (CERN) in Geneva and the Ettore Majorana Foundation and Center for Scientific Culture (EMFCSC) in Erice, Sicily.



A Lesson for the Future of Our Science - My Testimony on Lord Patrick M S Blackett
Author: Antonino Zichichi
ISBN: 978-981-4719-67-4
Price: 57,60 €

Given his patrician demeanor, it was almost inevitable that he would be elevated to the House of Lords – all this while being an outspoken advocate for left-wing causes.

Blackett also had an extraordinary student, Antonino Zichichi, currently emeritus professor of physics at the University of Bologna.

First and foremost Professor Zichichi is known as one of the world's leading experimental high-energy physicists responsible for numerous ground-breaking discoveries about the subatomic world. He is also one of the world's leading advocates for physics. By tirelessly engaging with the general public as well as with the decision-makers and politicians, he has ensured that physics occupies a prominent position in our scientific culture and in society.The existence of the big science projects in Europe such as the Large Hadron Collider at CERN in Geneva, the DESY accelerator in Hamburg and the Gran Sasso Laboratory in Italy, owe a great deal to Zichichi's advocacy and involvement.

He is Founder and Director of the EMFCSC, which is a magnet for the world's top physicists. I have met more Nobel Laureates in Erice than in the rest of the world put together. 2014 marked the 50th anniversary of the Centre and over the years Zichichi has generously hosted dozens of Imperial College faculty and students, so we were happy to welcome him to Imperial College to tell us all about his experiences with Blackett.

Blackett was one of Imperial College's most distinguished academics after whom the Physics Department Blackett Laboratory is named. He was, in fact, Department Head from 1953-1963. As one of his former students, Zichichi holds Blackett in high regard and you will find in Erice the Blackett Lecture theatre where the best students of the Erice School receive the Blackett Diploma. His talk was entitled "My testimony on Lord Patrick Blackett."

Zichichi's book of the same title was a result of this visit.

It is a wonderful collection of reminiscences involving not only Blackett but many of the great minds and ground-breaking discoveries of twentieth century physics, as well as the early days of CERN and EMFCSC. My only complaint is that I found all the different typographical fonts (italics, boldface,…) and boxes to be a distraction. Others may disagree.

A fascinating sub-plot is provided by the "Blackett Effect". Contrary to the prevailing popular belief, Blackett demonstrated that the way to minimize U-boat attacks on Merchant Navy vessels in the Second World War was not to send them one-by-one but in convoys distributed in concentric circles.

The book is partly an autobiography also and the reader is fortunate that Zichichi has enjoyed such a rich and rewarding career. I particularly enjoyed the anecdotes involving Pyotr Kapitza, Bertrand Russell, Murray Gell-Mann and Abdus Salam.

One of the author's reasons for the book was to remind us all of Blackett's conviction that physicists should communicate to society the contribution of science to the progress of our civilization. Never before has this been more pertinent.

There is another, perhaps unexpected, motive for this testimony on Lord Blackett. Zichichi maintains that the Blackett effect led to the liberation of Sicily in 1943 averting two years of further tragedy and destruction in that region.

This book deserves to be widely read.

Michael Duff,
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