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Data Analysis: a (not so) silent revolution

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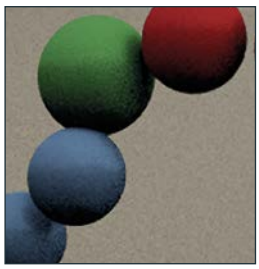
spontaneity of post-impact WTC towers collapse



▲ PAGE 24

Glass transition at interfaces

[EDITORIAL]

An open and peaceful world for Science

From several reports and podcasts it seems that Europe's leaders are not expecting a smooth ride in 2017 after a year marked by political upheaval, extremist attacks, unchecked immigration, and a rising military instability worldwide. Britain is struggling with its Brexit, America has inaugurated its new president with mixed reactions. With Antonio Tajani the European Parliament has also a new president.

Any criticism or failings of the EU will heavily weigh on him in a year of crucial national elections, such as in the Netherlands, France and Germany. According to EuroScience, 2016 was for science and scientists in Europe a challenging year as one is witnessing in many countries a political debate towards more focus on the short term. Indeed, research institutions, universities and scientists are under constraints because of increasing resources targeting towards innovation at the expense of fundamental research. But let's admit that the conduct of research and the dissemination of its results have undergone profound changes in the last decades. The enhanced digital technologies and the globalization of our society, the demand for accountable, responsive science that addresses the societal challenges increase the pressure towards open access for research results. This change of paradigm in the functioning of research has to be recognized with all the challenges that it generates for researchers and their institutions.

But, if you are tired of the bad news found in our 'Twitterworld', have a look at the Good News Network [1] to uplift yourself with positive things. Among 10 undeniable good things in 2016 you will read that the reported detection of Gravitational Waves ranks first. A wonderful scientific breakthrough, proving that Einstein was right!

Let's have a look back at some of the highlights of the EPS in the second part of 2016. Since October EPS has a new policy officer in its Brussels' office, Walter van Doninck, Belgian particle physicist recently retired from CERN. His role is to develop our point of presence in Brussels and interact with the European Commission (EC) and other stakeholders. To help with this task the newly created EPS Advisory Board on Science Policy (ABSP) met in December with Rolf Heuer, in his function as member of the European Science Advisory Mechanism (SAM). Also present was our new EPS president-elect Rüdiger Voss from CERN. Another step in the EPS engagement in Brussels is our participation to the new Open Science Policy Platform (OSPP) established to propose recommendations on Open Science Policy to the EC, following Commissioner Carlos Moedas' visions for Europe summarized by 'Open Innovation, Open Science and Open to the World'. The OSPP working members met already twice in 2016. EPS will continue its collaboration with the European Association for Chemical and Molecular Sciences (EuCheMS) and is preparing a joint workshop on 'Solar Energy for a circular Economy' for members of the European Parliament. Recently EPS submitted also its contribution to the Interim Evaluation of Horizon 2020 with a specific focus on the Societal Challenge `Clean, Safe and Efficient Energy´. Other relevant activities in 2016 include the 7th EPS Forum Physics and Society organized in London on 'Getting the Diversity Balance Right in Physics'. In November the Institute for Advanced Study in Princeton (USA) was formally celebrated as the second joint EPS-APS historic site, after the Einstein House in Bern in 2015. The EPS Young Minds programme with all its successful activities has kept growing in 2016, reaching about 40 sections in 21 countries. Worth mentioning is also the EPS Special Activity Fund aimed to finance projects on physics for development. One nice example is the assembling of solar kits for delivering light in remote areas of Morocco, a project presented at COP22 in Marrakech. Donations to this Fund are welcome.

Among 10 undeniable good things in 2016 you will read that the reported detection of Gravitational Waves ranks first.

Finally let me add that Europe will celebrate this year the 30th anniversary of the Erasmus+ Programme, which has enabled over three million students to spend time at another high education institution! Events all over Europe will mark this anniversary.

This being said, I wish all EPS individual members, national societies and associate members a very successful Year 2017 and let's hope for an open and peaceful world without dismissal of science. ■

Christophe Rossel,
EPS President

[1] http://www.goodnewsnetwork.org/

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EPS HISTORIC SITES

Uddmanska House

Kungälv, Sweden

On October 29, 2016, a ceremony took place to unveil an EPS Historic Site plaque at the pension where Lise Meitner and her nephew Otto Frisch stayed during the Christmas holidays in 1938. In discussions about recent experimental results from Berlin they realized that those data could only be explained by a process we know today as nuclear fission. The pension, now called the Uddmanska House, is located in Kungälv, near Gothenburg, Sweden. This is the latest EPS Historic Site.

By the end of 1938 physicists and chemists had accumulated a wealth of data on the effect of irradiation of nuclei with neutrons. Interpretation of these data were based on the assumption that such experiments result in more neutron-rich nuclei, which decay by beta-minus decay, thereby populating isotopes with one additional proton than the target nucleus. However, the data obtained by Italian, French and German groups did not fit together in a coherent picture and seemed to defy this assumption.

Such a situation is not uncommon in the history of physics and often preceded major scientific breakthroughs. At the time, new and better data, based on better chemical analysis of the radiation products, did not decrease the degree of confusion – on the contrary. This situation culminated when Otto Hahn and Fritz Strassmann managed to show that the irradiation of uranium with neutrons produced short-lived isotopes, which are chemically identical to Barium. Neither of them

▼ Unveiling of the plaque by the Chair of the Swedish Physical Society, Anne-Sofie Mårtensson.

was able to find an interpretation of this finding.

The solution to this problem came from an unlikely place – the small town of Kungälv, some 20 km outside of Gothenburg, Sweden. Here the Austrian physicist Lise Meitner and her nephew Otto Frisch spent their Christmas holidays in 1938, visiting Eva Bahr-Bergius, also a physicist and a friend of Lise Meitner.

Lise Meitner was one of the foremost physicists of her time in spite of the fact that she had to overcome many obstacles she faced as one of the first women in science at the time. She was only the second female PhD in physics at the university in Vienna and became the first female full professor of physics in Germany after she went to Berlin in 1907. Nonetheless she had an astonishing career and a reputation of a leading scientist in her field. Notably, Albert Einstein referred to her as "our Marie Curie".

In Berlin, Lise Meitner worked for decades with the chemist Otto Hahn and initiated experiments on the effect the irradiation of neutrons has on matter. The younger Fritz Strassmann, another chemist, joined them later.

In March of 1938 politics would break this scientific collaboration when the national-socialist Germany annexed Austria. Lise Meitner, an Austrian citizen of Jewish origin, had up to that point been protected from the racial laws in Germany by her nationality. Once this protection was gone, Lise Meitner had to flee from Germany and reached the neutral Sweden via Holland with the support of friends and colleagues, such as Niels Bohr.

Her situation in Sweden was not easy, and even though she found a position at the laboratory of Manne Siegbahn in Stockholm, she lacked the support to continue her work. Her former colleagues from Berlin kept her posted about their progress with letters and in November 1938 she met with Otto Hahn in Denmark, who was looking for guidance from someone who knew more about nuclear physics and could make sense of their results. Lise Meitner pushed them for more and better data from experiments, the results of which she received in a letter just in time to discuss them with her nephew on a walk in the snow-covered landscape around Kungälv. It was here that Lise Meitner and Otto Frisch came up with a radically different interpretation of the new results. By absorbing a neutron the heavy uranium nucleus gained sufficient energy to split into two fragments – a process they called nuclear fission and discussed it in terms of the liquid-drop model Niels Bohr had developed several years earlier.

▲ The plaque commemorating the discovery of nuclear fission in Kungälv, Sweden.

They also predicted that this reaction would release energy. This revolutionary approach, which was confirmed experimentally within a short time, became almost immediately common knowledge among the scientists.

The pension, where Lise Meitner and Otto Frisch stayed during their Christmas Holiday in 1938, Uddmanska Huset in Kungälv, became on October 29, 2016, a new historical site of the European Physical Society. This place is clearly associated with the birth of an idea that turned out to be one of the major scientific breakthroughs in the 20th century, and marks the place where a remarkable woman, in spite of many obstacles, improved our understanding of the nature of nuclei in a dramatic way. ■

Andreas Martin Heinz, Björn Jonson, and Imre Pázsit
Chalmers University of Technology, Gothenburg, Sweden

INAUGURATION AND FIRST BEAM OF PSI'S X-RAY FEL SWISSFEL

On December 5th PSI has inaugurated in the presence of the President of Switzerland Johann Schneider-Ammann the X-ray FEL facility SwissFEL after 4 years of construction. The facility consists of a low emittance injector, a 6 GeV linear electron accelerator, a string of 12 undulator magnets designed for FEL lasing at photon energies of up to 12.8 keV and the photon beamlines and end-stations. The SwissFEL building is located in a forest site nearby PSI. Its total building length is 740m. In the initial configuration SwissFEL is equipped with two end stations for user experiments dedicated for studies in photochemistry/photobiology, structural biology and condensed matter physics. First electrons were transported to the main electron beam dump on November 11th and very first lasing at a moderate wavelength of 24 nm was achieved on December 2nd. During 2017 the facility will be commissioned to nominal performance with first pilot experiments scheduled for fall'17. Regular user operation will commence 2018. In parallel the construction of a second FEL line dedicated for soft X-rays has been launched, which will be completed in 2020. ■

Hans-Heinrich Braun (PSI)

EPS HISTORIC SITES

Reale Osservatorio Vesuviano

Herculaneum (Naples), Italy

The first Volcanological Observatory in the World, home to Macedonio Melloni, Luigi Palmieri and Giuseppe Mercalli.

The Reale Osservatorio Meteorologico Vesuviano was founded in 1841 by Ferdinand II of Bourbon, King of the Two Sicilies. Located on the Salvatore Hill on the slopes of Mt. Vesuvius, at about 650 m of height, it was the first Volcanological Observatory in the World, built upon advice of several Neapolitan intellectuals, among whom Teodoro Monticelli, eminent scientist at the time. The Vesuvius Observatory has had eminent Scientists as Directors, who deeply influenced the history of Geophysics. These include:

- **Macedonio Melloni**, the first Director (1841), an eminent Physicist who discovered infrared electromagnetic radiation and its thermal effect. For this research he was awarded in 1835 the prestigious 'Rumford Medal'.
- **Luigi Palmieri** (1854), eminent Physicist mainly involved in studies concerning electromagnetism, who devised the first electromagnetic seismometer and discovered, for the first time, the presence of Helium on the Earth (1882).
- **Giuseppe Mercalli** (1911), eminent Seismologist and Volcanologist, Clergyman and Teacher, famous worldwide for his Earthquake Intensity Scale. Mercalli had as students Achille Ratti, who later became Pope Pius XI, and Saint Giuseppe Moscati.

▸ Luisa Cifarelli and Giuseppe De Natale, Director of the Osservatorio Vesuviano, after the unveiling of the EPS Plaque posed on the walls of the Reale Osservatorio Vesuviano.

▾ The Entrance of the Reale Osservatorio Vesuviano, founded in 1841.

Throughout the 20th century the Vesuvius Observatory maintained its leading role in Geological and Geophysical Research and fostered the emergence of quantitative Seismology and Volcanology in Italy. It coordinated the management of major crises such as the Irpinia Earthquake in 1980 and the 1969-1984 Campi Flegrei Bradyseism. Since 2000 it has become the Naples section of the National Geophysics and Volcanology Institute.

The Ceremony took place on May 23rd 2015, at the Old Building of Osservatorio Vesuviano just completely restored. The EPS Historic Site plaque was unveiled by Luisa Cifarelli, Chair of the EPS Historic Site Committee and past President of EPS, and Giuseppe De Natale, Director of the Osservatorio Vesuviano. Among the other authorities participating to the Ceremony there were, besides the whole Board of Directors of INGV, the President of CNR Luigi Nicolais, the Director of the Naples Zoological Station Vincenzo Saggiomo and the Campania Region Deputy for Civil Protection Edoardo Cosenza. The Ceremony included a piano concert by Fabrizio Soprano and a Modern Art exhibition *"THE WALK, Visitors and Vesuvians"*, organised by SVS Roma, ETH Zurich, HfG Karlsruhe, HfBK Hamburg, with Osservatorio Vesuviano, Soprintendenza Pompei e Parco del Vesuvio.

During the Ceremony, the President and Secretary of the old Chivalry Order Costantiniano di San Giorgio, the main Chivalry Order of the Bourbon Two Sicilies family, read a personal message of Congratulations sent by SAR Carlo II of Bourbon Two Sicilies, heir of Ferdinand II founder of the Observatory. Moreover, during the Ceremony was also unveiled the bronze bust of Giuseppe Imbò, Director of Osservatorio Vesuviano since 1935 to 1970. ■

■ **Giuseppe De Natale**
Istituto Nazionale di Geofisica e Vulcanologia Naples

Physics formulas on Leiden walls

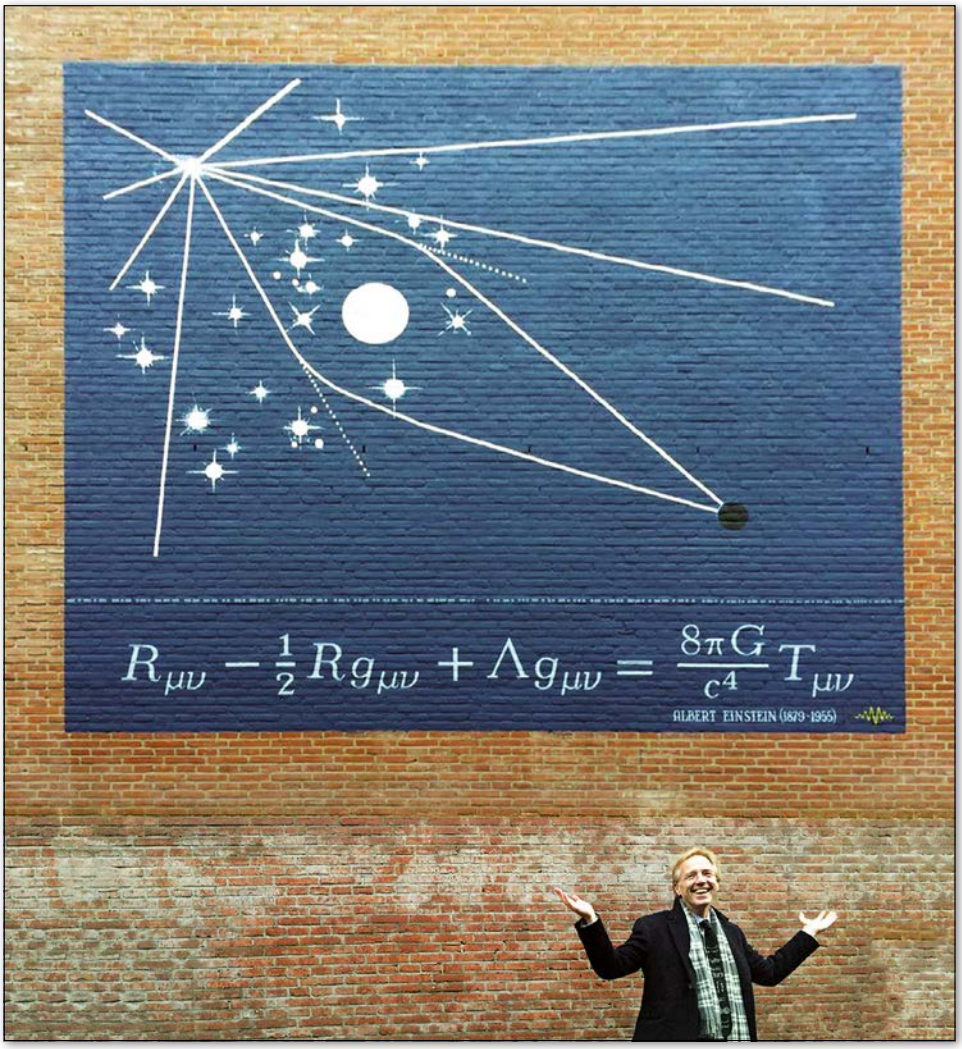
Since a couple of years visitors of the historical centre of Leiden in the Netherlands are treated to a cultural surprise. At several places in the city they can read a variety of poems in various languages, including Chinese and Russian, painted on walls.

This prompted physicists Sense Jan van der Molen and Ivo van Vulpen to propose a physics analogue. After all, Leiden is renowned for its science; think of people like Lorentz, Kamerlingh Onnes, Ehrenfest, Zeeman and Huygens, just to name a few. So why not put some key equations on the walls, and give the strollers some food for thought?

The idea was welcomed by the city and the university. The required funding was soon raised and before long the first wall formula was inaugurated on the 24th of November, 2015, by Robbert Dijkgraaf, professor at the University of Amsterdam and director of the Institute for Advanced Study in Princeton. Since then two more formulas have been painted on Leiden houses, as can be seen in the pictures.

This is just a beginning. Ten more formulas are in the pipeline, all of which have some relation with Leiden physicists. Perhaps this will inspire colleagues in other countries to follow the example. Decorating your city and making a bit of publicity for physics at the same time never hurts. ■

Jo Hermans



▲ Einstein's field equation, unveiled by Robbert Dijkgraaf in 2015 on the wall of the Boerhaave Museum (courtesy Hielco Kuipers)

▲ Snell's law of refraction (courtesy Erik Arends)

▲ The Lorentz force on a charge in a magnetic and an electric field (courtesy Erik Arends)

Pioneering SESAME light source circulates first beam

Allan, Jordan, 12 January 2017. A beam circulated for the first time in the pioneering SESAME synchrotron at 18:12 (UTC+3) yesterday. The next step will be to store the beam.

◂ The SESAME main ring.

This is an important milestone on the way to research getting underway at the first light-source laboratory in the Middle East. SESAME was established under the auspices of UNESCO before becoming a fully independent intergovernmental organisation in its own right in 2004. SESAME's Members are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority and Turkey. Its mission is to provide a world-class research facility for the region, while fostering international scientific cooperation. The first call for proposals to carry out research at SESAME was recently issued.

"This is a very proud moment for the entire SESAME community," said Professor Khaled Toukan, SESAME Director. *"SESAME is now opening for business."* SESAME, which stands for Synchrotron-light for Experimental Science and Applications in the Middle East, is a light-source; a particle accelerator-based facility that uses electromagnetic radiation emitted by circulating electron beams to study a range of properties of matter. Experiments at SESAME will enable research in fields ranging from medicine and biology, through materials science, physics and chemistry to healthcare, the environment, agriculture and archaeology.

Today's milestone follows a series of key events, including the establishment of a Middle East Scientific Collaboration group in the mid-1990s. This was followed by the donation of the BESSY1 accelerator by the BESSY laboratory in Berlin. A refurbished and upgraded BESSY1 now serves as the injector for the new SESAME main ring, which is a competitive third-generation light source built by SESAME with support from the SESAME Members themselves, the European Commission, CERN and Italy.

"This is a great day for SESAME," said Professor Sir Chris Llewellyn-Smith, President of the SESAME Council. *"It's a tribute to the skill and devotion of the scientists and decision-makers from the region who have worked tirelessly to make scientific collaboration between countries in the Middle East and neighbouring regions a reality."*

The first circulating beam is an important step on the way to first light, which marks the start of the research programme at any new synchrotron light-source facility, but there is much to be done before experiments can get underway. Beams have to be accelerated to SESAME's operating energy of 2.5 GeV. Then the light emitted as the beams circulate has to be channelled along SESAME's two day-one beam lines and optimised for the experiments that will take place there. This process is likely to take around six months, leading to first experiments in the summer of 2017.

In the meantime, scientists wishing to carry out research at SESAME are encouraged to submit their proposals following the procedure described at http://www.sesame.org.jo/sesame/component/content/article/85-uncategorised/440-cfp.html ■

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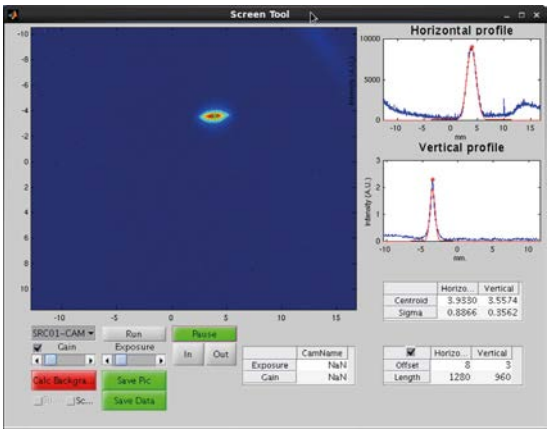


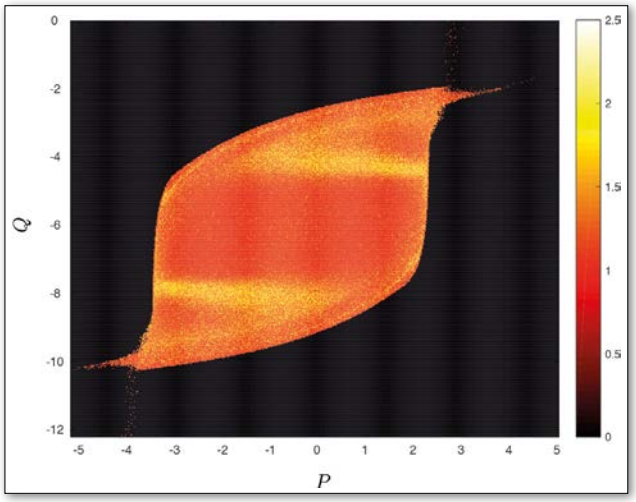
▾ The bright red spot on this display shows the passage of the first beam to circulate in the SESAME main ring.

Highlights from European journals

COMPLEX SYSTEMS

Structure-function clustering **in multiplex brain networks**

A key question in neuroscience is to explain how the brain's rich repertoire arises within relatively static anatomical networks: understanding the relationships between this structure and the 'functional' connections (inferred from the synchronisation of activity between brain areas) has the potential to address this. We employ a multiplex approach, in which anatomical and functional networks are analysed simultaneously. In particular,



▲ New multiplex structure-function clustering under variation of neural model parameters.

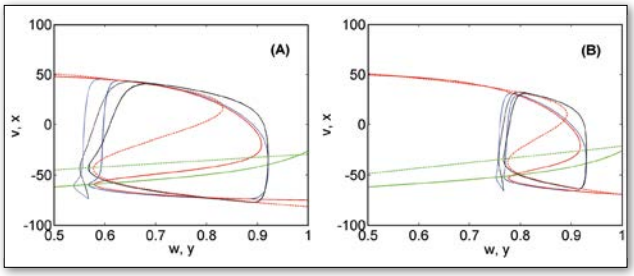
we consider a network describing the structural connectivity of the Macaque cortex, and a functional network derived from simulated neural activity. By comparison with single-layer approaches, our results provide the first demonstration that multiplex analyses of structure-function networks are better placed to capture emergent features of neural systems. Moreover, we propose a novel multiplex structure-function clustering measure that allows us to highlight the dependence of functional structure on the particular neural dynamical regime, and to characterise the emergent disparity between functional and anatomical networks. This divergence is fundamental to higher brain function - our new measure, that quantifies precisely this disparity, and our multiplex approach more generally, represents a new avenue towards understanding structure-function relationships at a more fundamental level. ■

▮ **J.J. Crofts**, **M. Forrester** and **R.D.O'Dea**, 'Structure-function clustering in multiplex brain networks', *EPL* **116**, 18003 (2016)

BIOPHYSICS

New neuron dynamics model better fitted **to the biological reality**

Scientists have now adopted a qualitative theoretical neuroscience model commensurate with actual measurements of neurons' dynamics



▲ The phase trajectories of the solutions for the simplified biologically relevant HH model and the scaled theoretical FHN model for neuron dynamics (black curve).

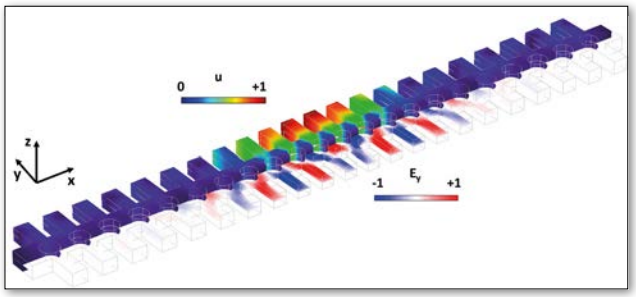
Neuroscientists are currently working diligently to understand the dynamics of thousands of coupled neurons. Understanding how they operate requires accurate models. The trouble is that each of the existing neuroscience models has its own shortcomings. The authors have, for the first time, developed an effective method for solving the equations of a well-known theoretical neuroscience dynamic model and make it more biologically relevant. These findings have just been published. They could not only help resolve problems in the neurosciences, but could also provide a deeper understanding of neuronal activity in the emerging sector of neurovascular dynamics, which describes the interplay between the brain's neurons and the blood flow. ■

▮ **E. B. Postnikov** and **O. V. Titkova**, 'A correspondence between the models of Hodgkin-Huxley and FitzHugh-Nagumo revisited', *Eur. Phys. J. Plus* **131**, 411 (2016)

OPTICS

Exploiting cavity optomechanics **for phonon lasing**

Phonon lasing in a mechanical resonator is a regime in which its oscillations are self-sustained, monochromatic, coherent and of high amplitude. The main limitations of conventional sources of coherent mechanical waves are that they are not self-sustained



▲ Mechanical and optical localized modes in an optomechanical photonic crystal cavity.

nor operate efficiently above a few tens of gigahertz. Phonon lasers overcome the former by definition, while the latter is one of the challenges being tackled to make a real technological impact. Phonon lasers based on optomechanical devices may provide a way out, where advances of nanofabrication techniques help push-up the frequency of the vibration modes that can be tailored and driven by radiation pressure forces, while integration into a high-quality optical cavity allows a dramatic increase of power efficiencies.

This work reviews several mechanisms and techniques that can drive a mechanical mode into the lasing regime by exploiting the radiation pressure force in optomechanical cavities. The authors pay special attention to circular microresonators and optomechanical photonic crystal cavities. The former were the pioneer optomechanical setups demonstrating phonon lasing action while the latter can be chip-integrated enabling straightforward connection to phononic waveguides or membranes for out-coupling the phonon lasing signal. ■

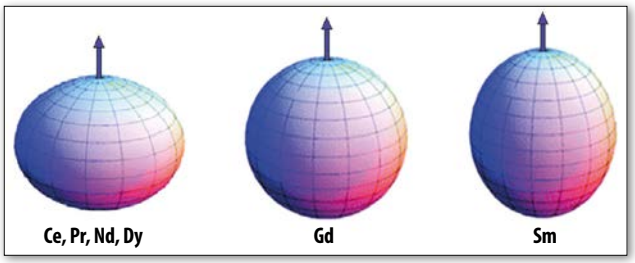
▮ **D. Navarro-Urrios**, **J. Gomis-Bresco**, **F. Alzina**, **N. E. Capuj**, **P. D. García**, **M. F. Colombano**, **E. Chavez-Angel** and **C. M. Sotomayor-Torres**, 'Self-sustained coherent phonon generation in optomechanical cavities', *J. Opt.* **18**, 094006 (2016)

MATERIAL SCIENCE

Pushing the boundaries **of magnet design**

New method to make permanent magnets more stable over time

For physicists, loss of magnetisation in permanent magnets can be a real concern. In response, the Japanese company Sumitomo created the strongest available magnet—one offering ten times more magnetic energy than previous versions—in 1983. These magnets are a combination of materials including rare-earth metal and so-called transition metals, and are accordingly referred to as RE-TM-B magnets. The authors have now been pushing the boundaries



▲ Representation of the magnetic anisotropy of single ions contained in the rare-earth components of the magnets in the study.

of magnet design, as published in a recent study. They have developed methods to counter the spontaneous loss of magnetisation, based on their understanding of the underlying physical phenomenon. They have now developed a simple additive-based method for ensuring the stability of permanent magnets over time, with no loss to their main magnetic characteristics. ■

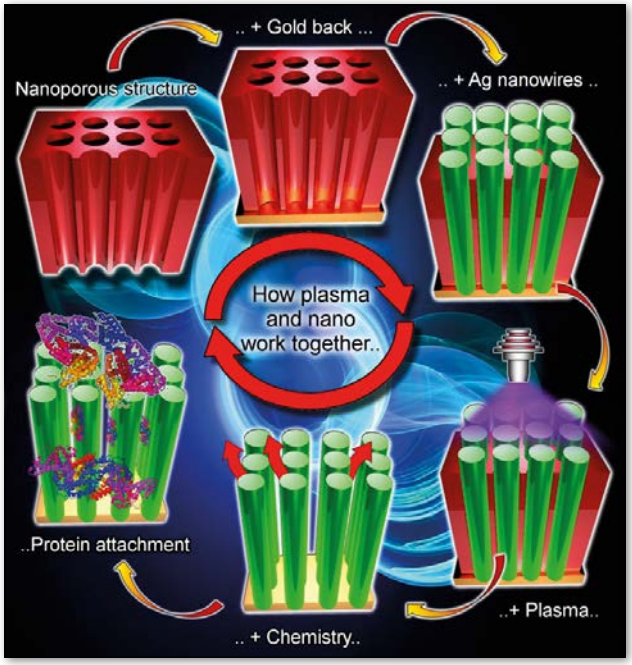
▮ **R.B. Morgunov**, **E.I. Kunitsyna**, **V.V. Kucheryaev**, **V.P. Piskorskii**, **O.G. Ospennikova** and **E.N. Kablov**, 'Giant effect of Sm atoms on time stability of (NdDy)(FeCo)B magnet', *Eur. Phys. J. Plus* **131**, 344 (2016)

PLASMA PHYSICS

Plasma and Nano put **novel biomaterials into life**

Low-temperature plasma, *i.e.* ionized gas produced by electric discharges in gas or liquid, is a powerful tool for fabricating novel biocompatible nanomaterials.

▼ Example of the sophisticated plasma+nano process: plasma and nano work together to produce biocompatible system of silver nanowires in nanoporous membrane.

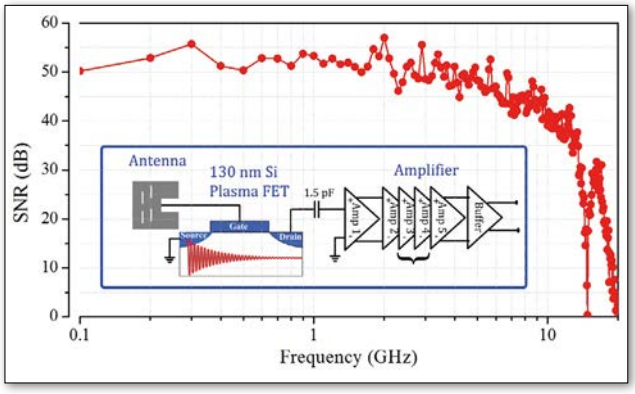


Typically, complex nanomaterials are produced using chemistry-based techniques. They are cheap and efficient, and could be further utilized to fabricate nanomaterials vitally needed for novel devices. However, emerging applications require a new generation of nanomaterials to boost their characteristics and occupy devoted application niches. The low-temperature plasma could play a pivotal role in the nanosynthesis of immense complexity. This review paper reveals advantages of approaches based on the plasma environment to fabricate nanoscaled biomaterials exhibiting very high biological activity, biological inertness, and other features of the biomaterials capable of making them highly attractive. Plasma-assisted fabrication of gold and silicon nanoparticles for bio-applications; carbon nanoparticles for cancer therapy; carbon nanotube-based platforms for enzyme production and bacteria growth control; and other applications of low-temperature plasmas in the production of biologically-active materials were discussed. The effect of plasmas have led to better results, as compared with the conventional neutral-gas based methods. ■

▮ **I. Levchenko**, **M. Keidar**, **U. Cvelbar**, **D. Mariotti**, **A. Mai-Prochnow**, **J. Fang** and **K. Ostrikov**, 'Novel biomaterials: plasma-enabled nanostructures and functions. Topical Review', *J. Phys. D: Appl. Phys.* **49**, 273001 (2016).

PLASMA PHYSICS

Silicon plasma wave receiver for terahertz wireless communication



▲ The signal to noise ratio (SNR) of the Si-CMOS receiver versus modulation frequency of the 300 GHz carrier. The inset shows the block diagram with the main components: the patch antenna, the plasma wave FET, with schematically shown damped plasma oscillations, and the integrated wide-band amplifiers chain.

This paper presents the design, manufacturing and characterization of an integrated circuit (IC) that uses the plasma oscillations phenomena in silicon nanotransistors (Si-CMOS) for the detection of a 300 GHz-carrier-frequency wireless signal. We present the strategies for a Si-CMOS-based, wideband, integrated circuit receiver comprising: (i) a physics based, specific plasma-wave-transistor design, allowing impedance matching to the antenna and the amplifier, (ii) a patch antenna engineered through a stacked resonator approach and (iii) a broadband amplifier that uses bandwidth enhancement circuit techniques.

The receiver rectifies a 300 GHz carrier frequency, with a flat and very wideband response, up to10 GHz. This is, to the best of our knowledge, the first demonstration of a low cost 130 nm Si-CMOS technology, plasma wave transistors based, fast and wideband integrated circuit receiver operating at 300 GHz atmospheric window. The results pave the way towards future large scale, and cost effective silicon-technology based, high data bit rate, terahertz wireless communication receivers. ■

▮ **S. Nahar**, **M. Shafee**, **S. Blin**, **A. Pénarier**, **P. Nouvel**, **D. Coquillat**, **A. M. E. Safwa**, **W. Knap** and **M. M. Hella**, 'Wide modulation bandwidth terahertz detection in 130 nm CMOS technology, *Eur. Phys. J. Appl. Phys.* **76**, 20101 (2016)

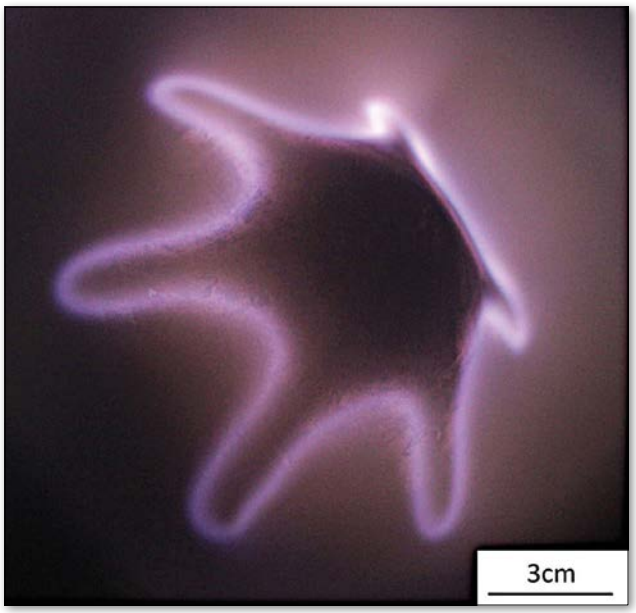
MATERIAL SCIENCE

New precision coating method for industrial granular material

Deposition of a thin film catalyst of a predicted thickness on the surface of novel hydrogen storage microbeads helps release hydrogen

As anyone who eats their cereal with milk in the morning knows: coating large volumes of granular material homogeneously is no mean feat. In a recent paper published by the authors, they have developed a new method, based on physical vapour

▼ Ignited plasma – starfish shaped racetracks.



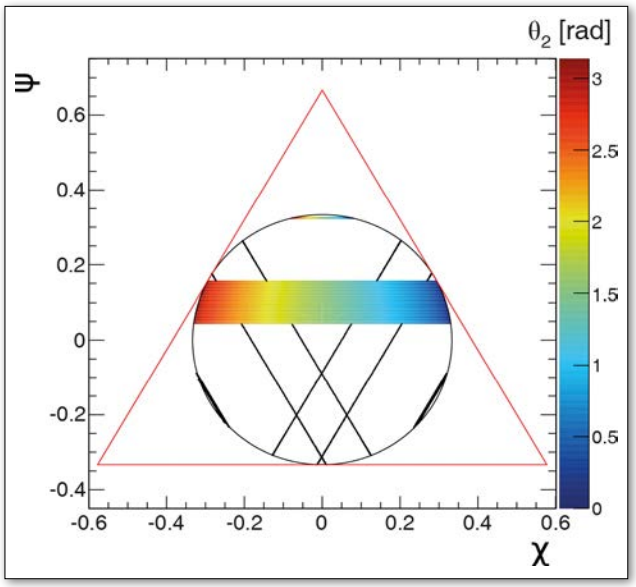
deposition, to upscale the quantity of coating without affecting the quality and homogeneity of the film. In this study, they also developed a model capable of predicting the film thickness. This represents a major step forward for industrial materials, as previous approaches relied on optical measurement after the coating had been deposited. Because this coating system is capable of implementing a plasma close to the granular substrate, it opens the door to new surface treatment and modification possibilities. Applications are expected for the many granular materials used in industry, including, for example, a novel hydrogen-storage system, which stores hydrogen in hollow glass spheres. Hydrogen stored in microbeads can be released by applying heat to the spheres. The new method helps meet the challenge of applying heat to the beads, thanks to a chemical reaction triggered by a catalyst, which is applied to the sphere's surface. ■

▮ **A. Eder**, **G.H.S. Schmid**, **H. Mahr** and **C. Eisenmerger-Sittner**, 'Aspects of thin film deposition on granulates by physical vapor deposition', *Eur. Phys. J. D* **70**, 247 (2016)

NUCLEAR PHYSICS

Breaking up: a convoluted drama at nuclear scale, too

Pursuing a detective's approach to carbon atom breakup yields clues relevant to fusion reactions and astrophysics phenomena



▲ Schematic distribution of the breakup

Regardless of the scenario, breaking up is dramatic. Take for example the case of carbon (^{12}C) splitting into three nuclei of helium. Until now, due to the poor quality of data and limited detection capabilities, physicists did not know whether the helium fragments were the object of a direct breakup in multiple fragments up front or were formed in a sequence of successive fragmentations. The question has been puzzling physicists for some time. Now, the authors have used a state-of-the-art detector capable of measuring, for the first time, the precise disintegration of the ^{12}C into three helium nuclei. Their findings, released in a study published recently, reveal a sequence of fragmentations, relevant to developing a specific kind of fusion reactions and in astrophysics. Their findings could have applications in devising an alternative to neutron-producing fusion reactions, a process called aneutronic fusion. In addition, they could help to improve our theoretical understanding of an extremely important reaction in astrophysics: the time-reversed process involving the fusion of three helium nuclei into ^{12}C.■

▮ **H.K. Laursen**, **H. O. U. Fynbo**, **O.S. Kirsebom**, **K.S. Madsbøll** and **K. Riisager**, 'Complete kinematical study of the 3α breakup of the 16.11 MeV State in ^{12}C', *Eur. Phys. J. A* **52**, 271 (2016)

HISTORY

The 1950s: the decade in which gravity physics became experimental

Experimental tests from a hundred years ago compare the gravitational accelerations of different kinds of material.

In the 1950s and earlier, the gravity theory of Einstein's general relativity was largely a theoretical science. In a new paper published recently, the author shares a historical account of how the experimental study of gravity evolved.

▼ Experimental tests from a hundred years ago that compare the gravitational accelerations of different kinds of material

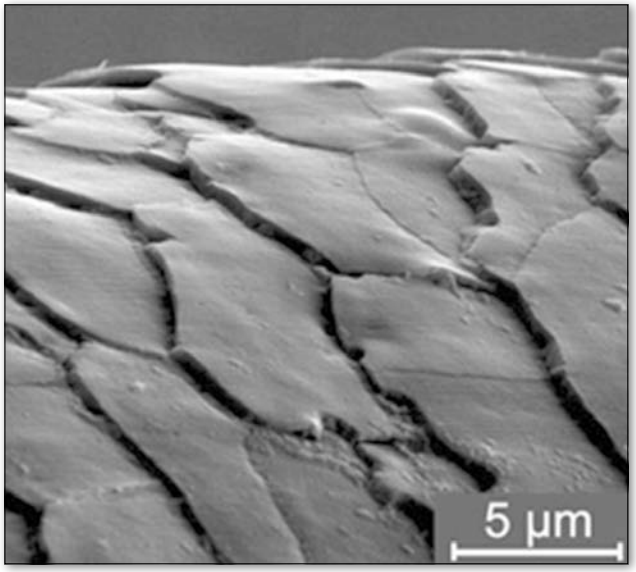
This review examines the broad range of new approaches initiated in the late 1950s, following through to the transition of experimental gravity physics to become a normal and accepted part of physical science in the late 1960s. Highlighting the importance of advances in technology in changing the lines of investigation in the field, it also emphasises the need for physical theories to be empirically tested, because experience shows that this can yield surprising results. In this context, the review examines the role of scientists such as the US physicist Robert Dicke in changing the former perspective. At that time, Dicke made the mid-career decision to lead a research group dedicated to the experimental study of gravity, following new research directions inspired by old arguments associated with Ernst Mach and Paul Dirac. ■

■ **P.J.E. Peebles**,
'Robert Dicke and the naissance of experimental gravity physics, 1957-1967', *Eur. Phys. J. H*, (2016) DOI:10.1140/epjh/e2016-70034-0

BIOPHYSICS

Nanoparticles hitchhiking their way along strands of hair

Massaging hair can help more quickly deliver nanoparticle-based treatment to the roots



▲ Corrugated hair surface.

In shampoo ads, hair always looks like a shiny, smooth surface. But for physicists peering into microscopes, the hair surface looks much more rugged, as it is made of saw-tooth, ratchet-like scales. In a new theoretical study published recently, the authors have demonstrated that massaging hair can help to apply drug treatment—encapsulated in nanoparticles trapped in the channels formed around individual hairs—to the hair roots. This is because the oscillatory movement of the massaging directs the way these particles are transported. This phenomenon was previously discovered in experiments on pork skin samples, which were conducted by Jürgen Lademann, dermatologist at the Charité clinic in Berlin, Germany, and his team. It is also relevant at the microscopic scale, in the transport on microtubules taking place in two directions between the cells within our bodies. By constrast, these findings could also help find ways of preventing harmful nanoparticles from being transported along hairs into the wrong places. ■

■ **M. Radtke** and **R. R. Netz**,
'Ratchet effect for two-dimensional nanoparticle motion in a corrugated oscillating channel',
Eur. Phys. J. E **39**, 116 (2016)

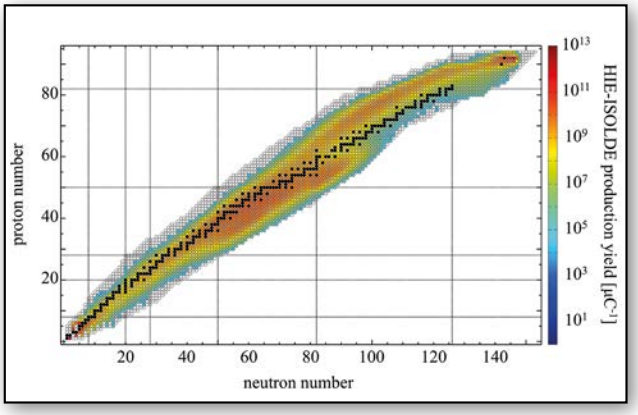
NUCLEAR PHYSICS

Unstable radioactive nuclei's dual traits study in open refereed paper

HIE-ISOLDE acceleration of radioactive beams to peer into the dual state of matter unique to nuclei.

Radioactive nuclides, found within an atom's core, all share a common feature: they have too many or too few neutrons to be stable. In a new review published recently, the authors explain how overcoming technical difficulties in accelerating such radioactive nuclei beams can help push back the boundaries of nuclear physics research. This fascinating topic is the first EPJ A paper to be subjected to an open referee process, whereby the referee's comments are included. The authors outline how the new CERN project HIE-ISOLDE will reach the energy levels needed to make two nuclei overcome the electric repulsion between them—referred to as the Coulomb barrier. This means that it will

▼ HIE-ISOLDE production yields.



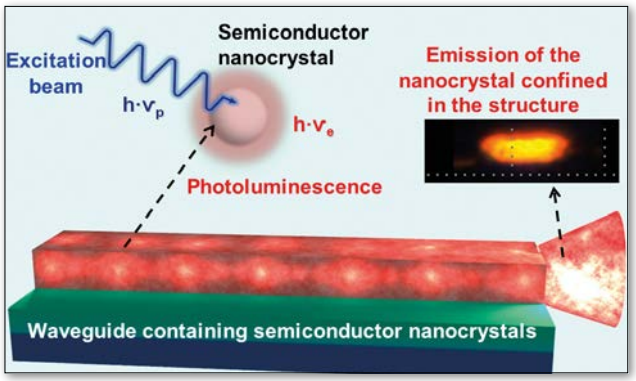
be possible to design experimental tools to explore both single-particle and collective degrees of radioactive nuclei freedom. This will improve our understanding of the unique duality in the degrees of freedom, which no other state of matter exhibits. Ultimately, physicists aim to have a "dial-a-radioactive-nuclei beam" of the same quality as stable nuclei beams. ■

■ **M.J.G. Borge** and **K. Riisager**,
'HIE-ISOLDE, the project and the physics opportunities',
Eur. Phys. J. A **52**, 334 (2016)

MATERIAL SCIENCE

Emergent gain materials **for active photonics**

Nowadays semiconductor nanostructures developed by colloidal methods have emerged as an alternative to the classical III-V semiconductors and rare earth technologies to provide active functionalities in photonic devices. Their outstanding optical properties include high absorption cross section, high quantum yield of emission at room temperature, or the capability of tuning the band-gap with the size/base material. As a consequence, these materials have been successfully applied in several fields, such as photodetection, amplification, generation of light or sensing.



▲ Example of an optical waveguide containing colloidal quantum dots. When the nanostructures are optically pumped the waveguide propagates and confines the photoluminescence. Above a certain threshold light is amplified.

For these purposes their solution process nature provides a cheap fabrication, and an easy incorporation on a broad range of substrates and photonic structures. This review summarizes the great effort undertaken by the scientific community to construct active photonic devices based on semiconductors fabricated by chemical methods. The work compares the performances demonstrated by semiconductor nanocrystals (colloidal quantum dots, quantum rods and quantum wells) with those provided by organometal halide perovskites, and describes their appropriate integration into photonic architectures (waveguides and cavities) to achieve stimulated emission. ■

■ **I. Suárez Alvarez**,
'Active photonic devices based on colloidal semiconductor nanocrystals and organometallic halide perovskites',
Eur. Phys. J. Appl. Phys. **75**, 30001 (2016)

CONDENSED MATTER

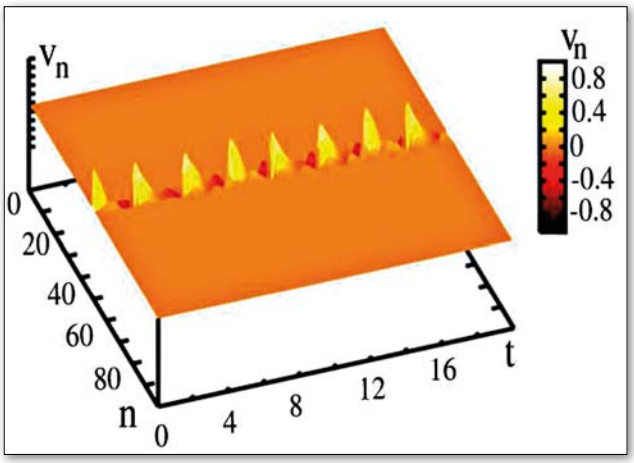
Supersonic phenomena, the key to extremely low heat loss nano-electronics

Supersonic solitary waves in nano-electronics crystals show potentials for electric charge or matter transport and energy storage with extremely low heat dissipation

Freak waves, as well as other less striking localised excitations, occur in nature at every scale. The current theory and models of such waves can be applied to physics and, among others, to oceanography, nonlinear optics and lasers, acoustics, plasmas, cosmological relativity and neuro-dynamics. However, they could also play a significant role at the quantum scale in nano-electronics. In a recent study, the authors performed computer simulations to compare two types of localised excitations in nano-electronics. Their findings, published in a recent study, confirm that such localised excitations are natural candidates for energy storage and transport. These, in turn, could lead to applications such as transistors with extremely low heat dissipation not using silicon. ■

■ **M.G. Velarde**, **A.P. Chetverikov**, **W. Ebeling**, **S.V. Dmitriev** and **V.D. Lakhno**,
' From solitons to discrete breathers',
Eur. Phys. J. B **89**, 233 (2016)

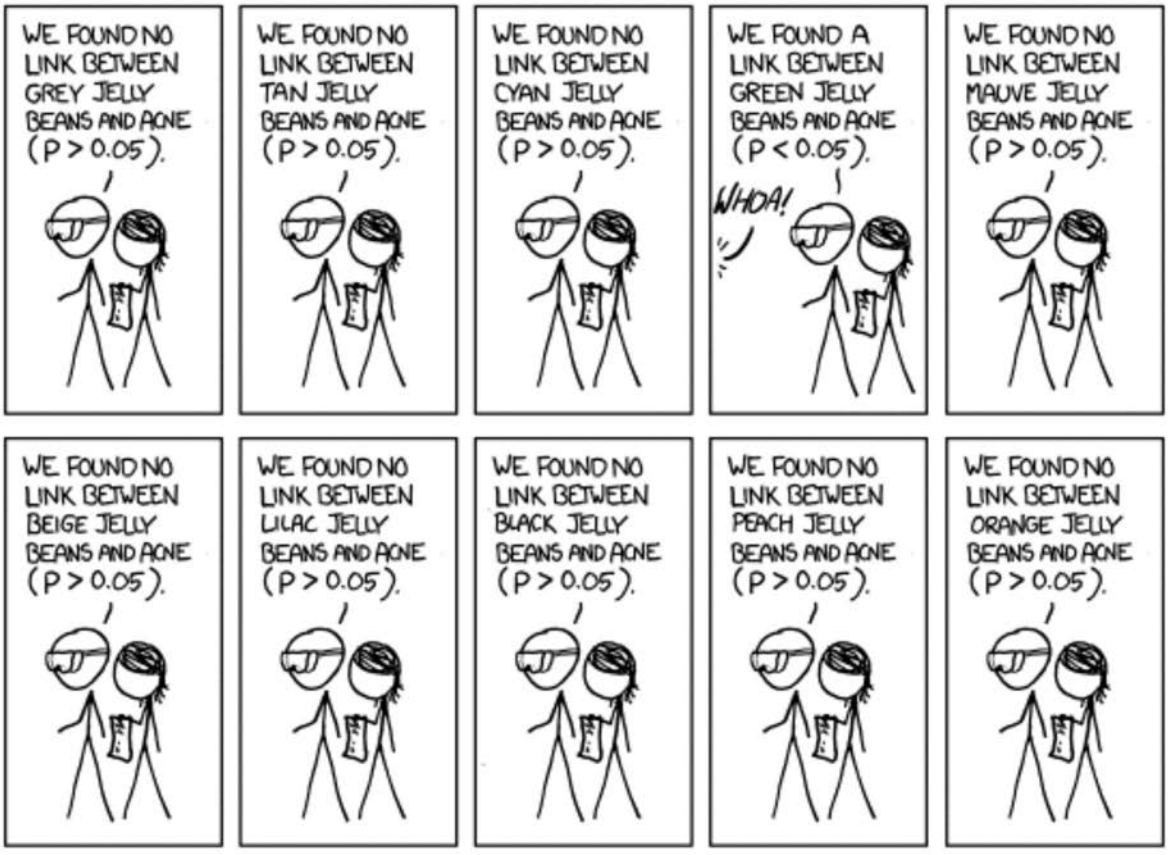
▼ Low-frequency pinned discrete breather when the on-site interaction largely overwhelms the inter-site force.



DATA ANALYSIS: A (NOT SO) SILENT REVOLUTION

Udo von Toussaint – Max-Planck-Institute for Plasmaphysics – 85748 Garching, Germany – DOI: https://doi.org/10.1051/epn/2017101

Good statistical practice is an essential component of good science. Unfortunately, in too many cases the analysis of experiments follows recipes taught already in introductory classes, sometimes even accompanied by misunderstandings about properties of statistical tests. One of these methods, significance tests based on p-values, was *the* widely accepted standard. So the warning by the American Statistical Association (ASA) against the use of p-values was thus a huge surprise to many. What were the reasons underlying this unique step?



Statistical reasoning...

It may have escaped the attention of most physicists that the recent statement [1] of the largest statistical organisation, the American Statistical Association (ASA), on the proper use of p-values sent shock waves through the community of statisticians. In a comment published in Science [2] the seriousness of the statement was even compared to a confusion of weight and mass in physics: *'Imagine the American Physical Society convening a panel of experts to issue a missive to the scientific community on the difference between weight and mass. And imagine that the impetus for such a message was a recognition that engineers and builders had been confusing these concepts for decades, making bridges, buildings, and other components of our physical infrastructure much weaker than previously suspected*'. However, even more surprising to many people was the large number of follow-up comments to the ASA recommendation, most of which supported the view that deficiencies of the concept of p-values have long been known and that the common practice with respect to hypothesis testing needs to be altered (see, *e.g.*, supplemental material in [1]). This may come as a surprise to many scientists who – almost by default – have been asked to provide p-values for suggested hypotheses.

To understand why the standard approach for assessing the validity of a new hypothesis has fallen out of favour it may be useful to recollect the concept of the p-value approach.

Testing a hypothesis using the p-value approach

The standard statistical approach to test a precise hypothesis follows the subsequent scheme:

1. Formulate a hypothesis H_0 (the 'null hypothesis')
2. Choose a test variable x of which the probability distribution (*i.e.*, the probability density function, pdf) $p(x|\ H_0)$ is known for the hypothesis H_0.
3. Choose an interval $[x_1,x_2]$ such that there is the probability α that x falls outside the interval: $P(x_1 \le x \le x_2) = 1 - \alpha$, with α commonly chosen as $\alpha = 0.05$
4. Perform an experiment measuring, *e.g.*, the data value x_m
5. Decide depending on the value of x_m: if $x_1 \le x_m \le x_2$, then accept the hypothesis H_0

else H_0 is rejected with significance level α.

The conventional procedure is illustrated in Fig.1. If the probability to observe x_m or values even more extreme is low (*i.e.*, below α) under the hypothesis H_0 then it is concluded that the hypothesis is unlikely. The underlying reasoning of the p-value approach is analogous to the familiar *proof by contradiction* [3]: One first assumes a hypothesis to be true but if a consequence of this hypothesis turns out to be false then the hypothesis can be rejected. In the p-value approach there are two critical modifications: a) the 'false' consequence is replaced by 'unlikely' consequence and b) the probability of any specific outcome $x = x_k$ is typically very small, such that every result would be significant. For that reason the integrated probability for the observation of x_m or even more extreme values is used ('tail probability'). Thus the p-value also depends on the probability of data which have not been observed, *i.e.*, in the present example all values of x with $|x| > x_m$.

So, given these apparently small differences from the logically sound approach of proof by contradiction, why then has it fallen out of favour, even to the extent that the comment of the ASA [1] states in No. 5: *'A p-value, or statistical significance, does not measure the size of an effect or the importance of a result.'*?

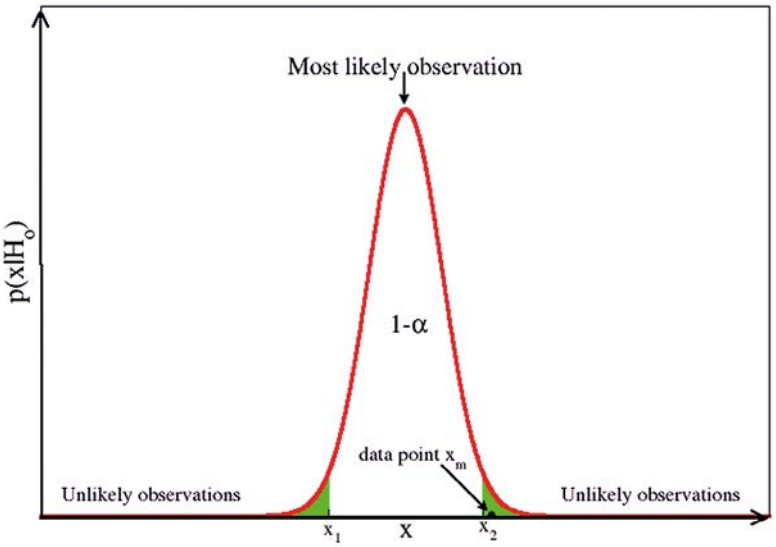
This can be better understood from a Bayesian perspective.

Bayesian model testing

Bayesian model testing is always based on the comparison of at least two different proposed models. There is no counterpart to the conventional significance tests which evaluate a model or hypothesis based on only a single model. The relevant probabilities are P(H|*data*) and P(*data*|H).

The posterior probability P(H|*data*) denotes the probability of the hypothesis H in the light of an observed data set data. More familiar is the probability P(*data*|H), the likelihood which describes the probability of the observables under the condition that the hypothesis H is true. It is important to note that these two probabilities are in general different. Consider, *e.g.*, P(red liquid| blood) *vs.* P(blood| red liquid). The probability of blood being a red liquid is close to one. However, the probability of a red liquid to be actually blood is much lower. A consequence of this is that maximum-likelihood estimates of parameters are only under very specific circumstances the most likely parameters given the data.

The Bayesian approach to model comparison simply computes the ratio of the probabilities for each model, which is given by the ratio of the likelihoods of the data



▼ **FIG. 1:** Hypothesis test scheme. Indicated is the probability density p(x|H) of the observation of x as function of x. The area of the shaded regions sums up to α. The data point at x_m would result in a rejection of the null-hypothesis with significance level α because the point is outside of the interval $[x_1,x_2]$.

under the models considered and the prior probabilities of the respective models, $P(H_i)$ and $P(H_j)$

$$\frac{P(H_i \mid Data)}{P(H_j \mid Data)} = \frac{P(Data \mid H_i)}{P(Data \mid H_j)} \times \frac{P(H_i)}{P(H_j)}$$

which can be derived in a straightforward manner from the elementary sum- and product rules of probability theory. This approach is also undisputed by the conventional statistics community if the prior probabilities are available. Taking this point of view it becomes evident where the problems of the p-value approach for statisticians are rooted:

Firstly: The significance test yields only P(*data*|H). However, the researcher is in practice interested in the probability of the hypothesis, given the data, P(H|*data*). Thus, in practice the significance levels are often incorrectly considered as probabilities of the hypothesis – despite all the warnings to the contrary of statistics experts. 'The null-hypothesis is rejected at 5% significance' is taken to mean the same as 'The null-hypothesis has only 5% probability to be true' [3].

Secondly, the p-value is based on the likelihood term only and neglects the prior contribution. This implies that the p-value measures whether an observed result can be attributed to chance under the null-hypothesis. However, the probability that the hypothesis is correct depends on how plausible the hypothesis was in the first place. If the a-priori probability for a hypothesis is 5% then a measured p-value of 0.05 (*i.e.*, a 'statistically significant' result) increases the probability of that hypothesis to be true by only 6%! [4]. If the a-priori probability of the hypothesis is larger, *e.g.*, 50% then the same result already implies a posterior-probability for the hypothesis of 71%. Thus, significance levels (p-values) can be a highly misleading measure of the evidence provided by the data against a null hypothesis [5,6,7].

This leaves us with the question: why was the p-value approach (apparently) performing not too badly in many cases? A possible explanation is the following: Hypothesis tests have often been performed when doubts about the null hypothesis were growing and reasonable alternatives became available. In that case the (implicit) prior ratio is approximately 1 and the likelihood of the alternative is larger than that of the original hypothesis, thus resulting in a similar outcome as the Bayesian approach (without the possibility of a quantitative measure of the model probabilities).

The third drawback – at least from a Bayesian perspective but also in practice – is the violation of the likelihood principle by the significance test [8,9]. *The likelihood principle* is implied by the generally accepted *sufficiency principle* [10] conditionally on the acceptance of a second principle, the *conditionality principle*: If two experiments on the parameter x, E_1 and E_2, are available and if one of these two experiments is selected with probability 0.5, the resulting inference on x should depend only on the selected measurement. This principle seems difficult to reject [11]. The violation of the likelihood principle introduces a dependence of the significance test result on unobserved data or stopping rules, which is criticized by Bayesian proponents [12, 13] because an evaluation based on the measured data only is not possible. A nice toy example of the induced problems has been given in [14].

The recommendations of the American Statistical Association conclude that in the view of *'the prevalent misuses and misconceptions concerning p-values, some statisticians prefer to supplement or even replace p-values with other approaches[...] No single index should substitute for scientific reasoning'*. This is now almost identical to the opinion of Fisher [15] – who introduced the p-value in the 1920s – already 90 years ago. He stated that *'the responsibility of forming correct scientific conclusions cannot be replaced by automated acceptance procedure'*. ASA's statement on p-values should thus be considered as an overdue start towards a more domain-knowledge-inspired and less entrenched approach to data analysis. ■

About the Author

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References

[1] R.L. Wasserstein, N.A. Lazar, *Am. Statistician* **70:2**, 129 (2016) DOI:10.1080/00031305.2016.1154108

[2] S.N. Goodman, *Science* **352:6290**, 1180 (2016)

[3] G. D'Agostini, *Bayesian Reasoning in Data Analysis*, World Scientific Publishing, Singapore (2003)

[4] R. Nuzzo, *Nature* **506**, 150 (2014)

[5] F. Davidoff, *Ann. Intern. Med.* **130**, 1019 (1999)

[6] S.N. Goodman, *Ann. Intern. Med.* **130**, 995 (1999)

[7] S.N. Goodman, *Ann. Intern. Med.* **130**, 1005 (1999)

[8] A. Birnbaum, *J. Am. Stat. Assoc.* **57**, 269 (1962)

[9] J.O. Berger and R.L. Wolpert, *The Likelihood Principle* (IMS, Hayward, CA), 2nd ed. (1988)

[10] V.S. Huzurbazar, *Sufficient Statistics* (Marcel Dekker, New York) (1976)

[11] C.P. Robert, *The Bayesian Choice* (Springer, Berlin) (1994)

[12] J.O. Berger and T. Sellke, *J. Am. Stat. Assoc.* **82**, 112 (1987)

[13] T.J. Loredo in *Statistical Challenges in Modern Astronomy*, edited by E. Feigelson and G. Babu (Springer, New York), p. 275 (1992)

[14] J.O. Berger and D.A. Berry, *Am. Scientist* **76**, 159 (1988)

[15] R.A. Fisher, *Statistical Methods and Scientific Inference* (Hafner, New York) (1956)

MECHANICS-BASED MATHEMATICAL STUDIES PROVING SPONTANEITY OF POST-IMPACT WTC TOWERS COLLAPSE

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DOI: https://doi.org/10.1051/epn/2017102

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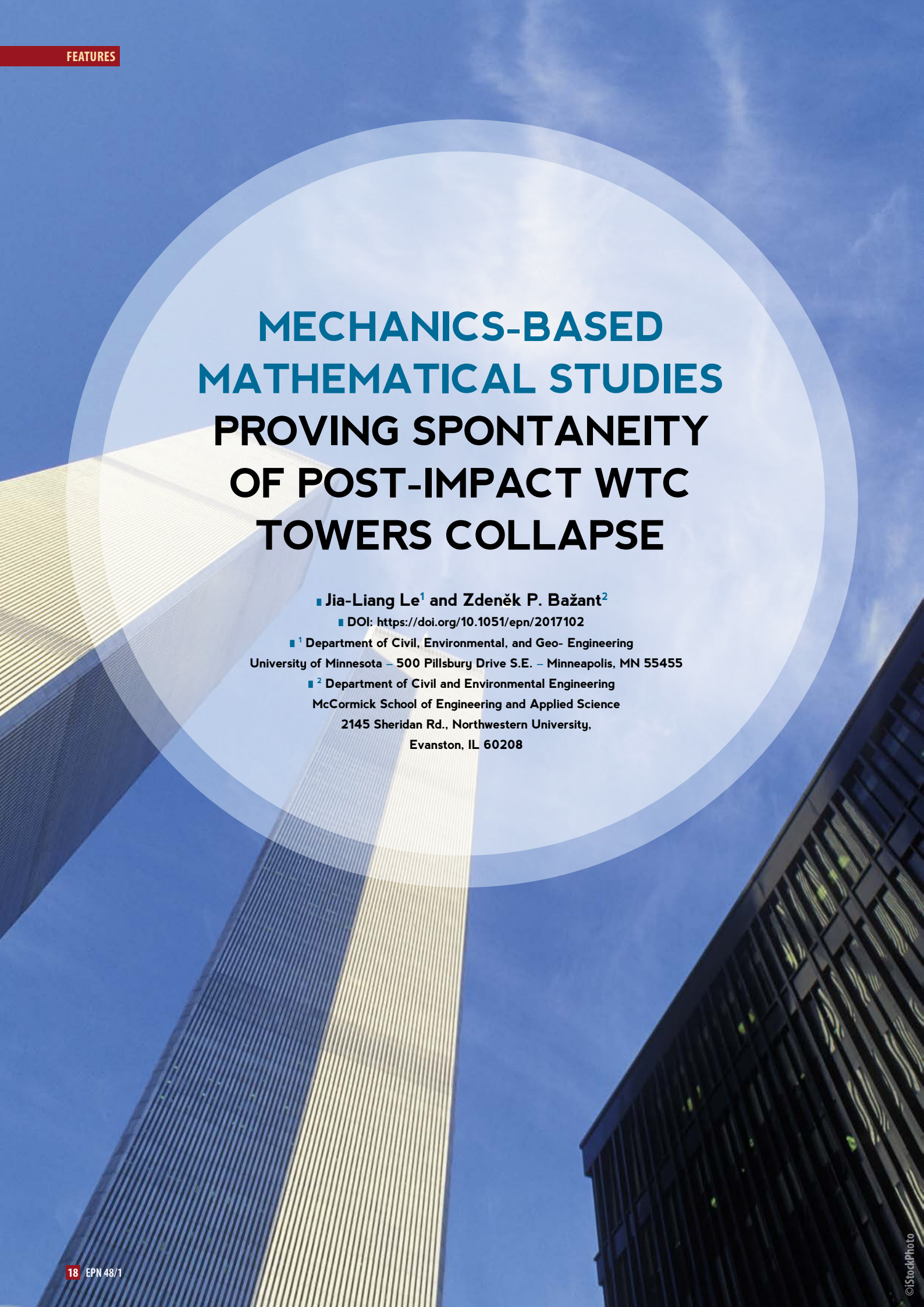


The cause of collapse of the World Trade Center (WTC) in New York on 9/11/2001, clarified mathematically by mechanical analysis, has been questioned by some lay critics without any meaningful calculations. They blame the collapse on controlled demolition, implying some sort of conspiracy. The present article summarizes the reasons why the collapse must have been spontaneous and an inevitable result of the aircraft impact damage and the subsequent fire, and how the collapse is explained by mathematical analysis based on mechanics and confirmed by all the available observations.

Previous Mechanics-Based Analytical Studies

The WTC towers were designed not to fail under the impact of an aircraft of almost the same size, and they did not fail. Their maximum horizontal deflections did not exceed 0.4 m, which is about one half of the deflection expected in a hurricane. The actual cause of collapse was an enormous fire that simultaneously engulfed three stories and caused viscoplastic buckling of steel columns, the thermal insulation of which was stripped during the impact and initial explosion of fuel [1].

The first simple analysis [2, 3], with a simple mathematical proof of the inevitability of collapse based on an approximate comparison between the kinetic and dissipated energies, was published soon after the collapse. This analysis was quite straightforward.

A detailed and more tedious mechanical model, published several years later, dealt with the entire collapse process [4, 5, 6, 7]. The results agreed with all the observations and showed that the progressive collapse must have been spontaneous, gravity-driven, and that after impact, no external weakening of the structure was needed to explain the collapse. Thes e results passed standard anonymous reviews in top journals and are generally accepted by the mechanics experts in ASCE, ASME, SES, Royal Society of London, IUTAM and in other reputable professional and scientific societies, as well as by the mechanics experts at the leading research universities.

Mechanism of Spontaneous Collapse Driven by Self-Weight

The main cause of the total collapse of the towers damaged by impact was a fire of enormous proportions (Fig. 1a and b). The simultaneous ignition of three floors was atypical. It differed from normal fires, which gradually spread from one place to the next and, when the next place is burning, the previous one has already burned out. This resulted in a slower release of heat and higher temperatures because the volume-to-surface ratio of fire zone was much greater than normal [1].

Furthermore, this atypical fire caused that most columns reached high temperatures almost simultaneously, rather than one column cooling down when another one is being heated. Although temperatures must have reached much higher, a mere half-hour of heating above 150 °C would have sufficed to cause marked viscoplastic creep of the structural steel used. This led to slowly growing lateral bowing of columns, which was documented photographically [1].

Meanwhile, the heating also caused a large thermal sagging of the steel trusses supporting concrete floors [1]. In consequence, many steel truss girders likely separated from the columns and beams, especially during the cooling phase. This is evidenced by photos of outward bowing of external columns [1]. It must have led to doubling, or even tripling, of the effective buckling length of some columns.

The buckling was aggravated by eccentricity of aircraft impact, which severed or damaged columns mainly on one side of tower [1]. With fewer columns functioning on one side, the individual columns on that side had to carry more than the average load of the remaining columns (and on the other side less than the average). After these columns buckled, the load on each of the remaining columns increased and caused them to buckle, too. Because of greater eccentricity of aircraft impact into the South tower, the resulting column overloads on one side were greater than those of the North tower. This agrees with the fact that the South tower collapsed earlier. The one-sided column overload is also confirmed by the observed tilt of the upper part of tower. That the observed tilt was mild is no surprise because calculations showed it could not have exceeded about 2.8° in the direction of impact eccentricity; see Eq. 7 in [3].

Compared to the conservative simplifying assumptions of the analysis that sufficed to prove the necessity of collapse, there were further aggravating factors:

1. initial impact damage to surviving (non-severed) columns,
2. stripping of column insulation,
3. the creep bowing of columns under prolonged heating,
4. increase of the effective length of some columns due to multi-story buckling,
5. the aforementioned one-sided column overloads,
6. creep growth of lateral deflection of bowing heated columns, and
7. loss of lateral supports of column ends by disconnected sagging floor trusses.

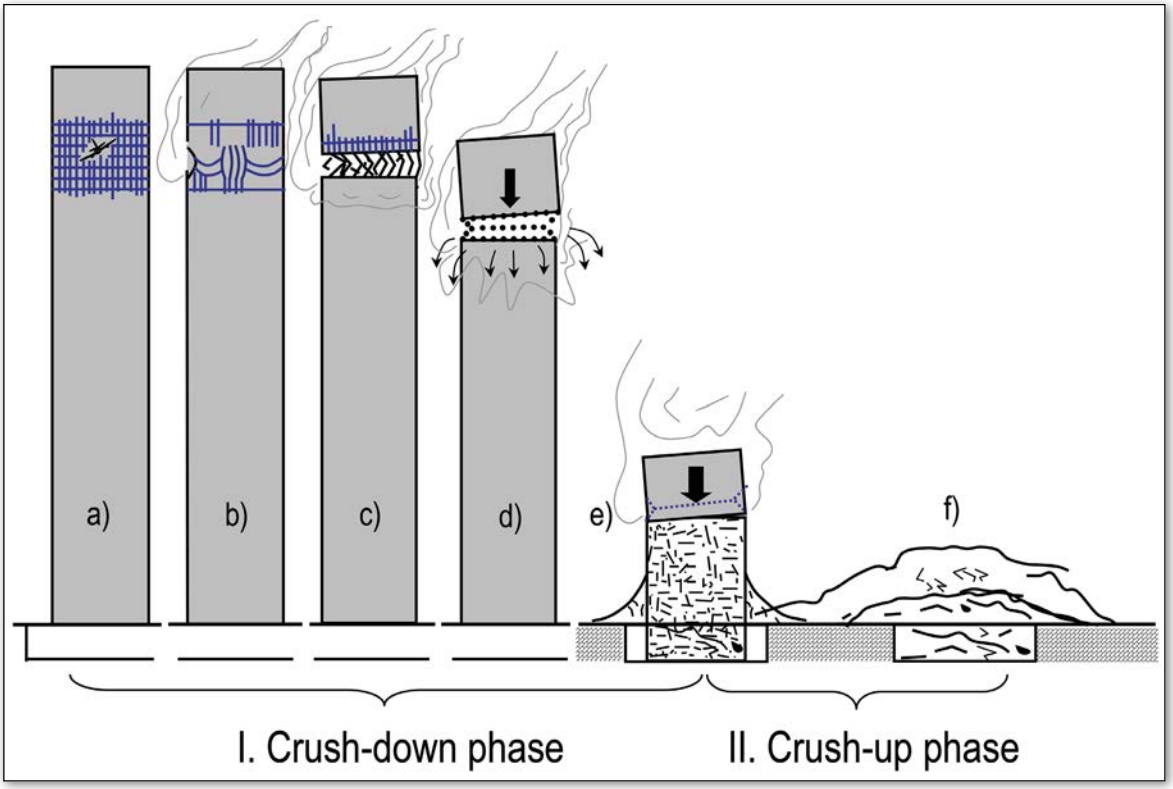
Because of insufficient quantitative information on these aggravating factors, they were conservatively omitted from the analysis of collapse trigger. But it is clear that they significantly enhanced the likelihood of reaching the stability limit and of triggering the vertical fall of the top part of building (Fig. 1c). Their consideration was unnecessary because even the minimalist assumptions sufficed to demonstrate the order-of-magnitude excess of the kinetic energy of falling mass over the energy dissipation capacity of the columns.

At the moment of downward impact of the top part of tower onto the undamaged cold story below the fire zone, the kinetic energy of the top part exceeded by an order of magnitude the energy required for complete buckling of all the columns of the cold story calculated under very optimistic assumptions, especially: 1) no fracturing of steel, and 2) fall of the top part through the height of only one story. If one takes into account the aforementioned aggravating factors, particularly the fact that the steel must have fractured, and that the initial fall was likely through the height of not one but two or even three stories weakened by fire, the excess of kinetic energy must have been even much higher.

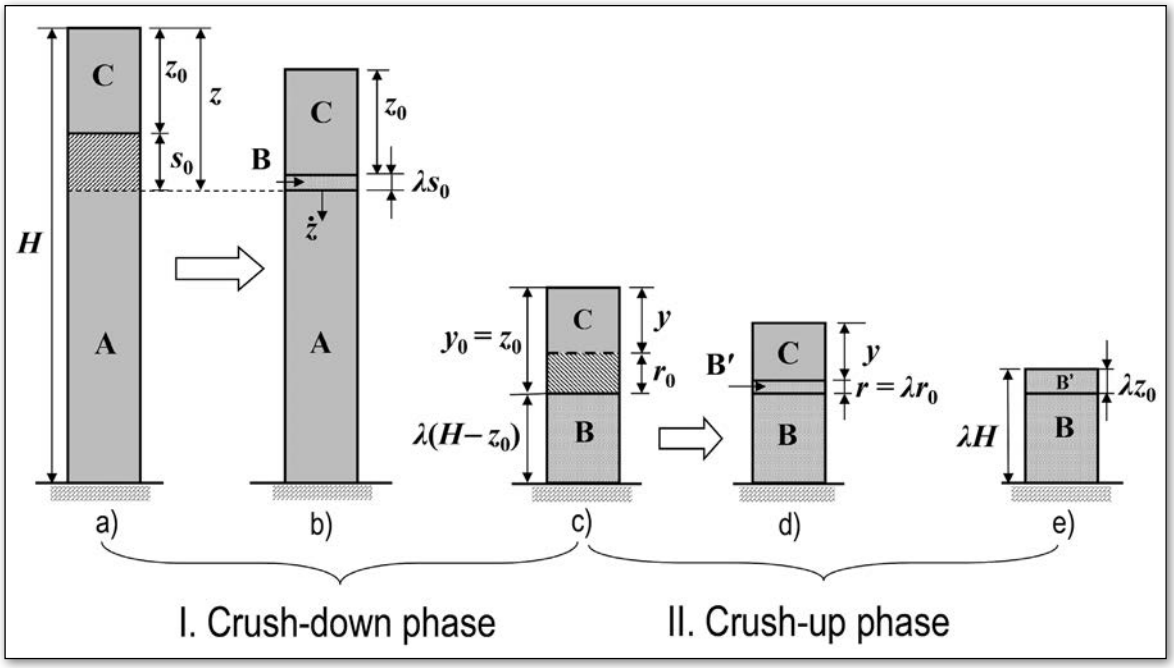
During the progressive collapse of subsequent stories, the velocity of the crush front and the kinetic energy excess grew rapidly. The duration of fall up to the moment at which the crushed part of tower hit the ground was calculated to be 12.81 s for the North tower, and 10.47 s for the South tower [5]. These durations agreed with the seismic record at Columbia University and were about 60% longer than the duration of free fall. After making corrections for the small tilt of the falling top part, it was also demonstrated that the calculated motion closely agreed with the video record of the motion of the topmost corner of the tower top during the first 2 or 3 seconds, before the top disappeared in smoke.

Recently, an objection was raised on the basis of reduced scale buckling tests of aluminum columns reported in [8], which indicated that the total energy dissipation during near-180° rotation in the aluminum plastic hinge was about the triple of the value calculated from the standard beam-theory expression for the yield moment at small rotations. However, in the interpretation of these experimental results, three crucial differences were overlooked (in detail, see [9]):

1. The ends of the tested columns were allowed to rotate freely about the edge of contact with the loading platens, while in WTC the column ends were elastically restrained by the adjacent structure.
2. The photo of the buckled test column revealed that the extensions of aluminum flanges exceeded 100% without any ruptures. However, the structural steel in WTC columns had a limited ductility, maximally 35% [10]. So, at larger deflections, the actual steel columns must have fractured and thus lost their resistance. That such fractures did occur is verified by photos of flying column segments.
3. The energy dissipation measured in these tests corresponded to the relative rotation of nearly 180° at the mid-height plastic hinge. But the rotation at the ends of WTC steel columns could not exceed 90° (see the sketch in [3]) and probably was much smaller because the end joints were also rotating. It follows that, even if the fracturing of steel before reaching the maximum possible rotation is discounted, the energy dissipation in each WTC column must have been still even smaller, by far, than the value estimated in [8].



▸ **FIG. 1:** Schematic of different stages of the collapse process.



◂ **FIG. 2:** 1D modeling of the crush-down and crush-up phases.

Critics now come up with the assertion that the initial kinetic energy excess must have been much smaller than the value calculated from the free fall over the height of one story. This assertion is incorrect because of the aforementioned aggravating factors, and especially for three reasons:

1. The columns of that floor were hot and partially broken, and so their resistance could not have been significant.
2. Many of these columns were destroyed already during the aircraft impact and explosion.
3. The excess of energy was likely much greater than the value calculated for the fall through one story height because the aircraft impact and subsequent fire afflicted three stories simultaneously.

Therefore, the collapse most likely began by a fall of the top part through the height of two to three floors. Indeed, photographs show perimeter columns with a lateral deflection over three floors exceeding 1 m [1]. This also indicates that at least some of the truss girders supporting the concrete floor slabs were detached from column joints before the collapse began. Thus the resistance against the fall of the top part was diminished further.

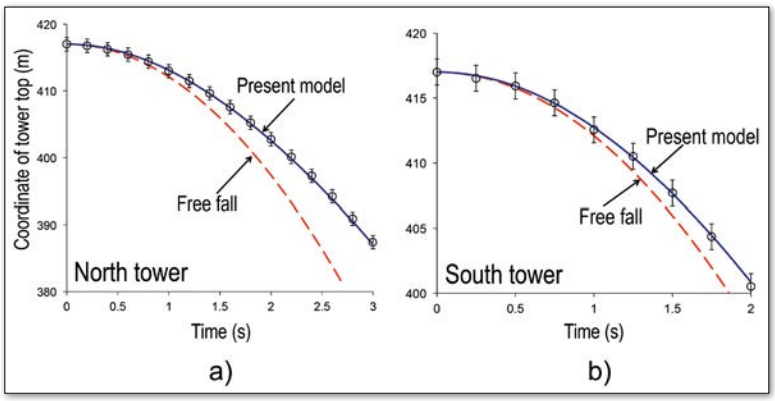
In the lower floors, one story got squashed within mere 0.07 s. Calculations showed that the air ejected from the story must have reached the velocity of sound, *i.e.*, Mach 1. So the sonic booms heard, the rapidly expanding dust clouds and the wide ejection of debris are no surprise (while some critics erroneously claimed that the booms could have been caused only by explosives). The size distribution of concrete particles, calculated from the energy of impact on floor slabs [5], matches the distribution of the particle sizes seen on the ground, which ranged from 0.01 mm up.

The critics claimed that such small particles could be produced only by explosives. Yet the experience from mining and tunneling (*e.g.*, [11, 12]) shows that such small particles could be produced by explosives only if the alleged authors installed about 150 tons of TNT into small holes drilled into all concrete floor slabs of each tower. The critics do not explain how such a massive operation, requiring many workers, could have been carried out in secrecy, no one leaking it later to the public. Many workers would have been needed even for the usual demolition by explosives installed on the columns of one story, and, to match the collapse progression as seen, the aircraft would have had to impact each tower just above the story wired by explosives.

Succinct description of the mathematical model

In [4], two phases of collapse were distinguished and their differential equations were derived. In the first phase, called crush-down, the stories are getting crushed at the lower margin of the crushed zone (see Fig. 1a-e and Fig. 2a-c). A simplified model treats each tower as a one-dimensional continuum of mass density $\mu(z)$ where z is the vertical coordinate measured down from the tower top in the original state. The upper part of tower, of height z_0 (labeled as C in Fig. 2), begins to fall at time t_0 and then progressively crushes the underlying stories. The coordinate of the crushing front at time t is denoted as $z(t)$, while $z(t_0) = z_0$.

In the crushed zone, the material is compressed to mass density μ_c (per unit height). The density ratio $\lambda=(1-\kappa_{out})\mu/\mu_c$ is equal to the ratio of the height of compressed material to the original height (κ_{out} = mass shedding fraction = fraction of the mass that is ejected outside the tower perimeter before the end of crush-down phase). The crushing process may be idealized as fully localized into the crushing front, which is moving down at velocity $\dot{z}$. During time interval dt, a layer of original height $\dot{z}dt$ gets compressed to height $\lambda\dot{z}dt$ and so the rigid compressed



▲ **FIG. 3:** Comparison between the predicted motion of tower top and the video record: a) North tower and b) South tower.

block above this layer moves vertically by $(1\text{-}\lambda)\dot{z}dt$. Therefore, the downward velocity of this block is $(1\text{-}\lambda)\dot{z}$.

The mass of the part of tower above the crushing front can be expressed as $m(z)=\int_0^z \mu(\zeta)d\zeta$. The momentum of this part is $(1\text{-}\lambda)m(z)\dot{z}$. The advance of the crushing front is resisted by force F_c needed for the destructive process below. At the same time, gravitational force $m(z)g$ acts on the tower part above the crushing front. In this manner, Bažant and Verdure [4] obtained the following differential equation:

$$\frac{d}{dt}\left([1-\lambda(z)]m(z)\frac{dz}{dt}\right)-m(z)g=-F_c(z,\dot{z}) \qquad (1)$$

A slightly refined equation, with variable distribution of λ over the crushed zone, was used by Bažant *et al.* [5]. It should be pointed out that Eq. 1 can also be derived rigorously from an extended Lagrangian formulation for dynamic systems with a moving mass varying as a function its spatial coordinate rather than the time [13].

At the beginning, the front of crushing is at level z_0 and its velocity is $\dot{z}_0$ The crushing process will begin if $m(z_0)g>F_c(z_0,0)$. This condition, of course, is not satisfied in the undamaged state of tower, and not even immediately after the aircraft impact. As a consequence of the fire, the resisting force F_c in the afflicted three floors gets gradually reduced. The contributions to this force are expressed by the sum $F_c=F_b+F_s+F_a+F_e$ where F_b is the force needed for buckling and fracture of steel columns, F_s is the force needed to provide the work of comminution of concrete floor slabs into small particles, F_a is the force needed for fast ejection of air as the floor is getting squashed, and F_e is the force needed for lateral ejection of some of the crushed debris. In the present continuum approximation, all the forces should be understood as averaged quantities which, when multiplied by the story height, are equal to the dissipated energy per unit height. Eq. 1 also indicates that, in addition to the aforementioned resisting forces, another major resistance is derived from the fact that the accreted mass at the crush front must be accelerated from rest to the velocity of the top part.

In [4], the analysis considered only force F_b, which is dominant in comparison with the resisting forces due to concrete comminution and air and mass ejection. In view of the order of magnitude difference between the energies of motion and of resistance, the analysis in [4] sufficed to reconfirm the inevitability of spontaneous progressive collapse shown in [3], to elucidate the role of various parameters and to show that spontaneous collapse had to occur for a broad range of input data. However, to clarify and match various observations, such as the duration of collapse, particle size distribution of comminuted concrete, video record of initial motion, speed of air jetting out, *etc.*, a more refined analysis was necessary [5].

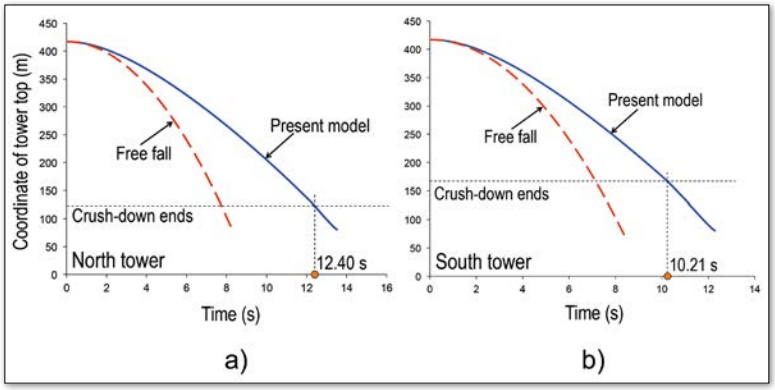
At the moment the crush front hit the ground, the second phase of collapse, called crush-up, got under way. Here, as the top part continued to fall, the crush front propagated upward (Fig. 2c-e). Under the same simplifying assumptions as mentioned before, the following crush-up differential equations was derived [4]:

$$m(y)\left[\frac{d}{dt}\left([1-\lambda(y)]\frac{dy}{dt}\right)+g\right]=-F_c(y,\dot{y}) \qquad (2)$$

Here y is the vertical coordinate of the upper boundary of the crushed zone measured from the top of tower in the initial undamaged state (Fig. 2d) [3, 4]. Based on the difference between the crush-down and crush-up motions, it has been shown that both phases of collapse could not proceed simultaneously [5].

Eqs. 1 and 2 have been solved numerically using the 4th-order Runge-Kutta method. The same input values were used as in the previous analysis [5], except that, based on recent information, the reduction factor β of the column resisting force was increased from 2/3 to 0.73 for normal-strength columns, and from 0.24 to 0.26 for high-strength columns (here $F_b=\beta F_p$, where F_p = column resisting force calculated based on standard three-hinge column buckling analysis [3,5]). The solution led to graphs describing the time evolution of motion of the topmost rim corners of the North and South towers. Fig. 3a-b compares the predicted motion with the available video record. Good agreement is found. Fig. 4a-b shows the calculated motion of the tower top during the entire collapse. The model (Eq. 1) predicted the durations of the crush-down phase for the North and South towers to be 12.40 s and 10.21 s, respectively. These predictions matched well the observed crush-down durations based on the seismic record (12.59 ± 0.5 s for the North tower and 10.05 ± 0.5 s for

▼ **FIG. 4:** Calculated motion of tower top for the entire collapse process: a) North tower and b) South tower.



the South tower) [5]. These analyses clearly demonstrated that a mechanism of spontaneous collapse driven purely by gravity must inevitably have developed.

Spontaneity of the collapse of WTC7: Explicable in retrospect

Lay critics also questioned the collapse of the WTC tall Building 7. Unlike the North and South WTC towers, Building 7 did not suffer from airplane impact. NIST's detailed analysis [14] of the reasons for collapse is worth summarizing here.

The burning debris ejected from the North and South towers hit Building 7 and ignited fires on multiple stories simultaneously. Meanwhile, the collapses of the North and South towers also damaged the city's water main. As a result, the sprinkler system on the lower stories (below 20th story) of Building 7 was not functional. The uncontrolled fire engulfing many floors caused a large thermal expansion of floor girders. Calculations showed that this expansion, occurring simultaneously on many floors, caused failures of the bolts attaching the ends of girders to the supporting beams.

Because of the loss of support by the floor systems, perimeter columns buckled over multiple stories [14] and caused the overlying floor systems to fail. The chain of structural failures that initiated the overall collapse of Building 7 was computationally simulated by a high-fidelity finite element code at NIST [14]. In Building 7, the collapse front propagated not only vertically but also laterally. In that case, the simple one-dimensional model of overall collapse formulated for the twin towers is insufficient.

In summary, the initiation of collapse of WTC Building 7 is explained by the uncontrolled fires burning for a long time simultaneously on many stories. These fires first undermined the floor systems, which led to progressive loss of columns and thus initiated a gravity driven total collapse.

Conclusion

From the viewpoint of physics, and structural mechanics in particular, it is perfectly clear that no WTC demolition took place. The collapse was triggered by an atypical fire ignited simultaneously in a large volume. It was driven by gravity, and was spontaneous. In hindsight, it was, under the given circumstances, inevitable.

For further information click 'WTC collapse' on the website http://www.civil.northwestern.edu/people/bazant, and download the articles [2, 3, 4, 5, 6] as well as various discussions with replies.

Editors note

This manuscript represents a response to the view presented in the article on the WTC collapse, published in EPN 47/4. In line with the new criteria for publication in EPN as outlined on the EPN webpage and in EPN 47/5&6, it was decided to publish this manuscript in order to conclude the discussion on this subject.

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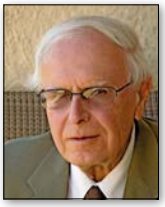

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References

[1] NIST (National Institute of Standards and Technology) (2005). *"Final report on the collapse of World Trade Center towers."* S. Shyam Sunder, Lead Investigator. Gaithersburg, MD.

[2] Z.P. Bažant, *Society for Industrial and Applied Mathematics* **34 (8)**, 1 (2001).

[3] Z.P. Bažant and Y. Zhou, *Journal of Engineering Mechanics ASCE* **128-1**, 2 (2002); with Addendum, March (No. 3), 369.

[4] Z.P. Bažant and M. Verdure, *Journal of Engineering Mechanics ASCE* **133 (3)**, 308 (2007).

[5] Z.P. Bažant, F.R. Greening, J.-L. Le and D.B. Benson, *Journal of Engineering Mechanics ASCE* **134 (10)**, 892 (2008).

[6] Z.P. Bažant and J.-L. Le, *Journal of Engineering Mechanics ASCE* **137 (1)**, 82 (2011).

[7] Z.P. Bažant and M. Jirásek, *český časopis pro fyziku (Czech Journal of Physics)* **66 (5)**, 280 (2016).

[8] R.M. Korol and K.S. Sivakumaran, *J. Struct.* Vol. 2014, Article ID 795257.

[9] J.-L. Le and Z.P. Bažant, *Int. J. of Structural Stability and Dynamics*, in press (2017).

[10] C.G. Salmon, J.E. Johnson and F.A. Malhas, *Steel Structures Design and Behavior*, 5th Ed., (2009) Pearson Prentice Hall, USA.

[11] R.J. Charles, *Min. Eng.* **9**, 80 (1957).

[12] R. Schuhmann Jr, *The American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) Technical Publication* No. 1189. New York (1940).

[13] C.P. Pesce, L. Casetta and F.M. dos Santos, *Journal of Engineering Mechanics ASCE* **138 (12)**, 1420 (2012).

[14] NIST (National Institute of Standards and Technology) (2008). *"Final report on the collapse of World Trade Center Building 7."* S. Shyam Sunder, Lead Investigator. Gaithersburg, MD.

GLASS TRANSITION AT INTERFACES

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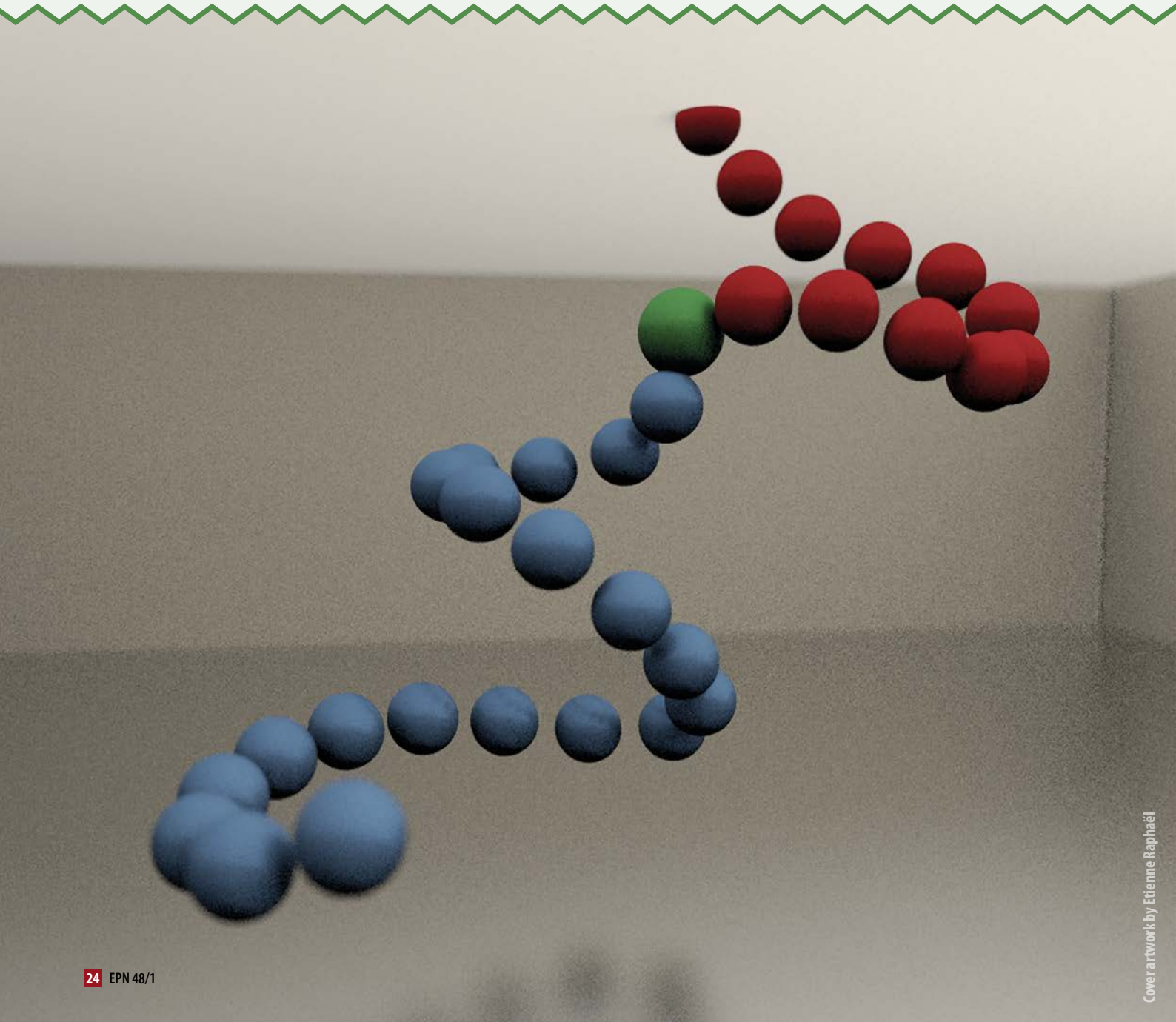


Cover artwork by Etienne Raphaël

We live in the twenty-first century. Almost all the changes between phases of matter are described by the theory of phase transitions. Yet, there is one phenomenon that still resists theoretical attempts at its description: the glass transition. Moreover, signatures of the glass transition seem to be modified in thin polymer films. These observations may provide insights into the detailed mechanisms of the transition and guide the use of thin films through promising applications. It thus appears crucial to understand the effects of confinement and interfaces on the glass transition.

A mysterious transition

The glass transition is a change of state between a viscous liquid and an amorphous solid obtained by cooling. What are the mechanisms at play in this phenomenon when the atomic structures themselves seem unchanged? Why is this common physical fact, mastered by glass blowers since the Roman Empire, so difficult to understand and why does it appear so different from the classical liquid-solid transition? These questions are far from being new but continue to stimulate important research activities [1]. This large effort is due to the central role of glasses and plastics (amorphous solids made from polymers) in art, industry and nanotechnology, as well as their broad diversity, which ranges from molecular to organic and polymer glasses, including metallic, spin and colloidal glasses, as well as jammed granular media.

Cooperativity and confinement

Despite the lack of a unified theory, a central concept appeared in the sixties from the work of Adam and Gibbs,in order to describe glassy dynamics: cooperativity. In usual liquids, molecular motions are uncorrelated. By contrast, crowding within glasses is important, and the dynamics might rely on spatial regions of size ξ in which the molecules rearrange collectively. This cooperative length scale, expected to grow rapidly near some finite temperature, could be the ideal observable for the glass transition, and continues to be the focus of intense investigations. Unfortunately, it is impractical to wait for macroscopic structural rearrangements in a glass due to the enormous time scales involved compared to those accessible to experiment. Furthermore, it seems unrealistic to resolve individual molecular trajectories in the bulk with existing microscopy techniques. One thus cannot currently measure ξ in a bulk glass.

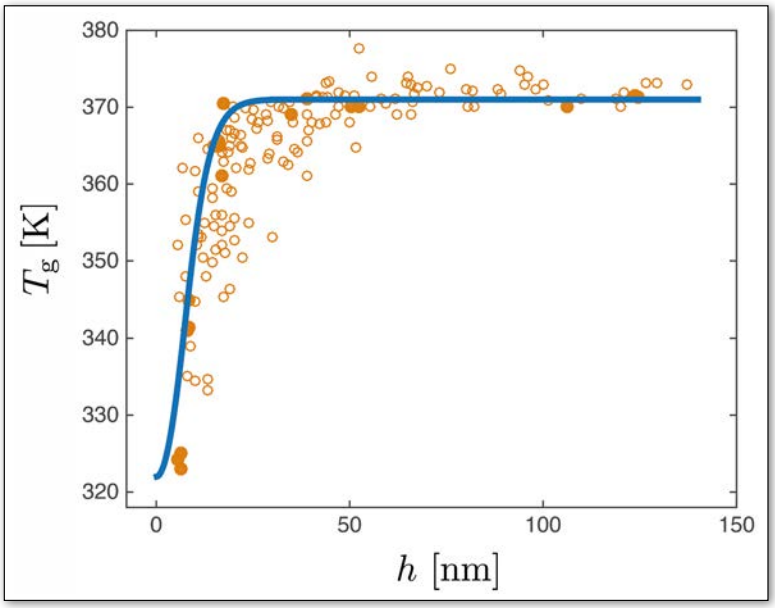
An alternative strategy emerged in the seventies: making glassy systems of a size comparable to ξ and observing their anomalies. However, since the elementary unit involved in ξ is the molecular diameter, one had to prepare and dynamically observe stable samples of a few molecular diameters. This was an impossible task, *a priori*. Polymer films offered an exception for a couple of reasons: first, polymer chains have a remarkable stability in the liquid phase (as noticed by industrialists); secondly, the sample preparation is relatively easy.

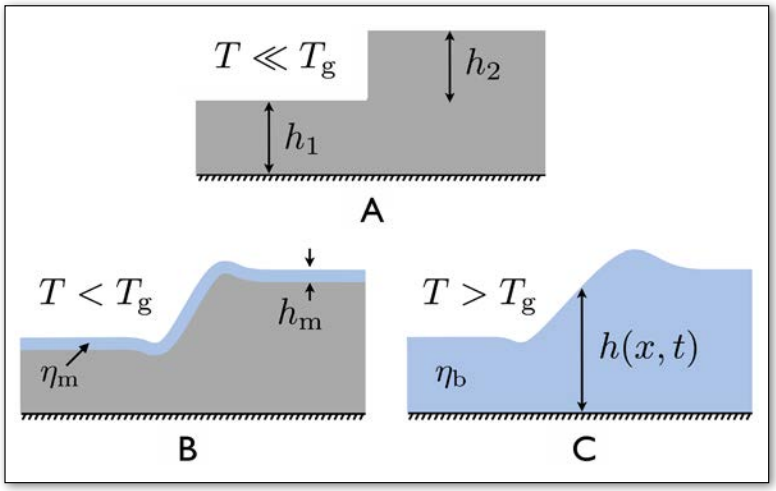
Anomalies in polymer nanofilms

Like most materials, a polymer film expands with temperature. This dilatation can be detected and precisely quantified by techniques such as ellipsometry (a measure of the change in the polarisation of light after reflection on a sample). By lowering the temperature, the system progressively contracts with a constant thermal expansion coefficient. Then, at a given temperature (about 100 °C for the case of polystyrene) the expansion coefficient changes abruptly: the point of this observed transition, and a related measure based on calorimetry, is often defined as the glass-transition temperature T_g.

In the nineties, using these methods, several teams reported that the glass-transition temperature of a polystyrene film depends on its average thickness, when the thickness is below 50 nm typically (Fig. 1, circles). In addition, experiments focusing on local dynamics, realized through embedding of gold nanoparticles, recording of capillary fluctuations, or tracer evolution, revealed a second anomaly in polymer films: the existence of a liquid-like mobile layer localized over a few nanometers

▼ **FIG. 1: Problem. Glass-transition temperature T_g of polystyrene films supported on silicon substrates, measured by ellipsometry, as a function of film thickness h (closed circles). For comparison, the literature data is indicated (open circles). The microscopic hypothesis of the random cooperative strings (see end of the article) allows one to quantify the local molecular mobility and thus the glass-transition temperature (solid line).**





▲ **FIG. 2: System and notations.** As prepared, the sample is a polystyrene stepped film with thicknesses h_1 and h_2 on the order of 100 nm, at room temperature T well below the glass-transition temperature T_g.

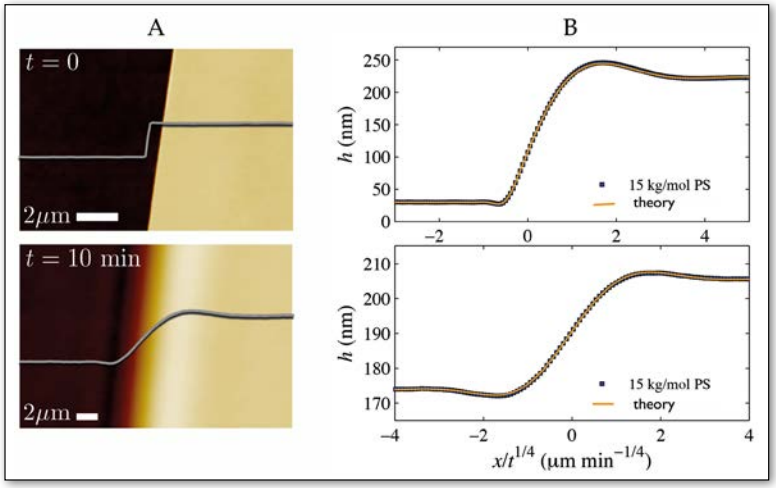
near the free surface. The interpretation of these measurements is still hotly contested. The origin and properties of the mobile layer are undetermined, and the link with the T_g shift remains hypothetical.

Interest in thin films and their rheology

Microfilms and nanofilms of polymers – molten, rubbery, or glassy – are of tremendous interest in a broad variety of interdisciplinary fields, such as physical chemistry, physiology, biophysics, microelectronics or surface science. Besides their fundamental importance, such films are frequently involved in industrial processes, optical, mechanical or chemical, through nanolithography, lubrication, paints, surface treatments, and elastic membranes. Future development of molecular electronics, organic multimedia displays, biomimetic devices, superadhesive or self-cleaning surfaces may even increase the importance of such materials. As an example, thin polymer films are potential candidates for massive data storage, through the IBM Millipede project. The idea is to indent the film surface at the nanoscale, in order to mechanically imprint information, and by this means to increase considerably the surface storage density with respect to microelectronic standards.

Through these potential applications, one easily recognizes that a detailed understanding of the physics at play behind the stability and dynamics of these systems is necessary. When the average thickness (10-100 nm) of polymer nanofilms is comparable to the typical macromolecular size, the effects of confinement may drastically alter their properties. The nanorheology of these systems raises a number of questions that are currently highly debated, at the boundary between the continuous and discrete descriptions of matter. Besides the glass-transition anomalies – central to the present article – let us provide two examples. First, the modification of intramolecular conformations and intermolecular entanglements, near surfaces and in confined settings, might directly impact the viscosity and thus the stability time scale of thin films. Secondly, interfacial phenomena may dominate over volume effects in thin geometries, and thus the overall rheology might strongly depend on the interfacial frictional and slip properties – the latter of which is strongly amplified for entangled polymers.

▼ **FIG. 3: Observations. (A)** Atomic-force-microscopy images of the levelling of a polystyrene (PS) stepped film, with 15 kg/mol molecular weight, initially and after some time t. The capillary stresses in the corners of the step are such that Laplace pressure generates a viscous flow together with surface oscillations and relaxation. **(B)** Comparison between experimental profile $h(x,t)$, where x is the horizontal position, and hydrodynamic model, for two different geometries (top: thick step, bottom: thin step), at time $t = 10$ min. The only adjustable parameter is an overall horizontal stretch factor related to the film viscosity η_b, and thus allowing for the latter's precise measurement.



The stepped-film technique

In order to understand the glass-transition anomalies in thin films, and more generally their rheology, a nanoprobe is needed. Such a probe is a device or method enabling the measurement of physical quantities at the nanoscale. For instance, in order to know if a material flows and to quantify this flow, the free interface of the sample can be deformed and the resulting evolution observed. This is what we instinctively realize when perturbing the surface of honey in a pot with a spoon: the deformation progressively vanishes under the action of gravity. That relaxation operates over a time scale that increases as the honey is cooled, which is directly related to the viscosity of the material.

At the nanoscale, the dominant driving force is surface tension (which also controls the shape of small water droplets and soap bubbles) rather than gravity. By starting with a non-flat polymer nanofilm supported on a rigid substrate, and by observing its capillary levelling over time, one can thus deduce the internal mobility of the material [2]. More precisely, the developed technique consists of making a polystyrene stepped film (Fig. 2) – by superimposing two flat films with typical thicknesses on the order of several tens of nanometers but with different horizontal extents – and then observing its relaxation using atomic force microscopy (Fig. 3A). The evolution and shape of the profile being well described by fluid

mechanics, one can precisely calibrate this nanoprobe (Fig. 3B).

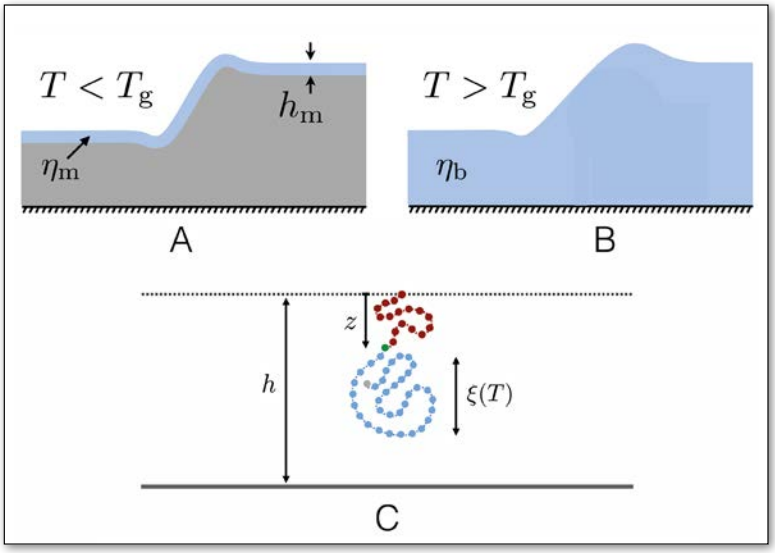
Measure of surface mobility in a glass

Using the calibrated stepped-film technique, it is then possible to study the capillary relaxation of polystyrene films below their glass-transition temperature T_g [3]. The conclusion is striking: the surface evolves! The evolution occurs over several hours, and is even observed a few tens of degrees below T_g. These observations can be understood using a simple two-layer mesoscopic model. Below the glass-transition temperature, the dynamics are heterogeneous and the film exhibits a liquid-like mobile layer (Fig. 4A) whose thickness increases and reaches the whole sample size (Fig. 4B) at the glass transition. The important result is that the mobility of this surface layer can be extracted (Fig. 5) from a fit to experimental data (Figs. 3B, 4A, and 4B).

The cooperative-string model

In order to understand the physical origin of such a liquid-like surface layer atop glassy films, and its possible link with the observed T_g shifts, one needs to develop a microscopic theory [4]. Inside a bulk glass, molecules are in an environment similar to the subway at rush hour. Each molecule is trapped in a cage formed by its nearest neighbours, and has very little free volume to move, to change position, and thus to allow for the material to relax towards equilibrium. Given the impossibility of individual motion, an alternative mechanism becomes cooperative motion: several molecules move simultaneously, just as passengers during the rearrangements occurring at stations. Moreover, using observations made in colloids, granular media and numerical simulations, one can assume that the cooperatively rearranging regions have the shape of one-dimensional chains of molecules rather than three-dimensional clusters. These are the so-called random cooperative strings. Based on this idea, and thanks to statistical physics, it is then possible to recover the usual phenomenology of bulk glasses.

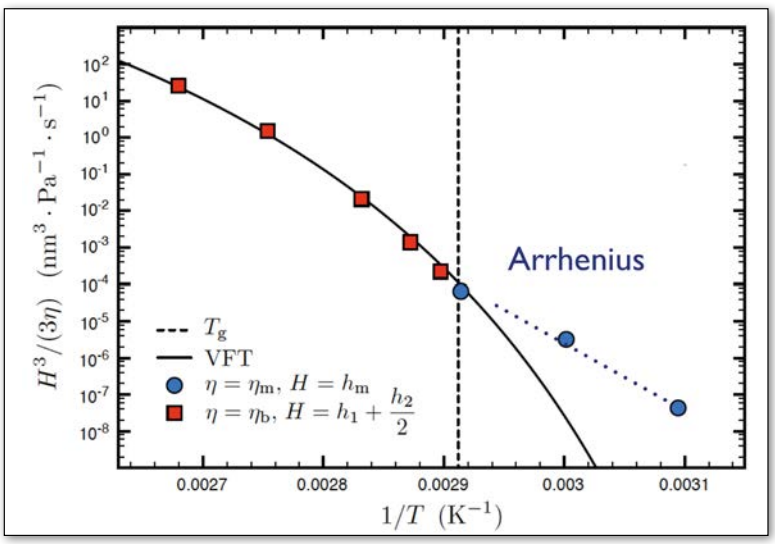
Finally, one can add a free interface to the description above. Doing so, it is possible to address quantitatively the two anomalies introduced previously. The key ingredient lies in the fact that a random cooperative string is truncated at the free interface due to the absence of crowding constraints (Fig. 4C). In other words, a passenger of the subway standing close to the exit gate does not require any collective motion to escape the train: the passenger can simply jump outside, as a liquid-like molecule. This type of behaviour fluidizes the neighbourhood of the gate. Invoking a Brownian description for the cooperative chains and the first-passage density of probability at the interface, one can quantify the local relaxation time in a thin film, and thus its mobility and glass-transition properties (Fig. 1).



▲ **FIG. 4: Models. (A)** (mesoscopic) For a temperature range below T_g, the flow is localized in a surface layer (blue) of thickness h_m, on the order of a few nanometers. As the surface evolves through the flow of the blue region, an initially immobile region (grey) can reach a distance to the free surface that is smaller than h_m, and thus becomes liquid (blue). This explains the rearrangement of the grey region as well. (B) (mesoscopic) For a temperature range above T_g, the flow occurs in the whole sample. (C) (microscopic) Truncation of cooperative strings at the free interface of a glassy film. At a temperature T, in a film of thickness h, and at a distance z from the free interface (dashed line), a molecule (green) can relax through a random cooperative string (blue) of size ξ in the bulk of the sample, but it can alternatively do so through a string that is truncated by the interface (red) – shorter and thus more probable – which increases the surface mobility and thus reduces the effective glass-transition temperature of the film.

> **In order to know if a material flows and to quantify this flow, the free interface of the sample can be deformed and the resulting evolution observed.**

▼ **FIG. 5: Results.** Poiseuille mobility $H^3/(3\eta)$ of a polymer film (defined by the thickness H and viscosity η of the flow region) as a function of the inverse temperature $1/T$. As a characteristic feature of the glass transition, the mobility varies over ten decades near T_g. When $T > T_g$ (squares), the flow occurs within the whole film (Fig. 4B), with an average thickness $H = h_1 + h_2/2$ and bulk viscosity $\eta = \eta_b$. The viscosity satisfies the expected Vogel-Fulcher-Tammann (VFT) law for supercooled liquids. When $T < T_g$ (circles), the flow is localized in a near-surface region (Fig. 4A) of thickness $H = h_m$, and viscosity $\eta = \eta_m$ which seems to follow an Arrhenius-like law, reminiscent of simple liquids. The viscosity η_m and thickness h_m of the mobile layer cannot be determined independently in such a measurement.



Conclusion

It is often thought that windows in cathedrals are thicker at the bottom because the glass slowly flows. Ironically, this hypothesis, while wrong for the windows, appears to be verified in amorphous nanofilms, near their glass-transition temperature. For instance, a polymer glass – a fundamental material in industry and nanotechnology – is traditionally described as a disordered solid, but it flows! This flow occurs near the free surface, and over a few nanometers in depth, which reduces the effective glass-transition temperature.

The stepped-film technique facilitates the ability to characterize the dynamic properties of glassy polymeric nanolayers as a function of temperature and for various compositions. The method is not limited to those materials and could more generally allow one to probe soft condensed matter in confinement, at the nanoscale, where interfaces and finite molecular sizes play a dominant role.

Finally, the microscopic cooperative-string theory presents two advantages: its analytical simplicity and its pictorial character, which might contribute to make it a practical tool to study the glass transition. One can thus hope to better understand the mechanisms of this phenomenon, as well as its anomalies in thin films and nanoparticles [5], and, for instance, to guide the fabrication of ultrastable glasses, these fascinating emerging materials. ■

Acknowledgments

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[Crossing borders]

by Istvan Daruka
Institute of Semiconductor and Solid State Physics
Johannes Kepler University – **DOI: https://doi.org/10.1051/epn/2017104**

Publication Stock Exchange (PSX)

After the historic epoch of science, after the secrets of all elementary particles and that of the dark matter were revealed with the help of the Equatorial Particle Accelerator circling about the globe, the main direction of research has shifted towards the development of artificial-intelligence-based publication writing and refereeing robots. In this way the more expensive and less reliable graduate students and postdocs – displaying some performance imbalance originating from their human traits – could be replaced by cheaper, more endurable, and more efficient automated systems. Scientific publication generation became a primary business, accounting for a mighty 7 percent of the world's GDP. The old fashioned research institutes, in which scientists were thinking, working in peace and contemplating on some fundamental questions became highly inefficient in terms of scientometric output, and were gradually replaced by highly effective business units of the thriving publication production industry. Publication engineering and publication generator operators became highly profitable mainstream occupations.

Due to the substantial involvement of intelligent, fully automated high-throughput publication generating algorithms, the empirical Moore's law for publication dynamics – expressing the exponential growth of paper production – still prevailed. In this way, the yearly number of publications reached ten billion, and typical journal impact factors were about one-hundred-thousand, with ten million scientific journals available in a highly networked, strict hierarchal arrangement. Besides publication flow engineering, journal engineering was also thriving. Successful journal names included "Ultimate Answers", "Biggest Discoveries Weekly", "Top Researcher of the Minute", "Highest Impact", "Citation Marketing", "Journal of Rejected Papers", *etc.*

In this automated, self-amplifying rush there was not enough time for reading scientific publications, the priority was put on their mass production. The average number of human-involved reading per paper dropped below 0.000001. The emphasis tacitly shifted from the content of the papers towards their citations and respective journal impact factors. From the constant threat of "publish or perish", many have sought temporal…

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▲ Left to right: Thomas Salez, Joshua McGraw, Kari Dalnoki-Veress, Elie Raphaël and James Forrest

References

[1] L. Berthier and M. D. Ediger, *Physics Today* **69**, 40 (2016).
[2] J. D. McGraw, T. Salez, O. Bäumchen, E. Raphaël, and K. Dalnoki-Veress, *Physical Review Letters* **109**, 128303 (2012).
[3] Y. Chai, T. Salez, J. D. McGraw, M. Benzaquen, K. Dalnoki-Veress, E. Raphaël, and J. A. Forrest, *Science* **343**, 994 (2014).
[4] T. Salez, J. Salez, K. Dalnoki-Veress, E. Raphaël, and J. A. Forrest, *Proceedings of the National Academy of Sciences of the USA* **112**, 8227 (2015).
[5] M. Arutkin, E. Raphaël, J. A. Forrest, T. Salez, *Soft Matter* **13**, 141 (2017).

[Crossing borders]

… relief in citation lottery, which became highly celebrated shortly after its introduction. For participants who purchased such citation tickets, a random number generator assigned and approved a certain number of citations. Besides citation lottery, citation prediction services as well as citation insurance and a highly advanced citation credit system were also developed. This latter feature credited a certain number of citations in return for a financial charge.

Citation management was taught already in primary school, making use of augmented reality devices. Scientific success engineering was one of the most highly sought jobs. In fact, PhD programs worldwide on success design were tremendously over-populated and fierce fights among candidates were taking place to get in.

For faster speed and higher efficiency, the journal names as well as the authors (robot identifiers) were later represented by binary numerical strings. This way, the entire publication industry became a gigantic, strongly correlated numerical matrix operation, running under the auspices of the Global Publication Matrix Agency (GLOPMA).

For a long time, the scientific output was accurately measured and characterized by the eigenvalue spectrum of an all-inclusive scientometric matrix (SciMa), surprisingly exhibiting an invariant trace of 42.

But then, as a scientometric breakthrough, the Profit Potential Index (the so-called PP-Index or PPI) was introduced and revolutionized the world of science at once. It rendered all scientific items (publications, citations, grant proposals, *etc.*) its estimated financial market potential, *i.e.* the most likely amount of profit they could produce. To simplify things further, and to make the system dynamics even more effective and free of ambiguities, potential instabilities, and free from the fallible/subjective nature of the human-based sluggish success assessments, scientific impact and scientific success became solely defined through the GLOPMA-assigned PPI.

This way the actual content of scientific items became fully irrelevant. There was no more need to carry out the actual scientific research, or to write and read publications. Proposal writing, scientific committees, and the unrewarding refereeing process became all obsolete. Time-consuming scientific thinking, doubts and word-based critics also lost their meanings. Everything was smoothly governed by the PPI-based GLOPMA and a perpetual exponential growth set in this way, constituting a highly celebrated sustainable avalanche.

This way science and economy fully merged into a "cross-profitizing", faultless unit: the worldwide Sciento-Economic Trading Association. Trading at the Publication Stock Exchange (PSX) was indeed lavishly thriving. The publication and citation exchange was mainly performed at a nanosecond base via trading robots. Bids on scientific commodities were placed making use of the PPI.

With the help of such superintelligent automation of the scientific and publication industry, the much awaited post-human era tacitly emerged. Science was pursued further at a perfected efficiency, without the presence of old fashioned, fallible humans: "the machine is running, the creator rests". ■

A PRIMER ON ENERGY FROM NUCLEAR FISSION

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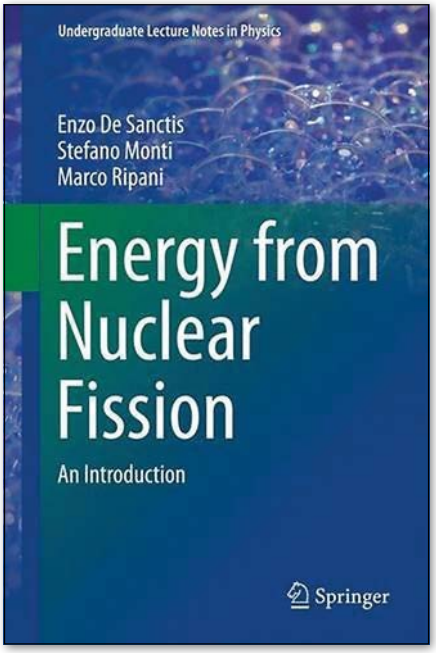
Despite several accidents in the last decennia, nuclear fission remains a very important energy technology that saves large amounts of CO_2. Moreover, nuclear energy is currently the only ready-to-use large-scale backup option for power production in an environment that is increasingly dominated by intermittent wind and solar power production.



Energy from Nuclear Fission: An Introduction (Undergraduate Lecture Notes in Physics)
Authors: Enzo De Sanctis, Stefano Monti, Marco Ripani
ISBN: 978-3-319-30651-3
Price: 59,54€

A book presenting a clear understanding of the scientific basis and technical safety principles of nuclear fission should be available for the technically interested public and policy makers but surely also for students that one day have to contribute to fundamental decisions for the national energy policy of his/her country.

"Energy from nuclear fission – An introduction" by E. De Sanctis, S. Monti and M. Ripani, recently published by Springer, is such a book: a refreshing introduction in the physics of nuclear reactions and nuclear energy.

The three authors are uniquely qualified, having been active researchers in the field for many years.

The book is divided in two main parts, and consists in total of 6 chapters. The first part discusses the basics of nuclear forces and properties of nuclei, nuclear reactions and radioactivity, and provides a detailed discussion of the fission process and relevant topics for energy production. The second part covers the technical aspects of nuclear fission reactors, fuel cycle and fuel resources, reactor safety, spent fuel and radioactive waste management.

Many illustrations supplement the text and help visualizing the concepts discussed. Reference is made to both milestone works as well as detailed articles. A large number of solved problems, placed throughout the text, together with additional problems (with answers) at the end of each chapter should further enhance the understanding and offer the order of magnitude of various physical parameters. A Glossary at the end of the book provides a handy reference to the terminology used in nuclear physics and nuclear energy.

The intended readers of this book, whether they are undergraduates, scientists or simply the curious should find therein not just a very good source of information but also an excellent collection of clear explanations of all aspects of nuclear energy. The mathematics is kept at a level that should be comprehensible to the general reader. Due to the large number of topics covered, it should also serve as a reference for those working in the field.

Improvements are always possible. I missed in particular an index at the end of the book. I would have liked some more details on the principals of enhanced safety applied in the Generation IV and on the advantages of thorium reactors. An additional chapter in the introductory part on nuclear reactions used to create the new high mass elements of the table of Mendeleev should be a nice and fascinating addition. Apart from these minor points, which might be improved in a following edition, the book will be a welcome contribution to the libraries of all interested in a subject that has become controversial and misunderstood since many years.

Jef Ongena,
Brussels, Belgium

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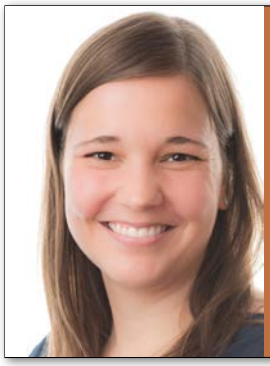

Opinion: why should one become involved in EPS Young Minds?

Ulrike Ritzmann, PostDoc, Johannes Gutenberg University Mainz

The EPS Young Minds Project aims to support young physicists to organize local events in self-organized sections. Starting in 2010, the project is growing rapidly and currently includes more than 40 sections in 21 countries. More than 400 young researchers from undergraduates to postdocs organize networking events, seminars, conferences and outreach activities all over Europe. In the last 3 years, I have been member of the Action Committee running the project. It is amazing to see how more and more young physicists become involved in the project and share their fascination for science.

Why should one become involved in social activities like the EPS Young Minds Project? In my opinion, the most important advantages are that you can explore a variety of research fields in physics and you can learn to meet various challenges beyond your daily routine as a researcher. Organizing public events requires convincing speakers to participate, getting funding for the event and advertising your ideas. Moreover, explaining your research to an unexperienced audience gives you a new insight about your own research. Can you explain with a few words to a public audience what you are doing and why your research is important?

I became involved in these activities during my bachelor studies in Berlin, when I joined the jDPG, the young association of the German Physical Society. I moved to Konstanz for my master studies. In the local jDPG group in Konstanz, we established a series of talks, in which experienced researchers from our physics department are introducing their research to students at all stages. We organized field trips, invited speakers from various industry branches and participated in the activities of the international year of light. In 2012, we joined the EPS Young Mind Project and after I attended the annual Leadership Meeting in 2013, I became a member of the Action Committee of the EPS Young Minds project.

Since I have joined the Action Committee, I have always been impressed by the amazing outreach activities that were run by the sections. For example, the EPS Young Mind section in Valladolid hosted various events explaining physical effects on shows entitled "Scary physics" or "a pirate's world". A lot of sections are involved in Science Fairs, as for example the section in Naples. For several years, they have contributed with various stands to the "Futuro Remoto", a large science fair in Naples with more than 100000 visitors each year. These are only two examples of the activities which were run by the sections. Every year, we invite one representative of each section to our annual Leadership Meeting to present the activities of the section and to share new projects. After each meeting, I went home with new ideas and more enthusiasm for the project. After three years, I will leave now the Action Committee with a lot of memories and great fascination for the different fields in physics.

Since I have joined the Action Committee, I have always been impressed by the amazing outreach activities that were run by the sections.

Finally, I want to encourage young researchers to become involved in activities outside their daily routine. Don't hesitate because of the extra time you will spend. If you have an idea you want to realize don't be afraid to try something new. Being part of these projects gives you many things in return. Being involved in social activities like the EPS Young Minds Project gave me a new perspective on my research field and even more fascination for science. ■

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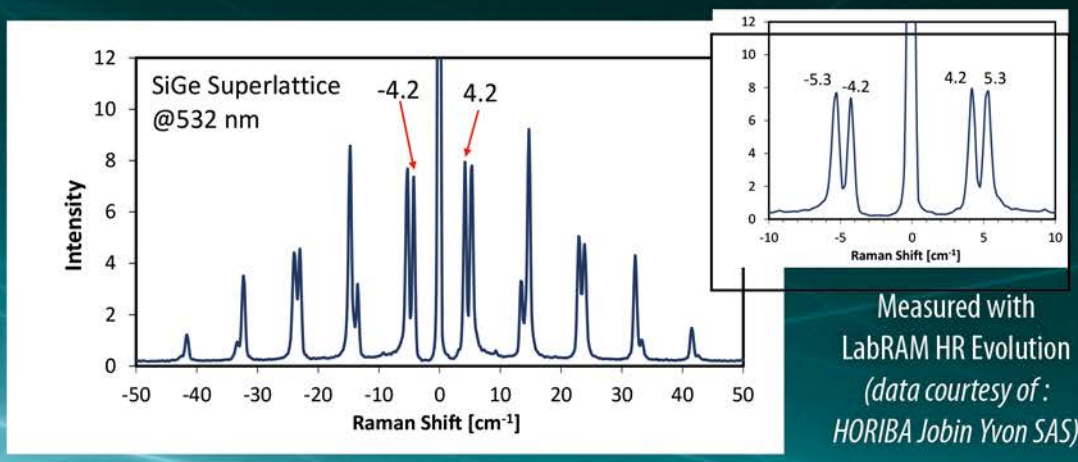

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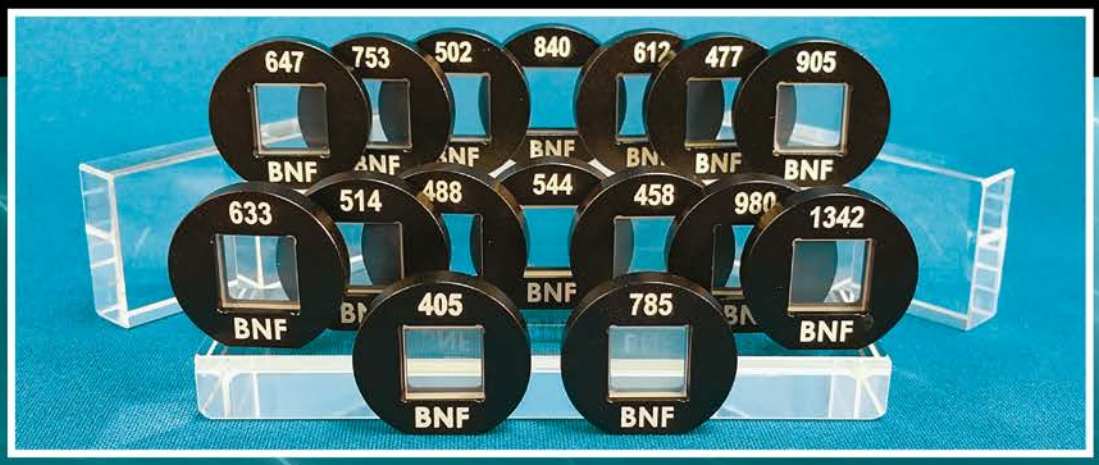

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