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Physics in space (part 1)
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Type II superconductors are 70 years old
Drink or Drive
The Fairy tale of electricity in museums in Serbia

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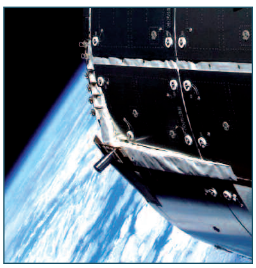
cover picture: A close-up view of the European Columbus laboratory (centre, right) - newest addition to the International Space Station - is featured in this image photographed by an STS-122 crewmember on Space Shuttle Atlantis shortly after the undocking of the two spacecraft. © ESA/NASA.



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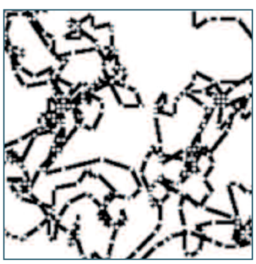
Physical Sciences onboard the ISS



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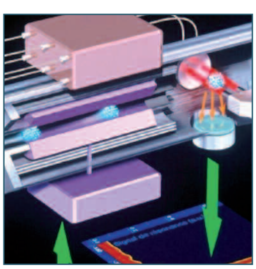
Dust in Space



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David Lee

WHY STUDY PHYSICS »» EDITORIAL

One of the recurrent themes in my 10 years at the EPS is the decline in the number of university students in physics departments. The EPS and all 40 of its National Member Societies, the European Commission and national governments spend millions of euros per year on campaigns to attract young people to follow scientific careers. How do we find and convince the next generation to embark on a career in research? In short, Why study physics?

When I ask physicists the question why don't people study physics, the answer I get most often is "it's hard". To be sure, 8 years for a PhD, with lots of math and vocabulary to learn, certainly takes a great deal of intelligence. But to be fair, it's hard to become a medical doctor, it's hard to become a lawyer, or economist or school-teacher or sociologist or graphic designer. So perhaps the question should be "Why study?"

We study mostly to find a rewarding career. Although one popular representation shows a physicist working in a dark laboratory, surrounded by a cloud of noxious fumes, wearing a white lab coat, we know that this is not true. The places I've seen tend to be ultra modern, with lots of neat equipment. People with physics degrees enjoy one of the lowest unemployment rates, have high mobility, have interesting careers, meet lots of very talented and cultured people, are involved in cutting edge research, and shape the future. But again, many other fields offer intellectual challenges, and have good salaries, job security, a happy family life and are equally rewarding.

People study for other reasons: interest, peer pressure, temporising, etc… So maybe the word "study" should be dropped, and we are left with the question "why?".

In my opinion, people who study physics are those interested in understanding "why". Why does the wind blow, why is there a rainbow, why do we not fall off the Earth and any of the myriad questions that we ask ourselves to try and understand the universe we live in. It takes a special person with, yes, a certain degree of intelligence, but more importantly a childlike curiosity to go on asking questions far beyond the answers that let the rest of us get by.

Curiosity is a quality to be nurtured and encouraged in our school systems, supported by our governments, and passed on by those currently in research to ensure that there is a next generation of people who are willing to ask "Why?". ■

David Lee,
Secretary General of the EPS

EPS COUNCIL IN MULHOUSE (F), 28-29 MARCH 08 >>> REPORT

Council 2008 was a special occasion. It brought together Council delegates from all 40 of EPS member countries and representatives of the Individual and Associate Members to discuss issues relating to EPS strategy and growth. Representatives from the American Physical Society, the Physical Society of Taiwan, the Canadian Physical Society and Euroscience among others were also present. In addition to the normal business of Council, the EPS celebrated its 40th anniversary with a special session, with three outstanding presentations from T. Stocker, G. Hasinger, and J.M. Gago.

Under the guidance of the President, F. Wagner, 2007 was an exceptional year for the EPS. As part of his programme, relations with the EPS Divisions and Groups were intensified. Divisions and Groups are the backbone of the EPS, active in promoting scientific excellence through their conferences, prizes and outreach activities. Creating a coherent conference policy, rationalising the number of meetings proposed and supporting the best conferences remains an important aspect of EPS policy.

Improving the dialogue with EPS Member Societies is also necessary for the development of the EPS. Some of the Societies have special relationships with the EPS, as a result from common projects, such as the study of the implementation of the Bologna project in Physics Studies, joint publications, and financial contributions to the EPS. Recognising the relationships means that the EPS needs to work closely with these societies in establishing our priorities.

Physics publishing in Europe is fragmented, which makes creation and implementation of a cohesive policy in publications difficult to implement. The EPS has begun discussions with the European learned society publishers in order to identify areas of common interest and where cooperation is possible. One such area is EPL, published under the scientific responsibility of the EPS, where EDP Sciences, IoPP, the SIF and EPS work together to produce Europe's flagship letters journal.

EPS also plays a key role in representing the physics community at the European Commission. In 2007, F. Wagner met with J. Potocnik the DG Research Commisioner, and with W. Langen, chairman of the European Parliament. The EPS has an agreement to distribute Brussels News Update (published by EuCHEMs), a monthly news bulletin, to its members. In addition to coordinating grants for European activities and studies, the EPS also provides input on EC policy and is now consulting with the Commission on measure to simplify grant agreements. The EPS also represents the physics community in ISE and in the EIROForum. The EPS will study in 2008 the opportunity of having permanent representation in and information from Brussels and the European Commission.

Through the Forum Physics and Society, the EPS participates in Science and Society issues, identifying areas where physics can make a significant contribution to issues such as sustainable development, science education, and public awareness. Moreover, through the Technology Group, and the Energy working group, the EPS is undertaking a study of the scientific and technical input of physics research to the energy debate.

In 2008, the EPS will organise EPS14 in conjunction with CMD 22 in Rome from 25-29 August 2008. A press conference will be held with CERN in Geneva on 26 September to discuss issues of physics research and to commemorate the founding of the EPS. A campaign to increase the number of Individual Members, and to increase the number of Associate Members will be undertaken.

In looking at 2007 and the projects for 2008, the EPS has increased its activity. Also, working more closely with Member Societies and Divisions and Groups has brought to light new projects in areas where the EPS needs to play a role to promote physics in Europe. For the past 10 years, the EPS has looked at cost savings and has an efficient and dedicated staff. In order to ensure that the development of EPS is to continues, the Executive Committee will be looking at the opportunity to propose an increase of the member fees in 2008.

F. Wagner was confirmed as President of the EPS. Council elected Maciej Kolwas as President – elect of the Society. He will act as Vice-president for one year, and be confirmed as President at the Council meeting in 2009. The Council also elected 9 members of the Executive Committee for a two year term: Marcin Auzinsh, John Beeby, Hendrik Ferdinande, Anders Kastberg, Françoise Masnou-Seeuws, Ana Proykova, Klaus Wandelt, Victor Velasco and Angela di Virgilio.

Council thanked the outgoing members for their dedication and hard work for the EPS: Berndt Feuerbacher, K. Hamalainen, Anne-Marie Levy, Ove Poulsen, Viktor Urumov.

As part of this year's Council meeting, a celebration was organised in the afternoon of 28 March. T. Stocker (University of Bern, CH) gave an insightful presentation on the input of physics research in understanding climate change. G. Hasinger (Max-Planck Institute for Extraterrestrial Physics, Garching, D) took us on a voyage from the beginning to the end of the universe. JM Gago, Portuguese Minister of Science and Education gave a personal view of the current status of the progress made towards the creation of the European Research Area.

This session was punctuated by the lively Piper and Drummers from Basel. At the end of the session, this group led all of the participants back to the EPS headquarters on campus in Mulhouse for a party, complete with birthday cake. ■

◄ The President and the Executive Committee of the EPS at the 2008 council meeting

A 'FESTAKT' AT THE COUNCIL MEETING

>>> 40YEARS OF EPS

In the afternoon of 28 March, Council took a break in their deliberations and met in the Auditorium 'Schutzenberger', which is adjacent to the EPS Secretariat on the Campus Universitaire in Mulhouse, to celebrate the 40th Anniversary of EPS.

Prof. A. Brillard, the President of the Université de Haute Alsace (UHA) and thus host of the EPS Secretariat — welcomed the audience to Mulhouse and expressed his appreciation of the fruitful and growing relationship between EPS and UHA.

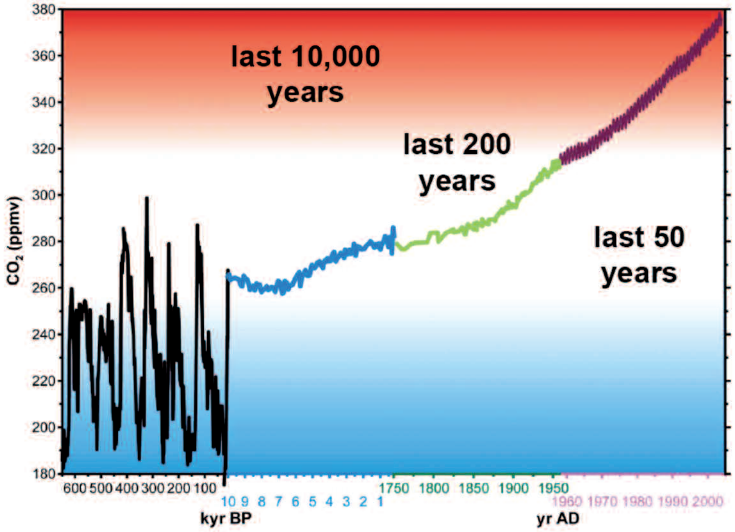
In his introduction, EPS President Friedrich Wagner, looked at the past and future of our learned society in his well-received survey of '40 Years of EPS –Achievements and Challenges'.

Two scientific talks followed: the first one by Thomas Stocker, Professor at the Oeschger Centre for Climate Change Research at the University of Bern, and a leading member of the Intergovernmental Panel on Climate Change (IPCC). In his lecture on 'Climate Change: the Physical Basis', he demonstrated that the conclusion "*warming in the climate system is unequivocal*", as stated in the latest Assessment Report of the IPCC, would not have been possible without the contribution of physics to climate science over many decades. Indeed, experimental physics enables us to read climate archives such as polar ice cores and so provides the context for the current changes. For example, today the concentration of CO_2 in the atmosphere, the second most important greenhouse gas, is 28% higher than at any timeduring the last 650,000 years (Fig. 1). Moreover, classical fluid mechanics and numerical mathematics are the basis of climate models from which estimates of future climate change are obtained.

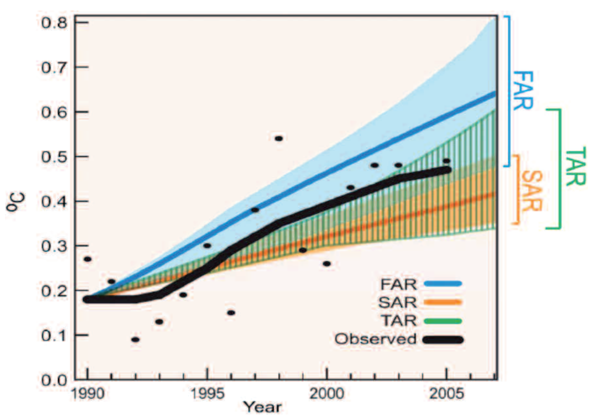
With some satisfaction, Thomas Stocker could also show the confirmation of previous estimates of the IPCC by the observations (Fig. 2). This Figure also reminds us that arguing 'anecdotally' about single years can be vastly misleading, if long-term trends are being discussed: averaging over a longer time span is needed to eliminate noise.

However, in spite of the confirmation of the predictions, we must be aware that major instabilities and surprises in the Earth System are still unknown. Only Physics will permit us to improve our understanding in order to provide the foundation for policy decisions facing the global climate change challenge.

At the end of the ensuing coffee break, the audience followed a surprising call back into the lecture theatre: a group of 13 drummers and pipers in the variety of masks and costumes that are customary for the 'Morgestraich', the early morning start of the Basel carnival – gave a taste of the cultural ambience of the tri-national region, where the EPS Secretariat is located (Fig. 3).



▶ FIG. 1: The concentration of the greenhouse gas CO_2 over the past 650 000 years, with stretched time scales to better accommodate the rapid rise in the more recent past (kyr BP: 1000 years before present).



▼ FIG. 2: Deviation of the yearly global average surface temperature from the mean of the years 1961 to 1990. The predictions, FAR, SAR and TAR, of the 1st, 2nd and 3rd Assessment Reports are shown as solid lines, with the range of estimated uncertainties shown by the shaded areas. The filled black circles represent the annual mean observations and the thick black line shows the decadal variation obtained by smoothing the time series using a 13-point filter.

▲ **FIG. 3:** The 'Schnoogekeerzli' were calling the audience back into the lecture theatre.

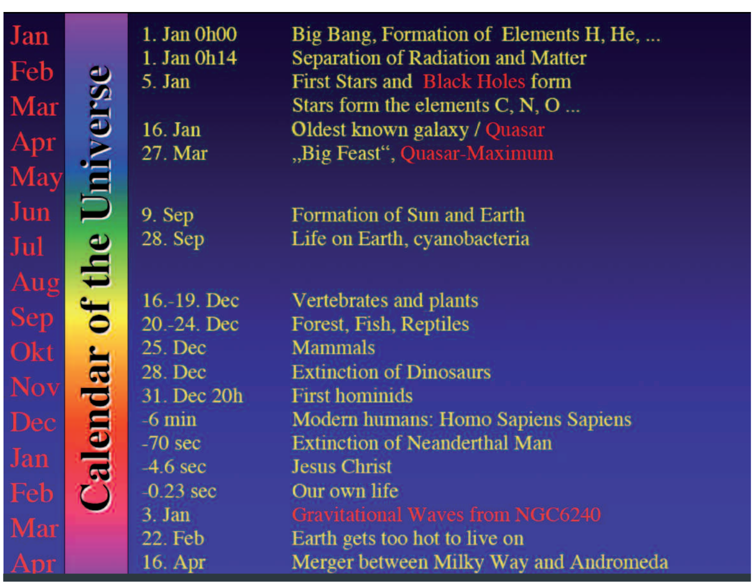
After the audience was back in its seats, the drummers and pipers gave a performance of the traditional 'Wettstein'-March. Günther Hasinger, Director of the Max-Planck Institute for Extraterrestrial Physics in Garching, then presented the second scientific lecture on 'The Fate of the Universe – New Cosmological Perspectives'. He explained how the observed receding movement of the galaxies, the structure of the microwave background radiation and the cosmic abundance of the light chemical elements can be explained in a self-consistent model of the Universe, where the Universe has started 13.7 x 10^9 years ago in an extremely hot fireball – the Big Bang. The further evolution of the Universe – the cooling, the formation of large-scale structures, the origin of galaxy clusters, galaxies, stars and planets can be described by detailed cosmological simulations, and also observed and actually measured with telescopes, spectrometers and detectors, whose capabilities and performance are continuously improving. By comparing observations and theory one can then derive the parameters determining the Universe, namely its mass, its energy, and the geometry of space.

The recent past has brought changes of paradigm in several domains of cosmology: the existence of 'dark matter', a still unknown kind of particles, which contribute about 85 % of the mass of the Universe, has been established. An utter surprise was the discovery of a 'dark energy', which dominates the Universe and further accelerates the galaxies. A further change of paradigm was the realisation that massive black holes exist in the centre of most galaxies, including our own – the Milky Way. The X-ray sky is dominated by a diffuse background radiation, which can be resolved in discrete objects – and lets us observe the growth of massive black holes over the entire history of the Cosmos. The black holes thus originated practically at the same time as, or even before the galaxies. And from then on, the merging of galaxies played an important role. In a nearby galactic collision two black holes, which eventually will merge, have been observed in the same galaxy for the first time.

If according to the latest findings the expansion of the Universe continues over unimaginable time spans, it is possible that in the end all matter will be caught in black holes. Günther Hasinger summarised his talk in a fascinating comparison of the history and 'near future' of the Universe – and our Earth – in a 'Calendar of the Universe', *i.e.*, compressed to a time scale of about one year, to which we can quite easily relate (Fig. 4).

European science policy, and in particular the creation of the European Research Council (ERC) was the subject of the closing address by José Mariano Gago, the Minister of Science, Technology and Higher Education of Portugal. A printed version of his speech will be published in the next issue of EPN. The drummers and pipers appeared again, and finally led the audience in a cortège to a reception with an apéritif into the EPS Secretariat. ■

Martin C.E. Huber



◄ **FIG. 4:** A Calendar of the Universe, starting with the Big Bang and extending beyond the present to the merger between the Milky Way and Andromeda.

▼ José Mariano Gago, Thomas Stocker

'FESTAKT' SPEECH OF PRESIDENT F. WAGNER >>> 40YEARS OF EPS

Welcome, Ladies and Gentlemen, dear guests,

Many outstanding physicists worked for the idea of a Europe without borders which allows the scientists to freely move and exchange information and share their knowledge and understanding. Gilberto Bernardini was the founding president of the EPS in 1968, and was followed by many famous scientists who are no longer with us like Werner Buckel, Hendrik Casimir, Maurice Jacob, Alan Mackintosh, Eric Rudberg, Ion Ursu. They represent the wide range of the physics done in Europe in an exemplary way – Other former presidents like Jacques Friedel and Renato Ricci, send us their best wishes but were not available to come. But many others are here and celebrate with us and share memories – of course of the good old days – Herwig Schopper, Martin Huber, Martial Ducloy and Ove Poulsen, my predecessor and I want to welcome you wholeheartedly as part of the large EPS family and as witnesses of the great legacy of physics in Europe.

We celebrate our 40th anniversary in Mulhouse because here is the centre of EPS. This venue is well selected because it reflects some of the European history – being French but twice in its history, it was German and for a while it was even part of the Swiss Confederation.

Mulhouse honours the past of science and technology with its famous technical museums and it characterises itself as a centre of industrial development. I welcome the President of the Université de Haute Alsace, Professor Alain Brilard, and the Dean of the Faculty of Science and Technology, Professor Christophe Krembel.

Others have helped that EPS found its place in Mulhouse, who are also here – Prof. Michèle Leduc and Prof. Claude Sébenne.

Dr. Ami Flatten represents the American Physical Society and the American Institute of Physics, Prof. Wu represents the Association of Asia Pacific Physical Societies, Prof. Minella Alarcon the UNESCO, and Prof. Lois Marchildon the Canadian Association of Physicists. I also welcome Prof. Gerd Wolf, representing the European Economic and Social Committee of the Commission.

We will have three contributions this afternoon, two scientific ones and one addressing science policy in Europe. We are honoured by the presence of two outstanding European scientists, Günter Hasinger and Thomas Stocker, who will take us into the cosmic wonder world but who will also remind us how vulnerable our own existence is on the small sphere in the universe, named earth. I would like to welcome you both. Later, Prof. Gago, the Portuguese Minister of Science and Technology will join us and speak to us. I also welcome Prof. Alex Bradshaw and Prof. Sir John Enderby. Both will also speak to us, one this evening, the other tomorrow in the second session of the Council.

This anniversary is embedded into the annual Council meeting. I have already welcomed all the presidents of national physical societies, the Secretaries General, the Chairpersons of the Divisions and Groups, the representatives of the Associate and Individual Members, members of the Executive Committee and the various Action committees as well as the editors of EPL, Prof. Dose, that of EJP, Alistair Rae and those of EPN, Claude Sébenne, G. Morrison and Jo Hermans and I enjoy doing it once more.

I also want to welcome our Secretariat in Mulhouse, who did all the preparatory work for this celebration. I do not know whether I should welcome David Lee, our Secretary General. He is not guest of EPS, he is our friend and memory.

I hope that I have not forgotten anyone in my welcome. Those who are here and do not fit into a specific category, are particularly welcome because they are true fans of EPS, the ideas and ideals of Europe and of physics in Europe. Two of them, I want to mention, Martin Huber and Berndt Feuerbacher. They have organised this celebration and the two others to come in this year. We will thank both of them, but not now, later – post festum.

At the end always the music - the Pfeiffer und Trommler from Basel; I will not translate it, music is international. They will entertain us but they also connect us to an old local tradition from medieval times and demonstrate in their way the cultural plurality of Europe. Welcome and thank you very much.

The European Physical Society was founded September 26th, 1968 in a small ceremony at CERN. The year before, the European Community was formed based on previous agreements and treaties as the next step in an ongoing unification process. Members were France, Germany – the Federation of Germany I have to say – Italy and the three Benelux countries. 1968 was a year of social turbulence with demonstrations of students in many countries; you remember the rituals of sit-ins. It was not too bad in physics because in this field there is more respect for those who are able to move the boundaries of our understanding on how nature works, which often depends on the extraordinary capabilities of the individual scientist.

1968 was also a year of severe political disturbances culminating with the invasion of the Warsaw pact troops into Czechoslovakia. The forces of disintegration of the Eastern Block could already be sensed. The founding of the Club of Rome in 1968 was the manifestation of growing environmental concern. In the wake of these developments a much more critical attitude of society emerged toward natural sciences – also physics - which remains until today. Nevertheless, the public respected science and technology and connected with them its hopes for a better future. Apollo VIII began manned spaceflight to the moon in 1968. In the following year, 1969, Neil Armstrong made his famous giant step.

In the years following 1968, the process of Europe's unification, political and social but also in science and research accelerated. In 1973, Denmark, Ireland and the UK joined the European Community, in 1981 Greece, followed by Portugal and Spain in 1986. The further expansion to 15 members was already in the frame of the European Union, in 2004 the Union grew to 25 members.

One could not foresee in 1968 that the forces emerging from the European ▶

Economic Community would lead to the removal of the inherent instability of many separate monetary systems, that the Germans would give up the Deutsche Mark in favour of a common currency, that one would be able to cross borders without passport, that UK would allow a tunnel so that never again fog would disconnect the continent from the rest of the world. But even more so, one could not expect that the Soviet Union and Czechoslovakia, and Yugoslavia would disintegrate whereas Germany re-unified. These political developments allowed EPS to grow to 40 members, more than the European Union with presently 27 member states. EPS members are also the physical societies of Russia, Israel, Turkey, Norway, Switzerland and many others.

Hendrik Casimir was EPS president from 1972-76. His name is connected to the Casimir effect – loosely spoken of as the force of the vacuum with boundaries – which just recently found excellent experimental verification in its classical formulation. He gave a talk in 1957, entitled “thoughts on the future of physics” at the occasion of the 25th anniversary of the American Institute of Physics. It reflects the status of Europe still shortly after the war and his description can help to recognise the tremendous progress since then.

He said: “*More-or-less there is a growing readiness in Europe to provide the necessary support for research. But once in a while, one meets the attitude, which a leading French politician stated: Research is a fashion; it will pass by.*”

◄ **Friedrich Wagner**

Later he said: “*Here [in Europe] are circumstances which prohibit the full use of the technical infrastructure and these are the national borders. […] as long as Western Europe does not form an economic unity (and heavens know whether it will ever come) there will be a drawback compared to the United States.*”

In the decades of European political integration, the network of European research institutions continued to grow on the basis of national bi- or multilateral agreements. My own research field, fusion, serves as a good example. Fusion research in Europe benefitted from joining forces. The strength of European fusion research, which made Europe possible as the site of ITER, is based on the European Association structure and on the additional funding by the Commission.

The instruments of the Commission to promote research and technology in Europe are framework programmes. It started in 1984 with the first framework programme; now we are amidst of FP 7. The budget of FP 7 is more than 12 times the one of FP 1 and 2.5 times FP 6. Though the definitions of the framework programmes have been changed, the development is nevertheless impressive.

Europe sees itself on the path to a European Research Area. Indeed FP 7 is by far the strongest financially. It also supports basic research in addition to the traditionally more politically defined fields. Because of the administrative principles of scientific self-organisation and scientific excellence as exclusive decision criteria, the founding of the European Research Council has a strong and positive resonance within the science communities. Also EPS applauds and made its support clear in all panels and committees. European Research Area may sound like a speech bubble to the more critical minds but it gains in symbolic value and I suggest to take it seriously and to work for it.

There is another development, which affects all of us and this is the target to develop a European Knowledge Area. University education is undergoing a transition to a homogeneous format, the Bachelor and Master degrees. This transition, which is enforced and should be completed in 2010 is not very popular in physics. In Germany, we hate to see that our much respected physics diploma is replaced by a universal degree – but ultimately, it was accepted. Meanwhile, 50% of the German physics departments have jumped; major casualties are not reported. Casimir, in his 1957 lecture said: *“The situation for the European university is not easy. In order to maintain their role, they have to abandon their grave und unhurried imprint.”*

Only two European universities – Cambridge and Oxford – are listed in the list of the top 20 universities world-wide. It is too early to say whether the new educational format will eventually meet its goal – European-wide acceptance of degrees, more transparency, more exchanges and mobility. The EPS Bologna project – this educational transition is interestingly named after the city with the first university in Western Europe – will shed some light onto this development.

More light will be shed on the overall development of a European Research Area and Knowledge Society by Prof. Gago, Portuguese Minister for Science, Technology and Higher Education when he talks to us, later in this ceremony.

CERN, founded in 1954, was a model which encouraged Bernardini, a member of the CERN board of directors, to venture the founding of EPS. CERN celebrated its 50th anniversary in 2004. Why do we need anniversaries, what brings us here together to celebrate the 40th anniversary of EPS? A jubilee is a good reason to collectively remember a memorable moment, which is important enough not to be forgotten but not so important to celebrate it every day or month or year. The beauty of the decadal system helps us to find a good compromise between continuous commemoration and total forgetting. This tradition is older than the Roman Empire though the Roman Caesars made ample use of it via the Dies Imperii. They celebrated the 10th anniversary, the Vicennalis, the 20th and 30th anniversary. Only 2 Caesars could personally attend their 30th anniversary. None survived 40 years in business.

This year, we will celebrate Max Planck’s 150th birthday and both the Max-Planck Society and the DPG will remember the founder of quantum mechanics and guide of physics in Germany through the dark period of the Nazi time. We will also remember that the fission of uranium happened 70 years ago. Otto Hahn and Lise Meitner, two of the principle scientists involved in the discovery and the interpretation of the unexpected observation that barium appeared, died in the year when EPS was founded – 40 years ago.

They also have to be commemorated together with others I have not mentioned. It will be interesting to see to what extent the public will take note of these instances and heroes and heroines of physics. The competition will be tough. Carla Bruni – better known under this name - will also celebrate her 40th birthday this year.

Nowadays, free mobility for scientists and scientific ideas and information is possible restricted only by the available financial means. With this topic – the financial restrictions – I want to finish examining the past and rather talk about the present. The financial possibilities of EPS come to a large extent from the contributions of the large physics societies of Germany and UK. A large contribution comes from the French Society in kind because the SFP prints free of charge EPN, Europhysics News, our society bulletin. The monetary value of this contribution is substantial. The Presidents of these three societies are here, Prof. Leduc from SFP, Prof. Saraga from IOP and Prof. Umbach from DPG. The three Nobel Prize winners of 2007, Prof. Ertl, Fert and Grünberg, are members of these societies. Congratulations!

EPS is grateful for the continuous support it gets from all of its members, particularly the large societies, which allows it to act and accomplish its own mission. Some of the EPS budget is used to help those society members which otherwise have difficulties to benefit from the scientific progress in the more established parts or Europe. EPS helps the young and not yet established scientists and EPS played an important role in the integration of physics after the decay of the Soviet Union. EPS is entrusted by the large societies to spend their money for the European ideals of providing chances and opportunities for all talents. We know that organisation helps science to progress; but this is not all. Individuals often initiated the revolutions in science. Such talents can grow everywhere and we are all aware of the tremendous scientific power of Russia. The traditions their great physicists have founded are still in place in the Eastern European countries. This potential is of high value for a developing Europe. Nowadays, many excellently trained graduates and post-docs from the East European countries work in western institutions and the connections they establish will tighten the European network when they return. It is the experience in Japan, Korea and China that those who once left often return with the introduction and the potential of a scientific career abroad.

EPS shares the situation of basically all European institutions. Its societies represent a wide distribution in membership, organisation, influence, history and self-conception. The DPG has 55 000 members, the IOP is the unique shareholder in one of the largest scientific publishing houses, which is not privately owned but part of a Learned Society. The DPG was founded in 1845, IOP in 1874, and Bernhard Nunner and Bob Kirby-Harris, the Secretaries General, may smile about our early efforts to celebrate EPS. Like the other European organisations, EPS has to find the balance between these partners of unequal weight and often disparate interests. We all must be informed and aware about the situation of other physics societies in Europe and we must develop a sympathetic understanding. Just as in other European aspects, the large and rich countries have a specific responsibility in the goal of providing equal opportunities in Europe and this responsibility roots in the benefits Europe ultimately provides also for those who carry a larger burden. The scale for our efforts is the progress of physics in Europe, which is embedded in overall peaceful development of and in Europe.

Such a course is not ensured, not automatic but needs and needed great efforts. The fate of Max Planck and his family reflects in a very exemplary form the long way Europe had ahead of it before it reached its equilibrium in the present peaceful period. Max Planck's brother, Hermann, was killed in 1871, in the German-French war; his oldest son, Karl, died in World War 1 in Verdun in 1916, his 2nd son, Erwin Planck, was killed by the Nazis January 1945, because of his involvement in the July 20th assassination attempt against Hitler. Nowadays, fates like this are unlikely to repeat themselves in Europe and scientists can concentrate much more than ever on their goal in life and they benefit more than ever from the growing scientific potential of Europe.

How will EPS develop amidst a process of ongoing consolidation of Europe? Luckily, the future is not deterministic. But still, one can think about the boundary conditions under which the future development will evolve. Europe - like other regions - will have to continuously sustain the pressure emerging from globalisation. The fascinating and breathtaking development of Asia will continue to affect Europe. The impact of globalisation on science will be manifold. The most critical aspect of globalisation will be the new volatility of the best brains which will concentrate where the working conditions are best. Globalisation will lead to new scientific centres and this process will cause winners and losers.

In the global competition, achievements in physics will increasingly be seen as European successes and not so much as national achievements – or, in the case where theydon't materialize, as weaknesses of the European system. Inside Europe, the large science institutions will abandon specific national attachments provided by their location, their history or their funding pattern. Like the large industrial players they will act supra-nationally – *e.g.* the Max-Planck society plans to found institutions also in other parts of the world.

But also the European regions will be newly arranged in a process where the national borders will not play a role as barriers any longer. The links to Belgium and Netherlands grow to a possibly larger importance for North-Rhine-Westphalia than those to its immediate German neighbours; similar developments can be observed in the upper Rhine area; Basel, Freiburg, Strasbourg, Karlsruhe see their future in a tri-national metropolitan area and there are plans to apply for the Olympics in 2020.

These developments continue a process which started in physics long ago, when the national languages lost their importance along with the journals who kept publishing in the national language. The large national physical societies, which have the power of but also the responsibility for a large membership, will come to recognise that within an expanding Europe the national shirt is too short. Their traditional importance, their financial means, their political and societal links will not be satisfied any longer by the exclusive restrictions to national limits and they will find that they have to replace a national mandate by a less restricting one. It is possible that the Balkan Physical Union, a union of 10 Balkan countries, already anticipates the replacement of the national focus for a wider perspective. The importance of EPS will grow in this period; but its role could eventually change.

This transition to larger spheres of interest and influence provides an opportunity and a risk that reflect the opposite end-points of the European development – cooperation and competition. The role of EPS will be to facilitate and mediate this process. The tasks and goals of EPS and national societies will no longer be in well-defined spheres. This was the case in the period where the European science integration was a small item on the national agenda. In the future, the impact of European integration will also have higher priorities nationally. Up to now, presidential reports at assemblies of national physical societies hardly touch European affairs and they did not include a chapter on the work of EPS or on the cooperation with EPS. I know that this is the case in the national society of my membership; I assume it is the same in others. This is a pity but I predict the period, where the report of a president of a national society to his members is incomplete if it does not reflect the work of EPS. It should be the ambition of EPS to keep this period short.

The consequences of this process will be that EPS and national physical societies identify joint areas of interest where they cooperate and carry out joint projects. According to the given interests, these project and goal oriented partnerships will not always include all national societies. Such sub-structures exist already for example for the publication topic, because only those national societies with major publication interests attend; the same is correct for the energy topic where 13 national societies are involved and will soon meet in Varenna, following the invitation of the Italian Physical Society, and for the Bologna study, which engages 16 societies. Out of activities with participation limited to those interested, affected and financially contributing, groups with preferential relations to EPS will emerge and these relations will define themselves according to the topic under consideration.

There are already many specific topics, which have to be tackled - like the development of a European publication platform – all interests are represented in this room, and I hope that we will make progress in the near future. Other topics are how to concentrate the disparate European conference activities, how to arrange conference activities with the national societies and to agree with APS and AAPPS on the sharing of large international conferences as recently the EPS accelerator group successfully managed in their field. We jointly have to implement a process that allows us to identify new and more interdisciplinary fields and we have to respond with new divisions. It would be highly desirable that such a process develops bottom up – the only way to success. In this category falls also the question whether EPS should penetrate the heart of the future decision processes and open – together with participating national societies - its own office in Brussels. The larger the weight of European decisions, the more important will be the reaction and response of EPS.

If this shift in weight toward a more central role for EPS, driven by the integration process of Europe and its increasing funding of science and technology, should indeed happen, it will not only affect the working habits of EPS but possibly also its structures to better reflect the growing representative character of EPS and its role as a spokes-institution. In addition to the main organisational structures of EPS, the Council and the Executive Committee and its meetings, there will be smaller, project-oriented activities and meetings with an attendance limited to those interested, affected and financially contributing, those who have – case by case – preferential relations to EPS.

The character of EPS is, however, determined by one major principle, which has always guided its deliberations – that it represents small and large societies in fundamental issues on equal footing. Equality is the backbone of EPS governance and with this principle, it met and still meets its responsibility to be a valuable and loyal partner of the European integration process.

Let me – at the end – remind you on the farsightedness of the founding fathers of EPS. EPS was on purpose constituted in its governance as an international and largely autonomous society based on individual members and not as an umbrella structure in the form of a federation of national societies. Thus EPS could avoid becoming the playing ball of national political interests. This independence allowed EPS to raise its voice in the Shakarov case or when physicists were imprisoned because they insisted on scientific freedom and the human rights as generally binding references. As the physicists were not forced to carry a mandate into the EPS organisations, which would easily have been dominated by the post-war or cold-war situation, by the invasion of Czechoslovakia, by military coups, or by the deployment of Pershing and SS-20 missiles, the strongest element in the personal relations between physicists could evolve and accomplish its beneficial action across borders and societal differences. This unifying element is the knowledge of the scientific achievements of others and the respect for them. Awareness and respect provide a profound basis of closeness, cooperation, trust and confidence which not only preserved the integrity of EPS and kept the society together during the periods of political confrontation but made EPS into a respected voice in the process of European unification and scientific development. The role that EPS played in this period of our history is a commitment and has set a standard we may not abandon when we try to shape the future or to adapt the society to the external changes. ■

VIEWS FROM PRESIDENTS STAFFORD AND RICCI ››› 40YEARS OF EPS

THE EUROPEAN PHYSICAL SOCIETY AND HOW IT ALL BEGAN

G.H. Stafford (UK),
EPS President, 1984-1986

I have in my possession a treasured document, beautifully produced, which summarizes the proceedings of a *'Meeting on European collaboration in Physics'* which took place in Pisa on the 16th and 17th April 1966 and which is listed as being under the sponsorship of the President of the Italian Republic. It was a meeting arranged by Professor Gilberto Bernardini at the Scuola Normale Superiore in Pisa. At the time he was head of that institution and had the splendid title of Grand Priore. It was a marvellous location to have as the place where the European Physical Society all began. One of the greatest scholars in humanities in the XIX century, Pasquale Villari, called the Scuola "*An institution founded on free principles where you must always put your cards on the table*"! I was privileged to have been invited to attend that meeting at which there were a total of 88 physicists from Europe and the USA.

The opening address was delivered by Bernardini and he started by reading out a message from the President of the Italian Republic which I copy below:

▼ G.H. Stafford

"I wish to convey my warmest regards to all the distinguished scientists taking part in today's conference organized by the Italian Physical Society. I should like to express my deep satisfaction at such a gathering, which, by setting out to examine the possibility of forming a single and free association of European Physicists, is an important step towards a more organic collaboration in the highest aim of Science. In this belief I send you my most sincere best wishes for a profitable and constructive meeting."

Bernadini goes on to say: *"It is an opinion shared by many people that the time is ripe for the institution of a European Physical Society. Already on many occasions we have felt that a "single and free association of European Physicists" would contribute towards strengthening the links existing among us, in a constructive and positive manner."*

Now the interesting thing is that although I am listed as a member of the Steering Committee (along with S.R. de Groot, H. Filtuth, A. Lagarrigue, C. Moller and A. Zichichi) I am sure that when I went along to Pisa I did not know that Bernardini had the founding of the EPS as his primary purpose. I am sure that it is not just a lapse of memory on my part because of the format of the conference and how matters progressed. There were four invited talks presented on a hotchpotch of topics namely:

1. How to improve the scientific level of the European journals of physics, by J. Hamilton;
2. The future of Il Nuovo Cimento, by G. Bernardini;
3. Should we have a European physical society? By S.R. de Groot;
4. Scientific and technical policy followed in some European laboratories, by T.G. Pickavance and G.A. Stafford.

The procedure we then adopted was to form a Working Party for each of the above subjects and on the last day we held a meeting of all participants to report the findings and agree on a resolution. The following was the resolution subsequently approved:

"The meeting was strongly of the opinion that steps should be taken to found a European Physical Society. Its functions would be:

1. To provide a forum for the discussions of subjects of common interest to all European physicists.
2. To provide means whereby action can be taken on those matters which cannot conveniently be handled by national bodies. For example, the formation of an information bulletin of a European journal similar to 'Physics Today'.
3. To fulfil a coordination function in the organisation of scientific meetings, summer schools and the like.

It is hoped that it will be able to improve contacts between the young physicists in Europe by, for example, the provision of travelling fellowships and so on. It is proposed that the Society should be open to all physicists but it is anticipated that to carry on its work a number of specialist sections will be formed. Although we consider that the function of the Society will be the furtherance of European physics we believe membership should be open to all qualified physicists.

In the short time that has been available and in view of the limited information and specialised experience at our disposal it has clearly not been possible to work out the details of such an organisation and indeed there are many possibilities, varying from a completely new Society to one which is merely a federation of existing bodies. There are obviously many shades of possibilities between these extremes.

We recommend that two steps should immediately be taken:

1. Existing European bodies as well as other organisations that may be thought to have an interest should be approached by Professor Gilberto Bernardini.
2. He should convene a small working group for further action.'

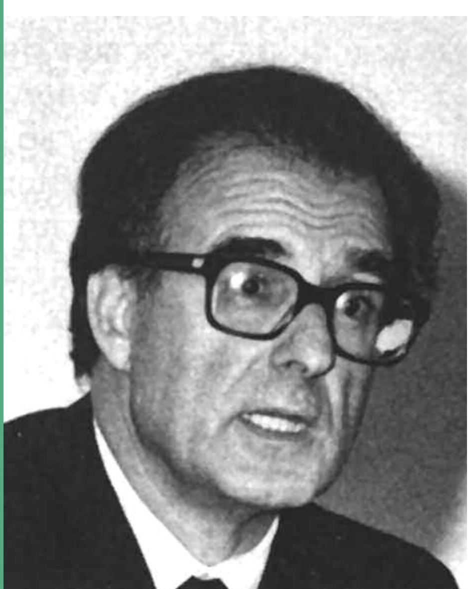
The small working group of which I was a member, was duly convene and two and a half years later in Geneva on 26 September 1968, the constitution of the Society was formally adopted and the European Physical Society came into being. Not surprisingly, Bernardini became its firs President. The formal creation of the Society was followed by an inaugural conference in Florence on 8-12 April 1969 under the title 'The growth points of Physics.' There were over 850 participants. The inaugural conference was made possible through very generous financial help from the Italian government. A considerable sum of money was expressly provided to enable young physicists to attend. It was a substantial sum for I recall spending the whole of the registration period signing cheques for the young physicists. I remember that the meeting was a great success both scientifically and socially. ■

EPS AT THE FOREFRONT OF THE CHALLENGES OF THE XXI CENTURY

Renato Angelo Ricci,
EPS President from 1988 to 1991, EPS fellow

"We do believe, then, that Europe is the country that has the best chance of bringing a fundamental contribution to the creation of this new approach to life where science will represent a new humanism for the structure of the Societies, as well as for the comfort of the individuals. The European Physical Society, according to us, should be framed within these hopes."

▼ **Renato Angelo Ricci**



This is the message of Gilberto Bernardini, one of the founding Fathers of the EPS and the first President of the Society, in the occasion of the inauguration ceremony in Geneva, September 1968.

No doubt that such a wish (more precisely the "dream" of the EPS pioneers) has been, during the 40 years of EPS life, the main object to be attained in the course of the various activities and enterprises by all the members of our scientific community. As a former President of the EPS during three years (1988-1991), I would like to remind you of at least three important facts where I was personally involved not only during my Presidency but also during my scientific career.

First, the creation of a common scientific journal, *"Europhysics Letters"* in 1986 by the merging of the French *"Journal de Physique Lettres"*, and the Italian *"Lettere al Nuovo Cimento"* (I was President of the Italian Physical Society at that time). The importance and the visibility of such an enterprise is today under the eyes of everybody.

Second, and this was very gratifying for me, the unification of the two German Physical Societies (the Eastern and the Western), under the auspices of EPS, just one year before the "fall of the Berlin wall" after long but useful contacts with our colleagues both from the West and the East. In fact the relationships with the Eastern European societies were, from the beginning, so strong and so determined that EPS has always been a very significant example and even a reference point of the possibility to realize the "European dream" of the pioneers. Let me remember especially in this context, just as for all the EPS activities, the very precious and continuous collaboration of the not to be forgotten Gero Thomas.

Third, but not least, the celebration of the 20th anniversary of EPS in Pisa in 1988, just after my election as a President, through a joint **EPS-SIF Seminar on "The Past and Future of Physics in Europe"** where (and I am quoting the report of E.N. Shaw in a special issue of *Europhysics News*) in spite of a storm *"bringing torrential rain in the hours leading up to the opening of the seminar… one could admire the robustness of our past leaders (many of whom are no longer young) who bright and sprightly were there for the opening ceremony, trousers soaked to the knees notwithstanding"*.

Those leaders were several of the former Presidents (before me): G. Bernardini, H.B.G. Casimir, A.R. McIntosh, A. Zichichi, G.H. Stafford, and W. Buckel.

In spite of the weather and in any case gratified by the floating down the Arno of a thousand burning candles to honour, as in every year on just the same day, the Patron of Pisa, Saint Ranieri, the meetingwas very successful and represented an important scientific event of EPS.

There were of course many other important occasions and issues of which one could remind you such as the EPS general Conferences; among them in particular the EPS-9 in Florence in 1993, marking the 25th anniversary of the Society, with the opening ceremony held in the magnificent **"sala dei 500"** of Palazzo Vecchio, where 25 years before the first EPS conference was held.

The opening address was given (and this was the last time he appeared in an official international event before his death) by Gilberto Bernardini.

Leaving my office to Maurice Jacob, whose recent death has been of great sorrow for me, in Budapest in 1991, I was and I am still convinced about the central role and the excellent future of EPS, with its involvement in so many challenging aspects of the modern society.

Just as I could say in 1988 (about 20 years ago) in my first Presidential address (see Europhysics News vol. 19, 5, May 1988): *"…This common heritage is a challenge for future actions and enterprises which will take EPS into the world of the XXI century. Just think of the problems posed by: energetic needs; improvement to the standard of life of more human groups; new ways of balancing technological development and environmental protection; and the new possibilities offered by informatics, biotechnologies and newly discovered materials. EPS with the essential support of all its members can play a consequential role in this challenging cultural and social venture. This is not only a wish, but also a commitment"*. ■

12TH INTERNATIONAL CONFERENCE ON MPTL »» CONFERENCE REPORT

MULTIMEDIA IN PHYSICS TEACHING AND LEARNING - HTTP://MPTL12.IFD.UNI.WROC.PL

This conference was held at the University of Wroclaw, 13-15 Sept. 2007, and organised by Prof. E.Dębowska and Dr. T.Greczyło in cooperation with the international advisory board. It belongs to a series of workshops [1], and was attended by 66 participants from 19 countries. In addition, members of the CoLoS group (Conceptual Learning of Science [2]) and the Supercomet 2 project [3] joined our meeting. On the day before the conference, a workshop for Polish high school physics teachers, on Modelling Science with Easy Java Simulations, led by Francisco Esquembre and Wolfgang Christian, was held.

The scientific program of MPTL12 contained 7 invited talks (see below), 29 interactive posters (traditional posters + PC and internet connection) and 16 oral presentations.

- J. Belcher (MIT, USA), "The MIT TEAL Simulations and Visualizations in Electromagnetism"
- W. Christian (Davidson College, USA) and Francisco Esquembre (U. of Murcia, Spain), "Modelling Science with Open Source Physics and Easy Java Simulations"
- Fu-Kwun Hwang (National Taiwan Normal U., Taiwan), "Integrating Java Simulations into Physics Teaching and Learning"
- R. Teese (Rochester IT, USA), "Video Analysis - A Multimedia Tool for Homework and Class Assignments"
- H. Schmidt (U. of Appl. Sci., Darmstadt, Germany), "Multimedia in testing industrial products"
- L. Mathelitsch (U. Graz, Austria) and H-J. Jodl, (Tech. U. of Kaiserslautern, Germany): "Evaluation of Multimedia Learning Materials in Condensed Matter Physics and Particle Physics"

The oral presentations were grouped into 4 main topics:

- Possible uses of multimedia in creating courses in physics, especially the Open Source Physics (OSP) project, which is a synergy of curriculum development, computational physics, computer science, and physics education for scientists and students wishing to author interactive computer-based curricular material.
- Simulations and visualizations.
- Videos and remote controlled laboratories.
- Multimedia in applied sciences.

Further Conference highlights were:

- Interactive poster session (2 sessions, 2 hours each)
- Evaluation of multimedia material in the teaching and learning of Condensed Matter Physics and Particle Physics - worldwide offered software products were evaluated by the European working group "Multimedia in Physics Teaching and Learning" and the MERLOT/Physics Editorial Board. Example of recommended materials were presented with a discussion of the common characteristics of these resources and general findings of the reviewers. Formal reports about equivalent evaluations concerning Electricity and Magnetism (Szeged 2006), Statistical and Thermal Physics (Berlin 2005), Mechanics (Graz 2004), Optics (Prague 2003) and Quantum Mechanics (Parma 2002) can be found in the websites of the respective workshops [1]. A summarizing article with updated evaluations of all recommended material is planned.
- The Saturday morning session in the Multi-Centre (Wroclaw Interactive Educational Centre). The aims of this institution are: to complement the more traditional methods of teaching and learning, to educate for the information society, to develop music, artistic and design skills, as well as to cooperate with Wroclaw schools, community centres and teachers' education centres.

The message in all contributions to this workshop was to point out the importance of the use of MM in the teaching and learning of physics. It was stressed that only very few multimedia products available in www pages are excellent.

The e-proceedings of the Wroclaw meeting can be found under the address http://mptl12.ifd.uni.wroc.pl/proceedings.html. E-proceedings from former workshops on MPTL and the additional information about this series of workshops can be obtained at the web address [1] or by contacting jodl@physik.uni-kl.de or robert.sporken@fundp.ac.be, previous and present chairmen of these workshops.

In 2008 the 13th workshop on MPTL will be organized as a GIREP-MPTL Joint Meeting on August 18-22 in Nicosia, Cyprus (www.ucy.ac.cy/girep2008/, contact: girep2008@ucy.ac.cy).

Ewa Dębowska

References

[1] www.mptl.eu

[2] www.colos.org

[3] http://supercomet.no/gb/supercomet_2

SELECTION OF CANDIDATE MISSIONS FOR ESA'S NEW COSMIC VISION PLAN 2015-2025 ››› PROJECT SELECTION

The first steps of the next phase of European space science have been taken with the selection of candidate missions in the framework of ESA's new long-term plan Cosmic Vision 2015-2025 [1]. At its meeting held on 17-18 October 2007 in Paris, ESA's Space Science Advisory Committee (SSAC) selected candidates for future missions from a broad list of 50 proposals submitted by the scientific community last summer. The maturity of most of the proposals and the level of international cooperation were two key features of the response. The final set of candidates, which have been selected for a first round of feasibility studies is given below.

The missions fit well within the four Cosmic Vision science themes (1): the conditions for life and planetary formation, the origin and evolution of the Solar System, the fundamental laws of our cosmos and the origin and structure of the Universe. This coherence speaks volumes for the prescience of the committee chaired by G. Bignami. It also shows the breadth of the European community and the vitality of their stock of ideas.

International cooperation plays a central part in many of the proposed missions. Inevitably the missions will thus be "world missions" and one can see in that an important role for ESA in orchestrating the cooperation.

Solar system

LAPLACE is a mission to Jupiter and its moons considered as a small planetary system in its own right. The mission will deploy three orbiting platforms to perform coordinated observations of Europa, the Jovian satellites, Jupiter's magnetosphere and its atmosphere and interior. The mission is proposed as a collaboration with NASA and JAXA, the Japanese space and exploration agency.

TANDEM is a mission to Saturn, Titan and Enceladus, composed of an orbiter and a carrier which will deliver a balloon and three probes onto Titan. The mission will investigate the Titan-Enceladus systems, their origins, interiors and evolution as well as their astro-biological potential. The mission is based on a collaboration with NASA. Based on the outcome of negotiation with the international partners, the final decision on the target planet, *i.e.* Jupiter or Saturn, will be made in the coming year.

CROSS-SCALE is devoted to a deeper study of near-earth space. It is proposed as a 12 spacecraft mission to make simultaneous spatial and temporal measurements of the plasma near Earth to address fundamental questions such as how shocks accelerate and heat particles or how magnetic reconnection phenomena generate or convert energy. The mission is proposed in collaboration with JAXA.

MARCO POLO is an asteroid sample return mission with JAXA. It consists of a mother satellite which carries a lander, sampling devices, re-entry capsule and associated instruments. The mission objectives are to characterise a near-earth object at multiple scales and return a sample to study the origins and evolution of the Solar System, the role of minor bodies in the process, the origin and evolution of Earth and of life itself.

Astronomy

XEUS, X-ray Evolving Universe Spectroscopy, is a next-generation X-ray space observatory to study the fundamental laws and the origin of the hot, million-degree universe (*e.g.* growth of super-massive black holes, evolution of galaxies and large-scale structures and matter under extreme conditions). The XEUS concept is based on a telescope satellite and a detector satellite that would fly in formation in a halo orbit around the second Lagrangian point. Discussions have been started with interested international partner agencies to ensure the earliest involvement in study work.

DARK ENERGY mission. Two proposals **addressing the study of** dark matter and dark energy have been received. **DUNE** (the dark universe investigator) is proposed as a wide-field visible and near-infrared imager, while **SPACE (the near-infrared all-sky cosmic explorer)** is conceived as a near-infrared all-sky

Call for candidates : Condensed Matter Division Board

The Board of the EPS Condensed Matter Division is organizing elections to recruit two new members to the CMD Board. Nominations should be sent, together with a short CV (1 A4 page) and a statement of acceptance from the candidate, either by email to **d.lee@eps.org** or by regular mail to:
EPS, Condensed Matter Division Board Candidate, BP2136, F-68060 Mulhouse Cedex (France).
Deadline for receipt of nominations: 31 July 2008.
Self-nomination is not possible.
The members of the Board of the Condensed Matter Division are expected to attend Board meetings, which take place twice a year. Among the activities of the Condensed Matter Division are the organization of the biennial EPS Condensed Matter Conference (www.cmdconf.org) and the award of the Europhysics Prize for Condensed Matter Physics. The CMD Division also provides input to EPS on issues related to condensed matter physics, and includes several sections which focus on specific areas of condensed matter physics.
For further information go to:
http://cmd.karlov.mff.cuni.cz/cmd_web/

spectroscopic surveyor. Given the significant differences between the proposed technical approaches, before the assessment study is initiated, an independent trade-off phase will be performed to define a European-led dark energy mission that is timely in the international context.

PLATO is a photometry mission for the detection and characterisation of transiting exoplanets and the measurement of the seismic oscillations of their parent stars. The mission is focussed on rocky exoplanets around brighter and better characterized stars than its predecessors. Observations will be complemented by ground- and space-based follow-up observations to derive the planet's masses and study their atmospheres.

SPICA is the next generation medium-to-far-infrared observatory equipped with a large-aperture cryogenic telescope. The mission is conceived to perform wide field, high sensitivity photometric mapping at high spatial resolution and spectral analysis to investigate the origin of galaxies and stars. It will also provide for coronography of planets and planetary disks. It is proposed in collaboration with the Japanese space and exploration Agency, JAXA, with ESA providing the telescope and a contribution to the operations and an imaging spectrometer via national contributions

All the mission candidates start now a competitive assessment study activity followed by an important down-selection at the end of 2009. The selection cycle will end in late 2011 when two missions will be adopted for implementation by ESA's Science Programme Committee, with launches planned for 2017 and 2018 respectively.

The assessment study activity will be complemented with a number of enabling technology studies related to proposals addressing highly ranked scientific objectives but that unfortunately lacked the technology readiness required for consideration in this selection cycle. These studies will cover the field of direct detection of terrestrial-size exoplanets and their spectroscopic characterization as well as the fields of ultra-high cosmic rays, ultra-stable clocks, cold atom interferometry, and accelerometry, solar probes and the development of RTGs.

Sergio Volonte, **Marcello Coradini** and **Fabio Favata**,
ESA Head Office, Paris

[1] Cosmic Vision, Space Science for Europe 2015-2025, ESA publication BR-247, 2005

IUPAP AWARDS ››› PRIZES

IUPAP SUNAMCO Senior Scientist Medals 2008

From time to time IUPAP Commission C2 (Symbols, Units Nomenclature and Fundamental Constants) awards a SUNAMCO medal in order to recognise outstanding contributions to the area of physics by laboratories or senior scientists within the ambit of the Commission. The awards of SUNAMCO Medals are made on the basis of nominations made to the Commission - from either within or outside IUPAP Commission C2.

The IUPAP Senior Scientist Medals in Fundamental Metrology 2008 are awarded to:

- **Heinz-Jürgen Kluge** (GSI Darmstadt, and University of Heidelberg, Germany) and **Georg Bollen** (Michigan State University, USA) for the innovation of the Penning trap mass spectrometry technique for short-lived isotopes and developing the highest precision in on-line mass measurements.
- **David E. Pritchard** (Cecil and Ida Green Professor of Physics, Department of Physics, Massachusetts Institute of Technology (MIT), Cambridge, MA USA) for contributions to the use of Penning ion trap mass spectrometers in the ultra-high precision determination of atomic masses.

SUNAMCO Young Scientists Prizes 2008

Commission C2 of IUPAP, that is concerned with symbols, units, nomenclature, atomic masses and fundamental physical constants, awards up to three IUPAP Young Scientist Prizes in Fundamental Metrology every three years on the occasion of conferences such as the Int. Conf. On Exotic Nuclei and Atomic Masses (ENAM) and Conference on Precision Electromagnetic Measurements (CPEM). The Prize is $1000 plus an IUPAP medal.

The recipient of the Prize should have a maximum of 8 years research experiences (excluding career interruptions) following Ph.D. on January 1 of the year of the Prize and should have performed a work of outstanding scientific quality in fundamental metrology.

The Prize winners are:

- Dr **Sébastien Bize**, Laboratoire Systemes de Reference Temps-Espace (LNE-SYRTE), Paris (FR), for contributions to improvements in the precision of caesium fountain clocks, precise optical frequency measurements and measurements that test fundamental physical laws and
- Mr. Dr. **Frank Herfurth**, Gesellschaft für Schwerionenforschung(GSI) Darmstadt (DE), for contributions to the development of traps for high-precision mass measurement of short-lived isotopes and measurements that test fundamental physical laws, are the 2008 laureates.

Adj prof Leslie R Pendrill,
IUPAP C2 SUNAMCO Chair

ECONOMISTS HELP CLIMATE SCIENTISTS TO IMPROVE GLOBAL WARMING FORECASTS

››› CONFERENCE REPORT FROM THE ESF

The ESF workshop "Econometric Time Series Analysis applied to climate research" was held in Frascati, Italy, in September 2007. Climate scientists are collaborating with experts in economic theory to improve their forecasting models and assess more accurately the impact of rising atmospheric carbon dioxide levels. Although there is broad consensus that there will be a significant rise in average global temperature, there is great uncertainty over the extent of the change, and the implications for different regions. Greater accuracy is urgently needed to provide a sound basis for major policy decisions and to ensure that politicians and the public remain convinced that significant changes in consumption patterns and energy production are essential to stave off serious consequences in the coming decades and centuries.

The climate modelling community has become increasingly aware that some of the statistical tools that could improve their modelling of climate change may already have been developed for econometric problems, which have some of the same features. The European Science Foundation (ESF) brought these two communities together for the first time in a recent workshop, sowing the seeds for future collaboration.

"We achieved our goal of bringing together people from two very distant but equally valuable fields," said the workshop's co-convenor Peter Thejll. *"It was designed as a one-way session whereby econometricians were supposed to convey knowledge of econometric methods to the climate researchers."*

This has already proved highly valuable because economic and climate models require similar kinds of statistical analysis, both for example involving serial correlation where the aim is to predict the future value of a variable based upon a starting value at an earlier point in time. In economics such a variable might be the price of a commodity, while in climatology it might be temperature or atmospheric pressure. In both cases the variables change randomly during successive time intervals subject to varying constraints within a closely defined zone, and therefore can be analysed using similar "random walk" techniques.

"To solve important climate problems related to climate change and change attribution with statistics, these methods have to be used and understood by climate researchers," said Thejll. *"We brought together people who understand these problems and had a great, and informative, time."*

Thejll is confident that the new found cooperation with the econometric community will improve climate modelling and forecasting, but first there is a need to digest some of the new tools and ideas. The aim is to introduce greater statistical sophistication into climate analysis, partly by understanding better the correlation between different aspects of change, for example how one region impacts another. *"We first need to see the spread of econometric methods so that we no longer read climate research papers that ignore important statistical problems"*, said Thejll wryly.

This will lead to an important first step towards better climate change predictions models – understanding the limitations of existing models. *"One improvement that can follow from the use of econometric methods in climate research is a better understanding of the level of ignorance we have,"* said Thejll.

One problem at present is that uncertainties are commonly underestimated, and this makes it very difficult to predict with much confidence even the broad climatic consequences of rising atmospheric carbon dioxide levels. But Thejll hopes and expects that by incorporating the key tools of econometric modelling, climate prediction will become much more accurate and valuable. ■

More information:
www.esf.org/fileadmin/be_user/ew_docs/06-047_Programme.pdf

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Conference announcements

NANOSEA 2008
The 2nd International Conference on Nanostructures Self-Assembly (Nanosea) will be held in Villa Mondragone Conference Centre (nearby Rome), 7-10 July 2008.

›››**Website:**
www.nanosea2008.roma2.infn.it

SigmaPhi2008
The International Conference on Statistical Physics (SigmaPhi2008) will be held in Crete, 14-18 July 2008.

›››**Website:**
www.polito.it/sigmaphi2008

10th Granada Seminar on Computational and Statistical Physics
The 10th Granada Seminar on Computational and Statistical Physics. "Modeling and simulation of new materials", will be held in Granada, Spain, from 15 to 19 September 2008.

›››**Website:**
http://ergodic.ugr.es/cp/

Chemical Control with Electrons and Photons
This conference, organised by the European Science Foundation (ESF), in partnership with the Austrian Science Fund (FWF) and University of Innsbruck (LFUI), will be held in Obergurgl University Centre, Ötz Valley, Austria, 22 - 27 November 2008.

›››**Website:**
www.esf.org/conferences/08261

COSTING ENERGY »» OPINION

John Beeby, Leicester University (UK), Treasurer of the EPS

Scientists, especially physicists, are frequently concerned about the unscientific nature of many media and political comments. Just one example is the comparison of like with unlike, a process especially prevalent in discussions of energy production, energy consumption and in the resulting policies. It is noticeable that the specification of renewable energy sources is frequently quoted in units of 'number of households supplied' without any reference to their duty cycle and the consequent need for back-up facilities. What offends me, and I am sure many others, is that it is effectively impossible for an observer without more detailed information to make a sensible judgement about the value of such projects.

This article is about the flow of energy into and out of various activities, rather in analogy with elementary fluid dynamics. Energy here means electrical power, heat and fuels from all sources. We obtain our energy from the ground in the form of coal, gas, oil and uranium and directly or indirectly from the sun in the form of biofuels (including wood), hydropower, wind power, solar heating and so on. We use the energy to provide us with food, clothes and other goods, heating and transport. It is the balance between the input of energy into activities and the flow of energy from them which is of interest here. This will be discussed with particular reference to the production of electrical power and to energy conserving projects.

For most purposes energy has a monetary cost. This differs between sources but should be kept in approximate equality (discounting taxation) through competition mechanisms. In the hope of simplifying and rationalising discussions regarding energy production and use, I suggest in this article a simple *rule of thumb* intended to provide a useful guide by means of which a quick comparative understanding of these energy issues can be readily obtained. The *rule* concerns the fundamental question of how much energy is used to provide particular goods or services. I argue that *"the cost in **input energy** of an item or a service is proportional to the **monetary cost** of the item or service"*. As will be shown, application of the *rule* of thumb casts serious doubt on the value of some current high-profile projects.

I am sure that this *rule of thumb* is already known and used, especially in some parts of the engineering sciences, but it is certainly not well known to decision makers! For example, physicists seeking to develop improved photoelectric devices always concern themselves with the efficiency required to produce a ***financially*** viable product which, according to the *rule*, will produce more energy than is required to produce it. On the other hand, both governments and individuals are sometimes content to invest in energy sources with excessively long, even infinite, monetary payback times on what is almost certainly a false assumption that such sources benefit the energy economy. According to the *rule*, if a project cannot pay for itself in monetary terms (calculated using constant energy costs as specified below) then its energy production, or saving, is less than the energy required to produce it, which benefits no-one.

Before analysing further the consequences of the *rule*, it is helpful to explain how it can be understood. The cost of a project can be split into three components: (1) the direct use of energy such as in heating, fuel or electrical power; (2) the provision of sub-components and construction materials; (3) labour costs and profits. The *rule* is obviously true for any energy directly consumed. Energy is also used to produce and transport the sub-components and materials and the amount of energy can be estimated using the *rule* as proportional to the monetary cost. Note that this kind of circular argument is generally very weak but can be applied with some confidence in the case of major capital products because of the high proportion of costs which are energy related. Indeed, as energy costs rise the *rule* becomes more accurate.

The argument with regard to the third component, salaries and profits, is slightly different. The point is that any money paid out in this way will be used by its recipient, whether an individual or a corporation, to purchase energy, goods and labour services. Again, each component will involve the consumption of energy so that monetary cost and effective energy consumption will once more be approximately proportional. In this case what is paid for is a ticket for use of energy in the future: the energy may not be used immediately but it will eventually be consumed. It is this implied energy use which is so often overlooked. In passing one might note that implied CO_2 emissions are also often overlooked.

The *rule* can clearly be argued in reverse: if an energy source will pay for itself in monetary terms ignoring subsidies and at constant energy cost, then its construction will cost less energy than it will produce. From this alternative viewpoint the *rule* can be stated as *"the energy used in providing a product or service is given approximately by its cost divided by the cost per unit of energy"*. This division certainly gives the maximum energy used. Notice here that the monetary calculations must always be done at constant energy cost, otherwise at a time of rising energy costs energy wastage could be disguised by monetary gain.

An important element of cost is the tax revenue. This is used by governments to pay for their expenditure on energy, goods and services and, just as with individual expenditure, the monetary and energy costs will be approximately proportional. In particular, it can be noted that government subsidies of energy sources effectively purchase part of the energy required to produce that source (spending the taxpayers energy) and so must be discounted when assessing whether a source will pay for itself in monetary or energy terms.

There is a current policy in Europe to build energy-efficient homes. Some aspects of this policy are clearly beneficial, such as the use of cheap, efficient heat insulation. But others are not, such as the use of photovoltaic arrays and small windmills some of which will not, in their lifetime, pay for themselves in monetary terms. The *rule of* ▶

thumb suggested above then implies that they will not pay for themselves in energy terms and so their provision will overall **consume energy**. The same argument casts doubt on some dwellings where reduced future energy consumption is achieved at high capital cost. Unless there is cost benefit in monetary terms there will not be benefit in energy terms.

Similar arguments apply to the current pressure to build renewable sources of energy. As already noted, if they require government subsidy before they can pay for themselves in monetary terms, then they will probably be net consumers of energy and should not be built. This is not an argument against any or all renewable energy sources, only a suggestion as to how they can be assessed for their energy effectiveness. The same arguments would apply to non-renewable energy sources, but usually subsidy is not available in such cases nor are other arguments advanced to justify inadequate monetary returns. Finally, it is worthwhile to stress again that when looking at a proposal for the future production of energy the monetary return should be worked out at constant energy costs to apply the *rule of thumb* and determine the energy payback.

It is important to observe that the *rule* says nothing directly about CO_2 emissions or climate change. Quite simply, there are a variety of possible energy sources and they have different climatic consequences. However, one thing is clear. The use of energy sources which in their lifetime do not pay for themselves and hence are net consumers of energy is bad for the climate and should be resisted. Indeed it is worse than that. The over-costly building of power plants amounts to storing and wasting energy, often produced from fossil fuels. This both brings forward and increases CO_2 emissions.

Is the *rule of thumb* exact? Probably not, since it was justified by a circular argument which has some small weaknesses. For example, the element of salaries or profits which is saved may be recycled slowly or quickly by the bank, introducing a capital term into the monetary equation. Nevertheless, for large capital projects the *rule* should be a good approximation and decisions based on it reasonably well founded. Indeed, as already noted, as the relative cost of energy increases due to increased pressures of demand the *rule* will become more precise. Even now, projects which appear, using the *rule*, to be wasteful of energy should be viewed with great suspicion.

Finally, in true textbook style, some problems for the reader:

1. It can cost less to fly from Scotland to London than to take the train, even though flights are taxed and rail is subsidised. How is this consistent with the *rule of thumb*?

2. The *rule* could be seen as defining an energy content of money. Does gold stored in a central bank constitute stored energy?

3. Is it energy efficient to obtain cheaper organic vegetables by flying them from distant sources rather than producing them locally?

4. The growth of maize for ethanol production has increased food prices and the value of some farmland. In the context of the *rule* should this crop be applauded or discouraged?

5. Can gross domestic product (GDP) increase without increased energy consumption?

Don't send your answers to the author! ■

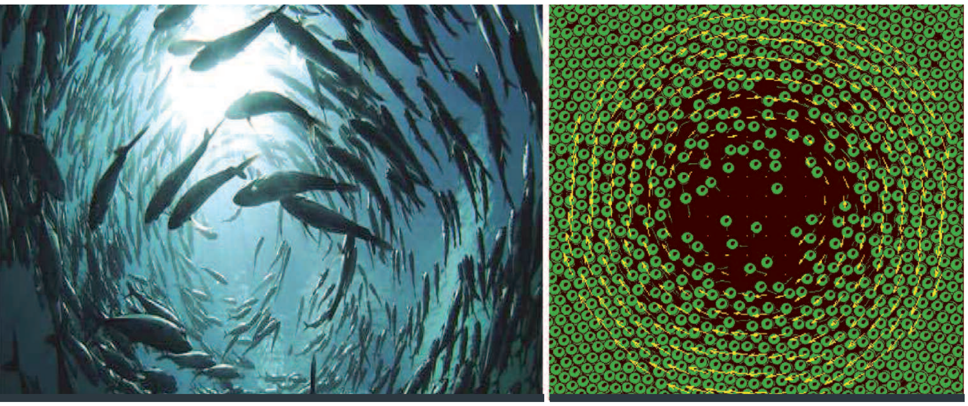
HIGHLIGHTS FROM EUROPEAN JOURNALS

Live Sand: Emergence of Animal-Like Collective Behaviour in Active Grains

Is there a connection between collective motions of a school of fish, a flock of birds and shaken sand? More than one would think, according to a study published in New Journal of Physics. Using a simple model, the authors argue that the behaviour of fish schools or bird flocks share dynamical motifs with much simpler granular matter, such as sand or gravel.

The study of animal collective motion utilizes agent models where the individual agent (animal) is described by a set of rules, reflecting the organism's ability in sensing the surroundings and steering its motion in a preferred direction. The hallmark of granular matter is irreversible loss of the kinetic energy in the course of collisions between the grains. The authors have started with simple isotropic colliding granular particles, but augmented them with a self-propulsion force modelling the ability of the animal to move. While these "propelled" grains are definitely no longer simple sand, they still lack any "biological" active sensing or steering abilities. Surprisingly, this model is sufficient for the emergence of vortices, group migration, and other collective movements mimicking motion of groups of animals.

The origin of collective behaviour, from bacteria colonies to fish schools, is a challenging problem in biology and is also recognized as a fundamental issue of statistical physics, Physics Today, Oct 2007. The new results show a surprising link between the dynamics of granular matter and the collective behaviour of animal groups: the simple physical mechanism of inelastic collisions is sufficient to produce motion resembling the behaviour of a complex biological system. By the same token, engineered algorithms of group behaviour can be useful for manmade autonomous systems, such as a swarm of robots scavenging a hostile environment. ■



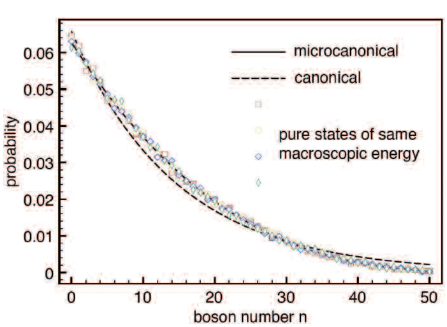
D. Grossman, **I.S. Aranson** and **E. Ben Jacob**, "Emergence of agent swarm migration and vortex formation through inelastic collisions", *New J. Phys.* **10**, 023036 (2008)

◄ **(a). Vortex of bigeye trevally in Malaysia (*New York Times, Nov 13 2007.*) (b). Vortex of self-propelled particles with inelastic collisions.**

Temperature of a pure quantum state

Statistical physics textbooks usually start with the equal a priori probability postulate. This postulate states that an isolated system in equilibrium is equally likely to be in any of its accessible states. Temperature is then defined as a statistical concept for this micro-canonical mixed state. Of particular interest are isolated composite systems consisting of a small system S weakly coupled to a large heat bath. In this case, S is found to be described by the familiar thermal equilibrium Boltzmann distribution.

In this article, the following questions are addressed: Does S relax to thermal equilibrium if the composite system is in a pure quantum state ? What temperature does the thermometer S show in this case?



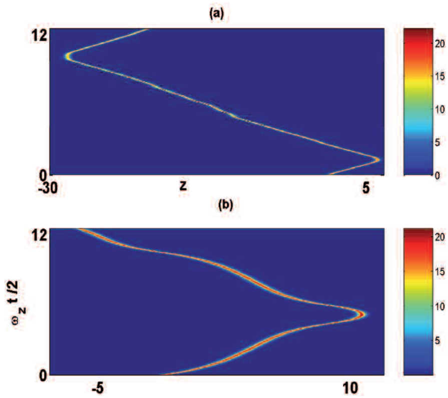
◄ **Probability of finding n bosons in the lowest eigenmode of a mass-spring chain for four typical pure states of same macroscopic energy. The chain consists of 5 masses, each coupled to its nearest neighbours by springs. The full and dashed lines are, respectively, the corresponding micro-canonical and canonical (Boltzmann) distributions. These two distributions merge for longer chains. For the short chain considered here, the pure states are already well described by the micro-canonical distribution.**

One considers an arbitrary system S in contact with a bath of harmonic oscillators and assumes that initially S is in any state and that the bath is in a typical pure state of macroscopically well-defined energy E. It is shown that the thermometer S relaxes to thermal equilibrium and indicates the bath micro-canonical temperature at energy E. The fraction of bath states of macroscopic energy E which do not thermalise S vanishes in the limit of a large bath. A key step in this derivation is the proof that, whereas the bath is not at equilibrium, its eigenmodes obey the Boltzmann distribution (see the figure). ■

S. Camalet, "Thermalisation by a boson bath in a pure state", *Eur. Phys. J. B* **61**, 193 (2008)

A new algorithm to study solitons in disordered quantum systems

This paper reports a numerical study of the behaviour of a one-dimensional Bose-Einstein condensate (BEC) in a regime where both disorder and non-linearities are strong. More specifically, we have investigated the dynamics of a bright soliton (obtained for attractive atomic interactions) in a random potential. Randomness makes it very challenging for conventional numerical schemes to be implemented. General relaxation methods where a given initial guess is iterated, are unlikely to converge in the presence of disorder. To that purpose, we have developed a highly efficient and rapidly converging numerical scheme based on spectral renormalization. This scheme has been used to study disordered, one-dimensional BECs in the Thomas-Fermi and in the confinement-dominated Gaussian limits where results can be compared to experiments. The most intriguing and unexpected result appears to be the case of the bright soliton whose stationary profile, unlike its width, appears to be independent of disorder. The dynamics of the soliton is obtained from a boost at a finite velocity V_s. Without randomness, the soliton travels a distance $z = V_s t$ over a time t without change in its density profile. For a weak and smooth enough disorder, the soliton



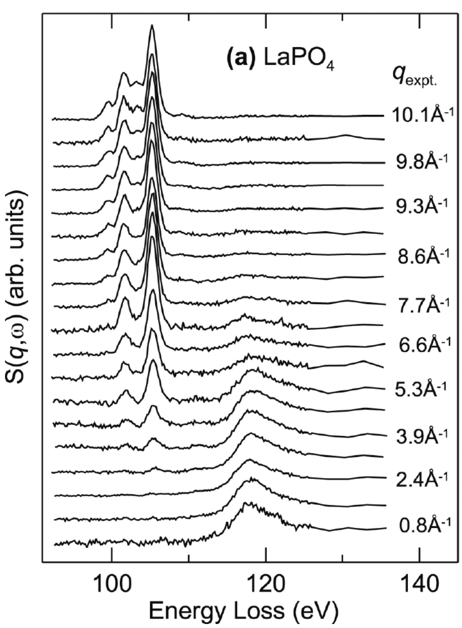
propagates retaining its initial shape, over distances comparable to the non-disordered case. For a stronger disorder, the soliton behaves classically and it bounces back from potential barriers higher than its kinetic energy without significantly changing its shape. When the strength of disorder is further increased, the soliton motion becomes non linear (Figure) as a result of the spatially varying force exerted by the disorder. ■

E. Akkermans, **S. Ghosh** and **Z. Musslimani**, "Numerical study of one-dimensional and interacting Bose-Einstein condensates in a random potential", *J.Phys. B: At. Mol. Opt. Phys.* **41**, 045302 (2008)

◄ **Colour online: Time evolution of a boosted soliton in the presence of disorder. (a) Weak disorder; (b) Strong disorder.**

High multipole transitions in NIXS

A recent study by an international team uses non-resonant inelastic x-ray scattering (NIXS) to provide a unique perspective on the electronic structure of *f*-electron materials. In the limit of low momentum transfer (*q*), hard x-ray NIXS provides an intrinsically bulk-sensitive alternative to soft x-ray or UV absorption spectroscopies and is seeing a rapid growth in applications, particularly where sample conditions are not favorable to soft x-ray or electron techniques. Several recent studies of *q*-dependent NIXS from compounds of light elements also find that monopole and quadrupole transitions can be used for a more complete characterization of low-energy electronic excitations.



▲ **The q-dependence of the contribution to S(q,ω) from the 4d initial state for a powder sample of $LaPO_4$.**

On the other hand, the new study by Gordon, *et al.*, finds a strong NIXS signal due to much higher-order multipole transitions from core to valence states at high *q* in heavy elements. Hund's rules indicate that the lowest-energy excited states in f-electron systems will be too high in angular momentum to be accessible by any spectroscopy obeying the dipole selection rule. As *q* increases (by increasing scattering angle), the NIXS spectra for 4*d* excitations of several rare earth compounds present new dipole-forbidden multiplet states at energies below the well-known UV giant dipole resonances. Good theoretical agreement is obtained through a *q*-dependent atomic multiplet approach involving transitions with selection rules varying from the dipole limit, $\Delta L=1$, to $\Delta L = 5$. While this essentially atomic physics is important for understanding mixed-valence behaviour in *f*-electron materials, a strong sensitivity to solid-state effects (hybridization) is also present through broadening of the atomic-like features. Such measurements should be applicable to many other lanthanide, actinide or strongly-correlated electron systems, with potential sensitivity to magnetism for single crystals and to changing f-localisation under pressure. ■

R.A. Gordon, **G.T. Seidler**, **T.T. Fister**, **M.W. Haverkort**, **G.A. Sawatzky**, **A. Tanaka** and **T. K Sham**, "High multipole transitions in NIXS: Valence and hybridization in 4f systems" *EPL* **81**, 26004 (2008)

Physical mechanism of the formation of a jam

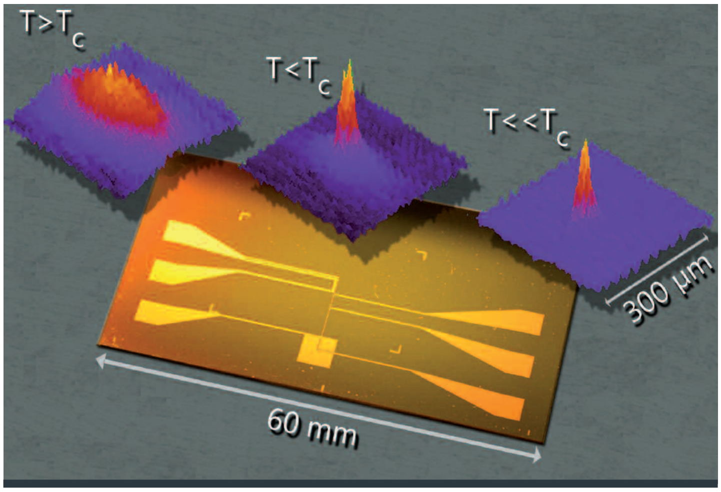
Why are we occasionally caught in a jam for no obvious reason? Physics give us the answer. Vehicular flow is a system of interacting particles (vehicles), meaning that vehicles slow down to change in spacing in order to avoid collision. The collective effect of such motions spontaneously leads to the formation of a jam, only if traffic reaches a certain critical density. No other feature, such as a bottleneck, is needed This phenomenon is a kind of phase transition. Traffic flow has two kinds of solutions to the dynamical equations describing the vehicular flow. One is a smooth flow, and the other is a jammed flow. Which state really appears corresponds to which solution is stable, and the change in stability occurs at the critical density. The decay of an unstable solution and the emergence of a stable solution is led by the enhancement of fluctuations caused by collective motions of vehicles. We have conducted a simple experiment with 22 vehicles on a 230-meter circular track, which shows that the physical theory for creating a jam really works in vehicular flow. Vehicles start out uniformly spaced and cruising at 30 km/h, and traffic initially flows smoothly. However, small fluctuations soon appear in the spacing between vehicles and grow breaking down the smooth flow, until finally several vehicles are forced to stop completely in a cluster. A vehicle leaving the front of the cluster and another vehicle joining the back, makes the cluster itself travel backwards around the track like a solitary wave. The velocity of the cluster is roughly 20km/h - the common value for a jam measured on real highways. This result provides the first experimental evidence that the formation of a jam is a collective phenomenon caused by 'dynamical' phase transition. ■

Y. Sugiyama, **M. Fukui**, **M. Kikuchi**, **K. Hasebe**, **A. Nakayama**, **K. Nishinari**, **S. Tadaki** and **S. Yukawa**, "Traffic jams without bottlenecks - experimental evidence for the physical mechanism of the formation of a jam", *New J. Phys.* **10**, 033001 (2008)

Cold atoms trapped by cold currents

Physicists at Laboratoire Kastler Brossel (ENS Paris) have produced a Bose-Einstein condensate (BEC) of rubidium atoms using superconducting micron-size wires, deposited on a chip. "Atom-chips" using normal metal wires at room temperature offer a versatile tool for manipulating ultra-cold atom samples at the micrometer level. However, thermal current fluctuations in the metal affect the trapping lifetime when the atoms are held close to the chip surface. These fluctuations are expected to be radically reduced close to superconductors. The ENS group has thus developed a cryogenic setup in which a chip with niobium superconducting wires is cooled down to 4.2 K. The currents required for the trapping (a few Amps) flow through the wires without producing any heat. The researchers trap for minutes millions of atoms, 440 µm away from the surface. With forced RF evaporative cooling they can cool the sample further and cross the transition towards BEC, below which a macroscopic number of atoms occupy the same quantum state. These results open the way to studies of the interaction of two quantum systems: a cloud of atoms in a Bose-Einstein condensate and a sea of Cooper pairs in a superconducting state. Using the dipole blockade phenomenon, it is also possible to excite one and only one Rydberg atom out of the very dense cloud. The latter could be very long lived in the cryogenic environment and manipulated to implement quantum operations. It becomes also possible to couple the atoms to superconducting circuits including Josephson junctions or coplanar cavities. ■

C. Roux, **A. Emmert**, **A. Lupascu**, **T. Nirrengarten**, **G. Nogues**, **M. Brune**, **J.-M. Raimond** and **S. Haroche**, "Bose-Einstein condensation on a superconducting atom chip", *EPL* **81**, 56004 (2008)



▶ Picture of the niobium atom-chip used for trapping the atoms. Three plots of the atomic cloud density distribution after a free expansion (not to scale) are also presented. A sharp peak corresponding to the BEC appears as the temperature T crosses the transition temperature T_c.

Why do the angular distributions of electrons from photoionization of H_2^+ and H_2 depend on the internuclear separation?

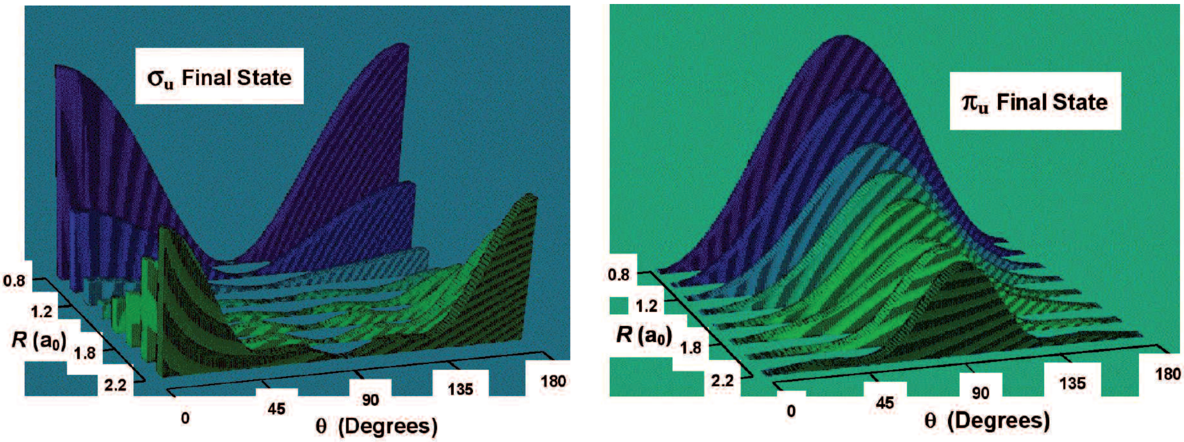
New experimental and theoretical work examining the double photoionization of H_2 has uncovered surprising changes in the resulting electron angular distributions as a function of the internuclear separation *R*.

A theoretical study was conducted of the electron angular distribution arising from the photoionization of H_2^+ at various *R*. The angular distribution displays a spectacular variation with *R* when the H_2^+ molecular axis is parallel to the light polarization direction, ε, (the $\sigma_g \rightarrow \sigma_u$ transition), whereas the distribution is found to be relatively insensitive to changes in R when the molecular axis is perpendicular to ε ($\sigma_g \rightarrow \pi_u$). The right-hand-side of the figure shows the $\sigma_g \rightarrow \pi_u$ transition, where the magnitude of the distribution decreases steadily as R increases, and the shape of the distribution is stable. The left-hand-side shows the angular distributions for the $\sigma_g \rightarrow \sigma_u$ transition, where as *R* increases, the shape and magnitude of the distributions change dramatically.

The variations of the distributions with *R* are due to a strong cancellation in the dipole matrix element for the *p*-wave component of the $\sigma_g \rightarrow \sigma_u$ transition (which does not occur for the $\sigma_g \rightarrow \pi_u$ transition), for a given photoelectron energy and *R*. In these cases the *f*-wave component dominates, resulting in an angular distribution of quite different shape and magnitude.

Although double photoionization of H_2 is distinctly different from photoionization of H_2^+, there is now compelling evidence that similar electron-ion effects are present in the double photoionization of H_2. ■

J. Colgan, **A. Huetz**, **T.J. Reddish** and **M.S. Pindzola**, "Internuclear separation dependence of the angular distributions from photoionization of H_2^+", *J. Phys. B: At. Mol. Opt. Phys.* **41**, 085202 (2008)



◄ **Electron angular distributions, with respect to the molecular axis, from R = 0.8 to 2.2 a_0, into the final states indicated.**

Attosecond Chronoscopy

A new type of experiment on attosecond chronoscopy, investigating the time evolution of atomic photoionization and relaxation, has been reported recently [Uiberacker *et al. Nature* 446, 627 (2007)]. The yield of multiply charged ions, produced by a combined action of an ultra-short extreme ultraviolet (XUV) pulse and a strong few-cycle infrared (IR) laser pulse, was measured as a function of delay time between the two pulses. In case of a Ne target, it was observed that the double ionization yield grows in a stepwise fashion relating to the number of IR cycles that are involved in the ionization, providing a direct proof of sub-cycle time dependence of the ionization rate. We have developed a theoretical model of this experiment, based on the numerical solution of the time-dependent Schrödinger equation. The ionization and shake-up, caused by the attosecond XUV pulse, are treated in the sudden approximation. Subsequent ionization by the strong IR field is evaluated by propagating the electron wave-packet up to termination of the IR pulse.

When the attosecond pulse precedes the IR pulse, the computed probability of Ne double ionization shows oscillations, consistent with the coherent excitation of an electronic wave packet by the shake-up process. The oscillations are more regular and pronounced in the probabilities of forward and backward electron emission. In the region where the attosecond pulse coincides with the most intense half-cycles of the IR pulse, a stepwise increase in the ionization yield is observed. The maxima in the electron emission in the forward and backward direction are split into doublets: one peak correlates with the zero of the vector potential and another one with a zero in the electric field. We believe that the doublet structure is due to the coexistence of two mechanisms (multi-photon ionization and tunneling) in the ionization process. ■

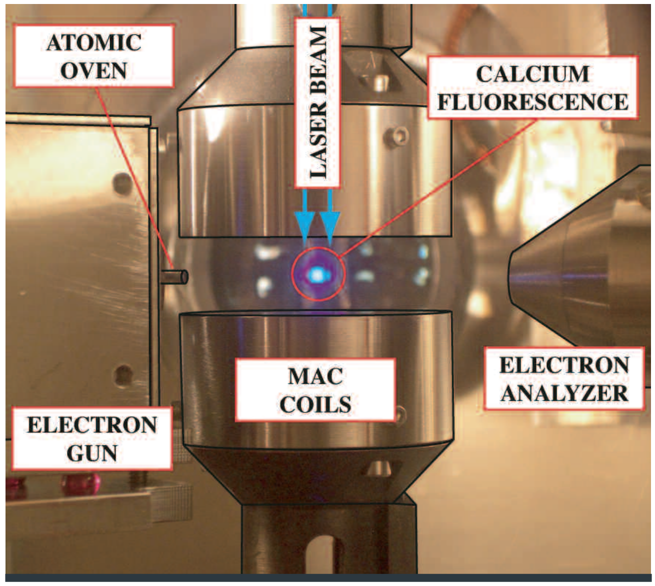
A.K. Kazansky, **N.M. Kabachnik** and **I.P. Sazhina**, "Quantum beats and fine structure in attosecond chronoscopy of strong-field photoionization of atoms", *EPL* **82**,13001 (2008)

Super-elastic scattering studies of calcium over the complete angular range using a magnetic angle-changing device

One of the key challenges in atomic physics is to understand electron impact excitation of atoms. By measuring the excitation probability over a wide range of scattering angles, the 'shape' of the excited atom produced in the collision can be determined and compared to theory. This is usually achieved by detecting the scattered electron, then looking at the polarization of the emitted photon when the atom relaxes. These 'coincidence' experiments are very time consuming, and are restricted to small angles due to their low efficiency.

Recent experiments in Manchester have measured this process by effectively reversing time – in these experiments the atom is first prepared in an excited state by a polarized laser photon, then an electron de-excites the atom and scatters through a measured angle. These super-elastically scattered electrons carry information about the collision, and by varying the laser polarization an equivalent set of data to coincidence measurements are obtained, but at rates many thousands of times faster.

These new experiments include a Magnetic Angle Changing (MAC) device whose well controlled magnetic field steers electrons to and from the interaction region (see figure). The Manchester MAC device [F.H. Read and J.M. Channing, *Rev. Sci. Inst.* 67, 2372 (1996)] is used here for the first time to determine the shape of electron excited calcium atoms over ALL angles. Data have been compared to different theories, and excellent agreement found. We have further modelled the laser-atom interaction in the magnetic field using a sophisticated Quantum Electro-Dynamic theory as part of this work [A.J. Murray *et al*, *Phys. Rev. A*, 77, 013409 (2008)]. This model will have wide applicability in different areas, including laser trapping and cooling. ■

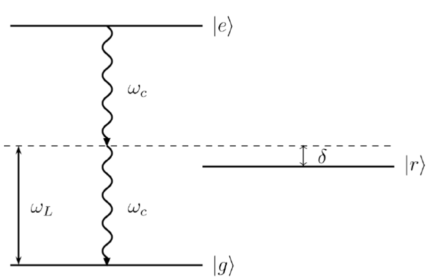


▲ The apparatus showing laser-excited calcium atoms between the MAC coils. The gun produces electrons of well controlled momentum which superelastically scatter from laser excited atoms before being detected in the analyzer.

M. Hussey, **A. Murray**, **W. MacGillivray** and **G. King**, "Low energy super-elastic scattering studies of calcium over the complete angular range using a magnetic angle changing device", *J. Phys. B: At. Mol. Opt. Phys.* **41**, 055202 (2008)

To emit one or not to emit one? What about to emit two?

The interaction between electromagnetic fields and matter plays a central role in physics. The quantum description of atom- field interactions in the low energy domain is the object of quantum optics. Among the several quantum optical models, there are special models which deal with competing processes in atomic transitions. In a two-channel model, the atom may pass from one state to another through two different paths. Interference between these two amplitudes of probability generally leads to interesting phenomena such as quantum beats and coherent trapping. A common aspect of these multichannel models has been the use of two or more modes of the quantized field, *i.e. different photons*. Would it be possible to elaborate a physical multi-channel model for an atom passing from one state to another through emission of different numbers of *identical photons*? This work is intended to provide a positive answer to this question. The physical system is composed of a three-level atom which simultaneously interacts with a single-mode quantized cavity field and an external laser field (see figure). Under appropriate conditions, the atom initially prepared in the excited $|e\rangle$ may emit either one or two photons into the *same* cavity mode. This is a new quantum optical model. ■



▲ Schematic diagram of the three-level atom in interaction with a quantized field (angular frequency ω_C) and a classical laser field (angular frequency ω_L). For sufficiently large detuning δ, the level $|r\rangle$ may be eliminated, and two-photon transitions between $|e\rangle$ and $|g\rangle$ are enhanced. Due to the presence of the laser, there is no energy limitation for the atom to make one-photon transitions between $|e\rangle$ and $|g\rangle$ as well. For atomic one- and two-photon transitions, it is meant emission into the quantized field mode.

F.L. Semião, 'Single mode two-channel cavity QED', *J. Phys. B At. Mol. Opt. Phys.* **41**, 081004 (2008)

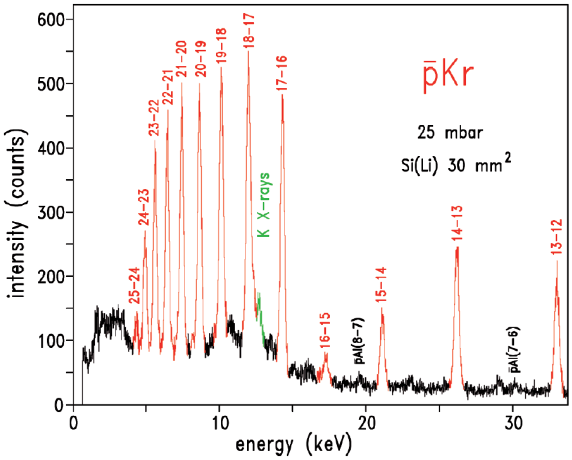
X-rays identify electron depletion in antiprotonic atoms

Antiprotons slowed down to atomic scale kinetic energies are captured into the Coulomb field of nuclei at about the outermost electron shell. Due to the large mass of the antiproton, this corresponds to main quantum numbers n above 100 for medium Z atoms. Consequently, the number of de-excitation steps in the subsequent quantum cascade becomes exceedingly large.

The de-excitation is determined by the competition of X-ray emission and depletion of electron shells by radiationless Auger transitions. Auger emission favours $\Delta n=1$ steps, *i.e.*, minimum kinetic energy for the ejected electron, and dominates whenever energetically possible for $n>9$. The preference of radiative de-excitation for $\Delta n>>1$ (maximum energy gain) leads to accumulation in the highest-angular momentum states. There the cascade continues only by slow $\Delta n=1$ X-ray transitions, as long as the energy gain does not exceed the binding energy of not yet ejected electrons.

An undisturbed cascade can be studied by using low density noble gases, where electron refilling is suppressed and chemical effects are absent. A shell-by-shell depletion up to complete ionisation for argon and krypton is revealed by appearance and disappearance of antiprotonic X-ray lines. In the case of xenon, the number of de-excitation steps is no longer sufficient for complete ionisation and several electronic L and K X-rays per atom are emitted when refilling holes created by Auger ejection of inner shell electrons. ■

D. Gotta, **K. Rashid**, **B. Fricke**, **P. Indelicato** and **L.M. Simons**, "X-ray transitions from antiprotonic noble gases", *Eur. Phys. J. D* **47**, 11 (2008)

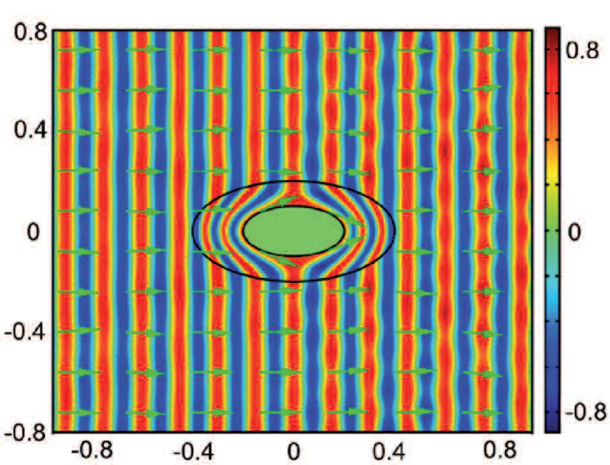


◀ **X-ray spectra of antiprotonic krypton show numerous and mostly saturated antiprotonic $\Delta n=1$ transitions (red). Auger emission of L and K electrons becomes possible for de-excitation steps larger than 2.7 and 17 keV, respectively, leading to a suppression of X-ray emission until depletion of the electron shell is completed. In a few cases, an electronic K X-ray (green) is emitted by a krypton atom during the antiproton's descent through the electron shells. The spectrum was recorded with a 3.5 mm thick Si(Li) detector.**

Arbitrarily elliptical invisible cloaks

Based on the physical principle, an electromagnetic wave or a beamlight follows the quickest route between two points. In a homogeneous and isotropic material, the route is a straight line. In an inhomogeneous material, the route becomes nonlinear to make the total traveling time minimal because the wave travels at different speeds. Hence one can control the route of wave by designing the material parameters. If a material shell guides the waves to propagate around the shell, the objects inside will be invisible. Hence the material shell is an invisible cloak to the objects.

The theoretical tool to study an invisible cloak is the so-called "transformation optics." Using optical transformation, an empty space can be transformed into a shell region to bend the path of electromagnetic waves. An optical conformal mapping method was used to design the material parameters that create perfect invisibility [Pendry *et al.*, *Science*, **312**, 1780 (2006)]. Based on this work, further investigations have been conducted on the invisible cloaking. However, most of them are devoted to circular or spherical cloaks.



In the present article, arbitrarily elliptical cloaks are proposed using the optical transformation. The elliptical cloak, which is composed of inhomogeneous and anisotropic metamaterials in an elliptical-shell region, can deflect incoming waves and guide them to propagate around the inner elliptical region. Such waves return to their original propagation directions without distorting the waves outside the cloak (see figure). General formulas of material parameters are given for arbitrary axis-ratio k. Hence the elliptical cloaks can make a large range of objects invisible, from round object (when k=1) to long-and-thin objects (when k is very large or very small). The authors of the present article are working on simplified material parameters to make the meta-material easier to be realized. The proposed cloaks could be used to shield sensitive devices from electromagnetic waves. ■

W.X. Jiang, **T.J. Cui**, **G.X. Yu**, **X.Q. Lin**, **Q. Cheng**, and **J.Y. Chin**, "Arbitrarily elliptical- cylindrical invisible cloaking," *J. Phys. D: Appl. Phys.* **41**, 085504 (2008).

▲ **FIG. 1:** ESA astronaut Hans Schlegel works on the exterior of the docked Columbus module (February 2008, Credit ESA/NASA)

[PHYSICS IN SPACE]

PHYSICAL SCIENCES ONBOARD THE INTERNATIONAL SPACE STATION

››› DOI 10.1051/EPN:2008302

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The development of virtually all living species is governed by gravity and all organisms unconsciously use or anticipate gravity effects. When gravity forces are not compensated, one talks about "free fall", and one of the features of satellites in orbit – far above the atmosphere that would otherwise slow them down by friction - is that, just like the moon, they keep free-falling around the earth. It is this particular feature of spaceflight that fuelled the interest of physicists to propose experiments in space. Many scientific experiments have already been performed that have yielded unique results and fed the natural curiosity and imagination of scientists.

When confirming the details of the European participation to the International Space Station (ISS) project in 1995, the Ministers representing the member states of the European Space Agency (ESA) acknowledged the potential of this research and emphasized the development of a vigorous European programme for both basic and industry-oriented research in space. ESA promoted the creation of teams of scientists with theoretical, computational and experimental expertise behind scientific problems to be tackled by experimenting under free fall conditions. Preparatory research on the ground helped define the specifications of the required instruments and establish databases of reference results for comparison when the experiments are performed in space. To the non-space industries involved in some of these projects, this preparation work provided further evidence of the usefulness of a clue from space!

In February 2008, the European module "Columbus" was docked to the ISS (see cover page and figure 1). In March, "Jules Verne", the first model of the Automated Transfer Vehicle (ATV), successfully docked automatically to ISS to provide fuel to the ISS and water, food, oxygen and equipment to the crew. In the mean time, the first scientific instruments were activated on Columbus. Europe thus has a laboratory in orbit to use for scientific research.

In this issue we start a series of articles on Physics in Space aiming to provide a snapshot of the programme for the scientific utilisation of the ISS in physical sciences, while making the science community aware of the availability of this tool.

The current ISS utilisation programme in physics spans a broad range of topics. Much is directed, shaped, conditioned, triggered or limited by gravity. Here are some of the topics:

Let's face it, atoms fall as well!

Recent Nobel Prize winning discoveries in cold and ultra cold atom physics have led to a new generation of high performance quantum sensors surpassing state-of-the-art instruments for accurate frequency measurements, ultra-precise monitoring of accelerations and rotations. At the same time, studies on ultra cold atoms, typically Bose-Einstein condensates are rapidly progressing, opening new exciting perspectives both for fundamental studies and for new devices based on coherent matter waves. Space is the natural environment for exploiting the high potential of these techniques. The interaction time between atoms and the probing field can be increased by several orders of magnitude, improving even further the already excellent performances of these devices, the applications of which are truly interdisciplinary. See this issue, p. 33.

Crystallising a cube of plasma!

Complex plasmas are classical plasmas in which microscopic particles are injected. These micro-particles become charged by capturing electrons and can thus interact with each other. If a comparison is made with atoms, the much larger scale and much slower dynamics of the particles make them amenable to simpler controls, stimuli and diagnostics. The reduced gravity environment that prevails in a spacecraft enables the formation and study of true three-dimensional structures and related process dynamics. The objective of this research is to generate and study phase transitions-like processes, self ordering of crystalline solids, wave formation, propagation and evolution, flow instabilities and collisions. See this issue, p. 30.

Dust! Dust everywhere!

The very early phases of the formation of a solar system and its constituents, the growth of dust particles to micrometer sizes, and the very late phase, from meter to kilometre-sized bodies, are believed to be reasonably well understood. However, the intermediate phase from micron to meter-sized bodies is not. On earth this growth cannot be reproduced. Similarly, there are many processes involved in the formation and evolution of clouds; they are intricate and have an important influence on the climate. The whole process of condensation of droplets and ice crystals is very cumbersome to study on earth because of sedimentation. Space experiments can provide quantitative data to understand the dust aggregation process or the full cycle of clouds. See this issue, p. 27.

Open your fridge and sort out your food products: emulsified and foamy products to the right and the others … well very few others as a matter of fact!

One of the most relevant problems in emulsion technology concerns the control of their stability. But the links between the physical chemistry of the droplets' interface and the collective properties of an emulsion are only qualitative, so that the criteria used in industry are mainly empirical. Investigating emulsions at different scales in space provides unique quantitative information that help develop predictive models of the stability of emulsions. Similarly, either unstable foams or "wet" foams, including metallic foams, can be investigated in space in a unique manner.

Watch a container with boiling water and think of all the phenomena going on. Now what would happen without gravity?

In fact, many superimposed physical phenomena governing the global process of heat and mass transfer in boiling are also present in many engineering fields. To develop predictive design tools, a multi-scale approach must be adopted to understand observations and theoretical modelling. Series of experiments at different scales conducted under low gravity conditions make it possible to observe effects masked under normal gravity conditions.

You will never give a pile of sand the same look again!

Granular media mechanically excited exhibit a wide range of behaviours depending on the dynamic coupling of the particles with the surrounding media and the intensity of the excitation. At low density, the solid particles can be considered as isolated bodies between collisions as in a dissipative gas. In space, in such a gas, stratification is eliminated even at high density ratios thus realising an effectively isolated gas of particles that is amenable to unique investigations.

Materials are the key!

There are strategic links between industrial processes, material structure and final properties of materials. It is important to understand how the hydrodynamic conditions affect microstructure and defect formation during the solidification process. Under low gravity one can control these hydrodynamics conditions. Benchmark samples are produced under well controlled conditions. Other experiments produce reliable and often unique thermo-physical property data.

With this issue, EPN starts the publication of a series of articles on important issues that are addressed in the programme on physical sciences in space (some specific studies were reported previously in EPN). Three consecutive issues will include a total of nine articles authored by teams of scientists involved in several different projects.

Acknowledgments

We benefited from the expertise of L. Cacciapuoti (Fundamental physics), A. Orr (Complex plasmas, Dust particles and Atmospheric physics), D. Jarvis and D. Voss (Materials sciences), S. Mazzoni (Thermophysics and crystallisation), S. Vincent-Bonnieu (Complex fluids), A. Pacros (Fluid dynamics and heat transfer) at ESA. ■

[PHYSICS IN SPACE]

DUST IN SPACE

››› DOI 10.1051/EPN:2008303

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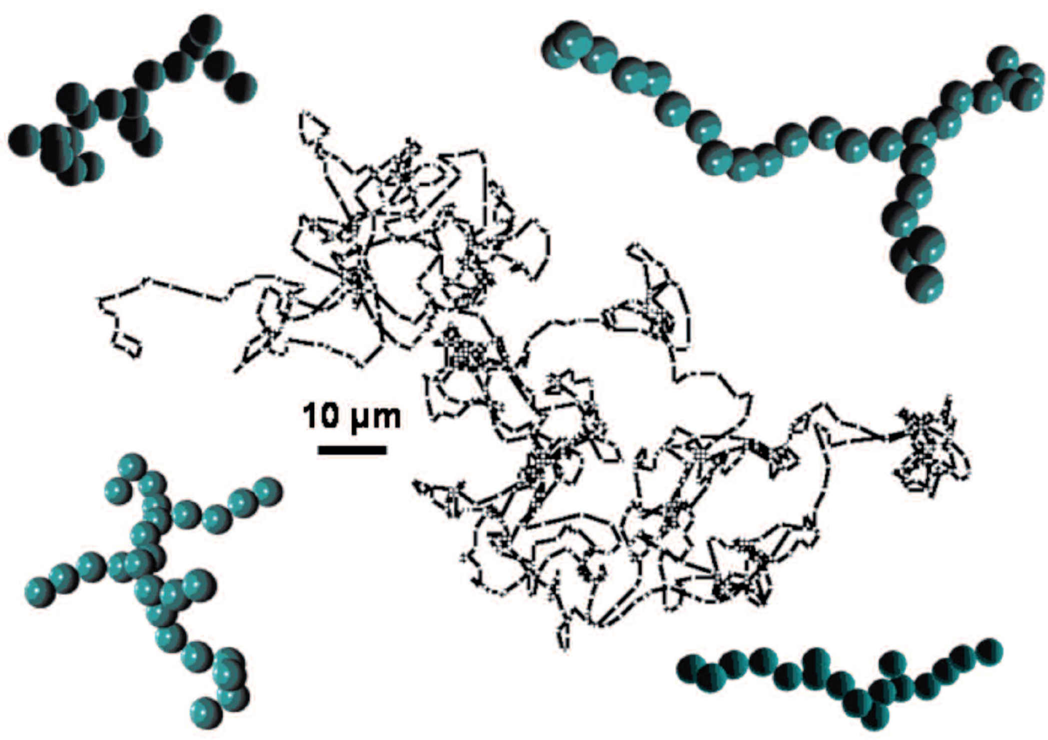
Space is far from being empty. Besides stars and galaxies, microscopic dust particles, often immersed in a gaseous medium, are ubiquitous and play an important role in a variety of cosmic and atmospheric environments. Nanometer- to micrometer-sized particles can be observed in different situations such as:

- stellar outflows, in which freshly-bred material is provided to the chemical reservoir of a galaxy,
- molecular clouds, the cradles of star formation,
- protoplanetary discs, in which planets are born,
- planetary atmospheres and in Earth's atmosphere, where they determine the chemistry and temperature distribution and, thus, climate and weather of the planet, and
- cometary comae and tails, the best source for pristine solar-system material.

In contrast with the much larger dust particles found on the surfaces of solid planetary bodies and in Saturn's rings, small dust grains always experience considerable attractive van-der-Waals or hydrogen-bonding forces whenever they collide with each other. The presence of a gaseous environment generally damps the relative speeds so much that at least some of the inter-particle collisions can result in the sticking of the grains. The dust agglomerates so formed exhibit interesting morphological, mechanical, and optical properties. Systematic investigations of these quantities can help to understand the cosmic material cycle, the formation of the first solid bodies in the solar system, the evolution of planetary atmospheres, and the cometary composition, activity and evolution at successive perihelion passages. In addition, future space missions to the Moon, Mars, or asteroids can benefit from knowledge about the physical interactions of small dust particles. Technical questions of how deep space probes sink in or how well rovers can drive on regolith-covered surfaces can only be answered if the fundamental properties of the small solid particles and their behaviour under different gravity conditions are known. In our own atmosphere, aerosols influence the global energy budget and cause the formation of rain drops, which efficiently cleanse the atmosphere of pollutants, and are thus of important environmental interest. More investigations are also required to better understand the role of aerosols in global climate change.

Why long-duration microgravity conditions?

Laboratory and theoretical studies have shown that collision velocities required for the formation of cosmic dust agglomerates are typically well below 1 ms^{-1}. Most of the above-mentioned astrophysical and planetary environments exhibit rather low gas densities and gravitational accelerations. Ground-based laboratory experiments involving ensembles of dust particles with dif-



◄ **FIG. 1: Four examples of dust aggregates grown by Brownian-motion-induced collisions [2]. The displayed dust aggregates were reconstructed from three-dimensional microscopic images in a space-shuttle experiment and consist of SiO_2 spheres with 1.9 µm diameter. The centre of the image shows a trajectory of a single SiO_2 sphere with 1.5 µm diameter, recorded in a drop-tower experiment [4]. The trajectory consists of 1024 position measurements and has a total duration of 2.2 seconds. The gas pressure in the experiment was 100 Pa.**

ferent sizes or compositions suffer from fast particle losses and systematic segregation or de-mixing due to gravity. Moreover, large dust aggregates are extremely fragile so that they are compressed under their own weight.

Low-gravity experiments can offer the solution. The collision behaviour of *individual* dust aggregates can be studied even in short-duration experiments, *e.g.*, in drop towers or parabolic flights. However, the study of the self-consistent evolution of an *ensemble* of dust agglomerates or aerosol particles requires investigations under long-duration reduced gravity conditions.

To address the issues, astrophysicists, planetary and atmospheric scientists from all over the world joined forces and expertise in an ESA-supported 'Topical Team'. The team defined a long-term research programme along with an experimental facility for the International Space Station (ISS). The following issues are addressed:

- The *dust-dust interactions* control the formation of dust aggregates. These aggregates are characterised by a growth rate, a fractal structure and the distribution of their mass in a particle ensemble. All depend on the relative-velocity fields determined by the physical environment.
- Changing the gas density and the effect of Brownian motion, *i.e.* the *dust-gas interactions*, will also affect the dynamics of the aggregates and eventually their growth and morphology.
- Most of the astrophysical clouds are only observed from the light they scatter. Understanding dust-light interactions thus becomes a necessity to interpret observations. By analysing the light scattered by dust clouds whose composition, optical indices and evolving morphology are known as aggregation proceeds, one can establish a reference database. This requires measuring the angular distribution of the scattered light at different wavelengths, and of its polarised components.
- The case of aerosols in Earth's atmosphere is even more complex because of the combination of *dust-light-gas interactions*. On top of the momentum transfer between the dust agglomerates and the ambient gas, light absorption and differential particle heating also influence the dynamics of the particles in the cloud (photophoresis and thermophoresis).

Learning from space experiments

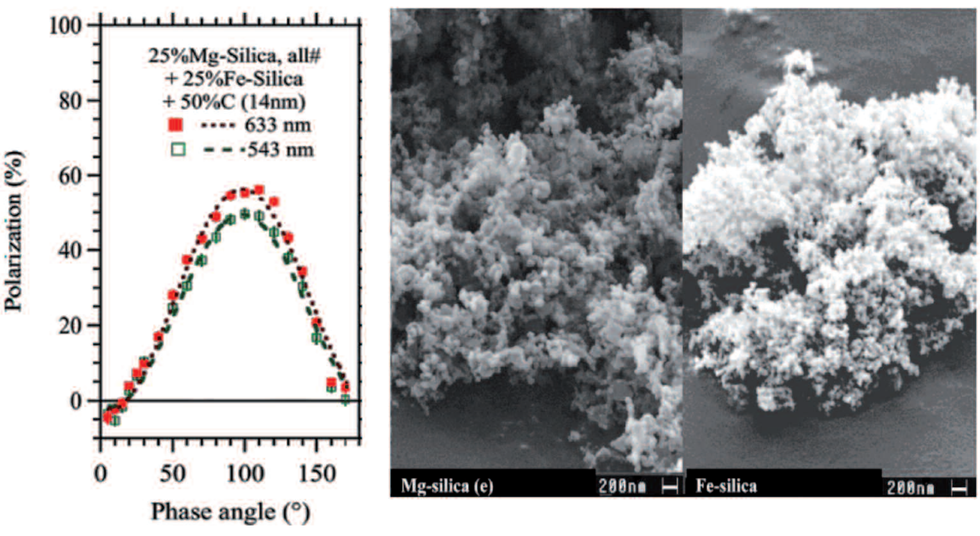
Extensive studies have been carried out in short-term low-gravity environments on the production of monomers and aggregates [1] that are important precursors of cosmic dust particles. Experiments in the drop-tower in Bremen, on a sounding rocket and on the space shuttle showed that large fractal dust agglomerates can be grown in a rarefied-gas environment using the extremely slow Brownian motion of the dust particles [2, 3].

To characterise the individual mass of agglomerates, their structure as well as the random motion of the particles as featured in Figure 1, long-distance microscopy with micrometer resolution and large depth of fields is employed in combination with stroboscopic illumination. High-speed digital cameras are then a must.

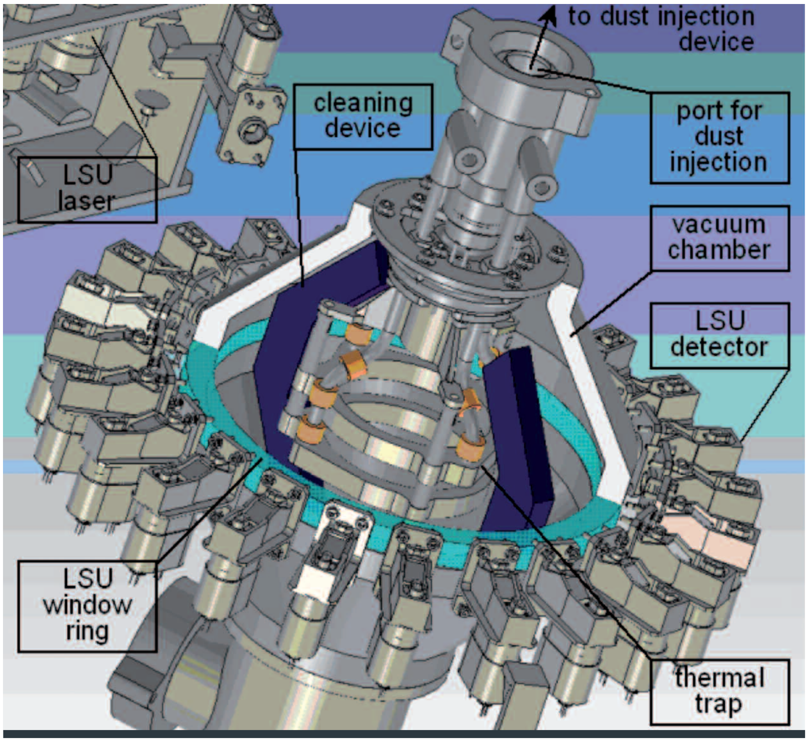
Along with the experimental programme, models were developed on the basis of rate equations and molecular-dynamics-inspired simulations. Matching the model predictions with the agglomerate morphologies and growth rates measured in these two space missions successfully yielded the collision cross sections of fractal dust agglomerates [5,6]. Moreover, the angular scattering and polarisation pattern of the fractal dust agglomerates was measured by a light-scattering instrument.

Further light-scattering experiments on aircraft flying parabolic trajectories and in the laboratory yielded multi-wavelength brightness and polarisation data for dust clouds of various compositions, sizes and morphologies [7]. When compared with remote and in-situ observations of comets, these data, as well as numerical light-scattering simulations on dust grains and fractal aggregates [8], suggest that compact grains and fluffy dust aggregates are present in cometary comae. And both are made up of rather transparent silicates and absorbing organic material as illustrated in Figure 2. The validity of these results was demonstrated - at least for comet Wild 2 - by analyses of the cometary dust samples collected by the Stardust mission [9].

The first long-duration dust agglomeration experiments provided a demonstration of how to operate in a low-gravity environment. Agglomerate sizes of a few tens of microns were observed. These results opened up the perspective of thoroughly studying dust aggregation processes in space.



◄ **FIG. 2:** Left panel: percentage of linear polarisation of light scattered in two wavelengths, as measured for levitated dust particles on parabolic flying aircraft. Mixtures of porous grey aggregates of Mg-silica, Fe-silica (featured in the SEM images on the right panel) and sub-µm-sized carbon-bearing materials match the observed scattering properties of cometary dust (see text).



◄ **FIG. 3: Sketch of the design of the new instrument for Columbus with its crown of detectors of the Light Scattering Unit (LSU). The inner diameter of the chamber (light blue ring) is about 10 cm (courtesy of Verhaert Space).**

A new instrument on Columbus

The instrument under development encompasses an accurately thermally-controlled experiment chamber in conjunction with a thermal particle trap. The trap enables one to confine particle ensembles within the volume of observation. Much larger dust agglomerates can thus form within the duration of the planned experiments of 30 minutes. Besides Brownian motion, whose influence on the agglomeration will be studied in a wide gas-pressure range of 10-1000 Pa, other velocity fields among the dust aggregates can be generated with a particle manipulation system so that also runaway growth of single dust agglomerates can be observed. Being a long-term initiative, the instrument will enable one to study the agglomeration behaviour of dozens of different dust samples. A sketch of the current instrument design is featured in Figure 3; it incorporates solutions to many technical challenges that were jointly tackled by scientists and engineers.

Controlling dust with heat and light

Among these challenges, a *dust-storage device* was developed to store a large number of different dust samples under vacuum conditions and along with it, a *dust-injection device* enables one to choose an individual sample at any given time [10]. A *thermal trap* (similar to a Paul trap for charged particles) has been designed that allows the "holding" of a cloud of dust amidst the intrinsic disturbances of the ISS and thereby the study of highly mass-loaded dust-gas mixtures. The *particle manipulation device* is based on the photophoretic effect by which a dust particle or agglomerate travels (mostly) away from a light source. As the photophoretic velocity increases with increasing dust-aggregate size, large agglomerates can incorporate the small particles in their paths, thus mimicking run-away growth. Moreover, a specific dust agglomerate can be selected and positioned in the observational volume of the diagnostic system for detailed inspection. Measurements in the cloud are made by means of an *overview observation system* including a *particle-tracking* capability, a *digital holography microscopy*, a *long-distance microscope* and a *light-scattering unit*. The instrument developers are looking for an effective window cleaner; unfortunately, no astronaut is allowed to volunteer!

The measurements to be performed in this instrument are crucial for the understanding of the evolution in very dense dusty systems such as the mid-plane of protoplanetary discs in which the essential stages of early planet formation take place. It will be the stepping stone for further investigations on dust-particle research onboard the ISS for cosmic and atmospheric sciences. ■

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[PHYSICS IN SPACE]

THE PLASMA STATE OF SOFT MATTER

>>> DOI 10.1051/EPN:2008304

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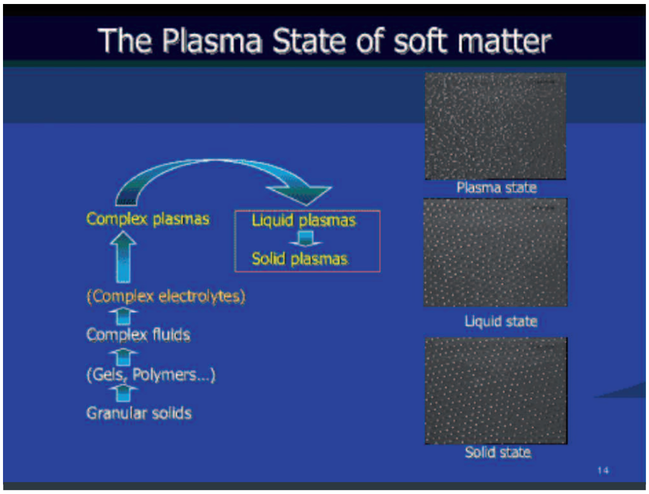
[3] Université d'Orléans, Orléans, France, [4] Royal Institute of Technology, Stockholm, Sweden

Practically all plasmas contain "dust". This is true for a number of astrophysical plasmas, *e.g.* the solar wind contains dust from the zodiacal light cloud, magnetospheric plasmas may contain dust from planetary rings, interstellar clouds are weakly ionised plasmas containing about 1% of their total mass in the form of tiny dust particles and last, but not least, the planets – our Earth – would not exist if the protoplanetary nebula, out of which we were all formed, did not contain dust. Dust is also found – often as an unwanted by-product – in many industrial plasma applications, notably in plasma vapour deposition (productions of flat screens and panels) and in microprocessor and chip production. In these industrial processes the desire is to eliminate the "dust contamination".

For these and many other reasons it is not surprising that research into dusty plasmas has become the second most important plasma research topic next to fusion. Whilst the original motivation was environmental (*e.g.* understanding the processes that occur in thunderclouds), astrophysical (with the dominant topic the formation of our solar system) and technological (understanding the plasma chemistry, aerosol formation, particle growth and transport) a discovery made in 1994 added a completely unexpected dimension to "dusty plasma research". This was the discovery of spontaneous self-organisation of dusty plasmas (or complex plasmas, as these systems are now called) into strongly coupled crystalline states. [ref 1-3].



▲ FIG. 1: **Schematic illustration of the different states of soft matter. The inserts show three examples of complex plasmas in the "gaseous (plasma)", "liquid" and "crystalline" states. Each white spot is a (supramolecular) microparticle illuminated by laser light and recorded with a CCD camera. In the liquid state the structural disorder is seen and the somewhat higher mobility of the particles. In the disordered (or gaseous) state, the particles move much faster leaving tracks during a single exposure image (from [5]).**

Imagine the most disordered state of matter – plasmas – becoming the most ordered state. Crystals!

Not surprisingly, this discovery led to a huge number of publications aimed at characterising and understanding this new form of matter.

Why the name "complex plasmas"? This name was chosen in analogy to the so-called "complex-fluids", which consist of colloidal particles immersed in a fluid-system which are very important industrially from emulsions, photonics to novel composite materials, and which in addition have been widely used to study basic processes in crystal physics and phase transitions – in particular melting (observed at the individual particle level).

Now, complex fluids are part of the chain which classifies the states of "soft matter" – a name coined by the late Nobel Prize winner Pierre Gilles des Gennes (1991). The definition of what constitutes "soft matter" all but appeared to rule out a plasma state:

Soft matter are *"supramolecular substances which exhibit special properties such as macroscopic softness or elasticity, which have an internal equilibrium structure that is sensitive to external forces, which process excited metastable states and where the relevant physics is far above the quantum level".*

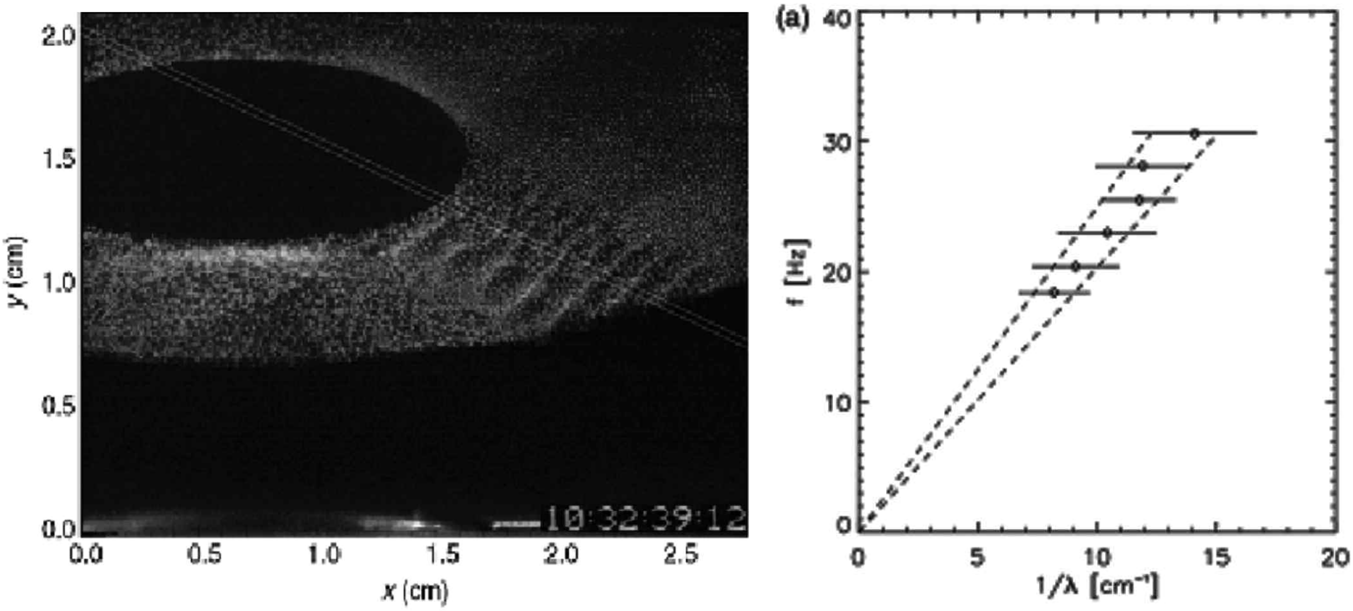
Soft matter comes in a variety of forms, from granular solids, gels, foams, emulsions to colloids (complex fluids). It turns out that, rather surprisingly, complex plasmas also satisfy all these requirements [4] and hence the discovery of plasma crystals in 1994 also marked the discovery of the "plasma state of soft matter". Figure 1 shows the hierarchy of soft matter states – as they appear now.

But what exactly are complex plasmas and why can they become crystalline?

Liquid and crystalline plasmas are supramolecular. This means they consist of atomic (or molecular) components – electrons and ions – as well as microscopic particles (containing 10^{10} to 10^{14} atomic mass units). In usual experiment conditions the microparticles are charged negatively (the same as the electrons), the ions are charged positively and each system is overall charge-neutral (as is usual for a plasma). The charge on the microparticle is large – several thousand electron charges. Such a large charge introduced locally in an electron-ion plasma naturally leads to a spatial rearrangement. Electrons are pushed away, ions are attracted. Overall this results in two things:

First, ions and electrons are captured and absorbed by the microparticle leading to a mean charge which, however, fluctuates statistically due to the impacts.

Second, ions and electrons form a cloud around the microparticle, which screens the charge of the "intruder" over a



▲ FIG. 2: Wave motion in complex plasma in microgravity. Left: within a three-dimensional dust cloud a thin layer is illuminated by a 150 nm thick laser sheath from the side. A channel of externally excited dust acoustic waves extends from the centre towards the lower right. Right: the dispersion diagram, *i.e.*, the experimentally obtained wavelengths plotted against the excitement frequencies (from [6]).

characteristic distance (called the Debye length, λ_D named after the famous physicist Peter Debye).

Consequently, the force between such microparticles is electric and it has a limited range of typically a few such Debye lengths. Therefore, if the particles are too far apart, they will not notice one another – the system is said to be "weakly interacting". This is the usual case encountered in nature – *e.g.* in the interstellar medium, in protostellar clouds, in the Zodiacal light cloud, in planetary rings, lightning clouds etc. However, if the particles are close enough, then their motion influences that of their neighbours directly, they become strongly interacting. This is illustrated in the inserts of Fig. 1, where strongly interacting fluid and even crystalline complex plasma states are depicted.

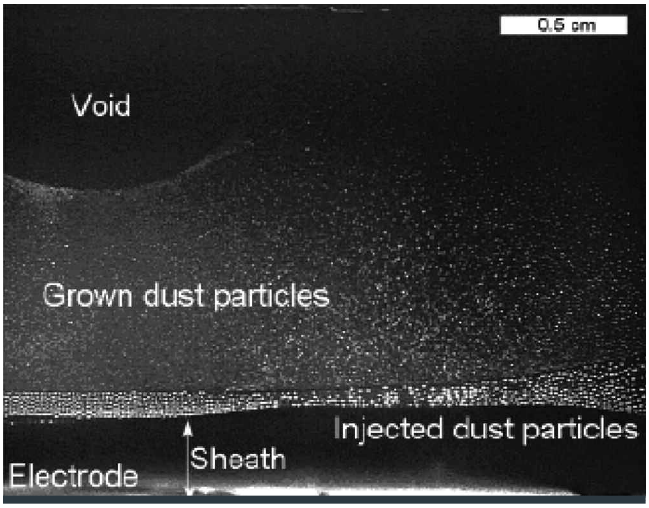
Complex plasmas are fascinating systems for studying generic properties of self-organisation in matter. They are optically thin (this means they can be visualised in three dimensions to typically 1000 lattice planes), the particles can be individually resolved and the large mass of the microparticles (many billion times more than atoms) implies that all relevant time scales (*e.g.* for lattice vibrations, wave propagation etc.) are stretched and are of the order 10's of msec rather than fractions of a microsecond as in natural atomic or molecular systems.

The large mass of the microparticles implies, however, that gravity provides an important constraint for precision measurements. Hence it is natural to propose experiments in Space under microgravity conditions. For the remainder of this paper, we will briefly summarise three experiments performed with our Space Laboratories "Plasma Kristall" (out of a total of about 50 discoveries published to date).

Wave analysis and dispersion relation

Plasmas can support a large variety of wave modes that do not exist in solid, gaseous, or liquid matter. The basic reason is that a plasma contains a mix of particles with different properties such as mass and charge and that those particles can play fundamentally different roles in the wave motion. Also, interaction at a distance via electric and magnetic fields is added to the close collisions of a purely neutral species. In classic plasma physics investigation of the growth, propagation, and damping of waves is therefore an important tool for studying the basic interaction mechanisms through their macroscopic properties.

All this is still true in complex plasmas, but here also the kinetic level of the wave motion can be studied by direct observation of the particle motion. By adding microparticles, new wave modes are added and existing plasma modes are modified. One of the basic new modes are dust acoustic waves, in which the dust grains themselves move and the restoring forces are electric. Although numerous experiments on dust acoustic waves have been made since the mid-90's, problems with experiments in gravity are the occurrence of self-excited waves, and that such experiments are inherently anisotropic due to the electric field necessary to levitate the grains.



▲ **FIG. 3:** Cross sectional image of the particle distribution obtained in the PKE plasma laboratory on the ISS. The "void" (a particle-free zone) is at the centre, the image shows approximately one quadrant. Careful analysis shows two generations of grown particles, the younger (smaller) "fog" located around the void, the older (larger) population further out (from [7]).

In the "Plasma Kristall Experiment" (PKE), on the International Space Station, three dimensional, unmagnetized, isotropic, complex plasmas can be studed at the kinetic level. Figure 2 (left) shows a snapshot from the overview camera of the PKE experiment, in an investigation of dust acoustic waves. This is the first study of dust acoustic waves in the regime of low-amplitude oscillations where comparisons with linear theory can be made. The thin white lines define the strip within which the wave data is taken. The waves were excited by applying an ac electric modulation of variable frequency to the radio frequency electrodes that sustain the plasma. The excitation amplitude was varied with frequency to ensure a sufficiently linear regime of the dust density perturbations. In the right panel the observed wave dispersion is compared with a multispecies dust acoustic wave theory (dashed lines).

Particle growth under microgravity conditions

In plasma reactors usually one observes the formation of fine dust particles. The processes are complicated, they depend on the non-equilibrium plasma-gas chemistry for (initially) cluster formation with subsequent growth due to attachment and coagulation. In principle one would imagine that the gas-phase chemistry and hence the whole nucleation/growth process should not be influenced by gravity in a serious way – however, our experiments carried out in the ANDROMEDA mission on board the ISS showed that gravity does indeed play a role – even if the details are not yet understood. It probably has to do with the overall inhomogeneity of the plasma (sheath, pre-sheath, bulk) and the gravity-induced differences where even small clusters spend most of their time. In this sense results from space experiments could have a profound impact on reactor designs on Earth, *e.g.* for the nucleation, growth, dynamics and transport of dust particles in low pressure cold plasmas for different chemistries (SiH_4, CH_4, CH_4-N_2 and polymer sputtering). In the framework of the PKE program, experiments have been conducted on the formation of dense carbon dust particles, the formation of the central void region and the different self-excited instabilities related to the dust growth. It was shown that the dust particles keep a small residual charge, which can be positive or negative. The distribution of this residual charge was measured. These results are of prime importance for the dust particle transport in the afterglow and thus open the door for many applications where dust particle manipulation is needed.

Particular attention was paid to the dust particle growth mechanisms. The results obtained on the ISS show that the process is a stepwise one, with several generations of grown particles forming, each with their own characteristic size (see Fig. 3).

Discovery of electrorheological plasmas

Electrorheology is a process, whereby an external electric field modifies the structure (rheology) of a given substance in such a way, that the properties are changed (*e.g.* viscosity, elasticity). This effect is well-known in colloids and has significant application potential in photonics, hydraulics and suspensions. During the ASTROLAB mission experiments were performed to test whether electrorheology also occurs in complex plasmas (as it does in complex fluids) [8]. The results are shown in a video on **www.mpe.mpg.de/pke/electrorheology_movie** It is clear that such external electrostatic manipulation makes significant changes to the rheology of (liquid state) plasmas – and correspondingly leads to associated changes in the bulk properties. This discovery will be used for future generic research into the properties of soft matter (or condensed matter generally) and for possible application potential.

In summary, microgravity research of complex plasmas (the plasma state of soft matter) has been enormously successful, with major discoveries that are novel and complementary to research carried out on Earth. ■

Acknowledgements

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[PHYSICS IN SPACE]

COLD ATOMS AND PRECISION SENSORS IN SPACE

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Cooling atoms, which means slowing them down to very low velocity, enables scientists to realise accurate physical measurements based on quantum transitions between atomic energy levels. A well-known spin-off is the astonishing precision of atomic clocks. Measurement accuracy improves as the interaction time between atoms and excitation field increases. Laser cooling can reduce the velocity of the atoms and increase the interaction times, but it cannot cope with Earth gravity without perturbing the measurement. In ground-based laboratories, atomic fountains help to circumvent gravity and extend the measurement duration. This naturally led scientists to envisage experimenting with ultra-cold atoms in space where long and unperturbed evolution times are possible in a freely falling laboratory. Such an environment enables one to exploit the potential of cooling atoms close to stand still permitting:

- extension of the measurement time by one to three orders of magnitude in a perturbation-free environment;
- quantum evolution unbiased by gravity;
- reduction of the kinetic energy by up to three orders of magnitude, down to the sub-pico-Kelvin regime.

Atomic clocks

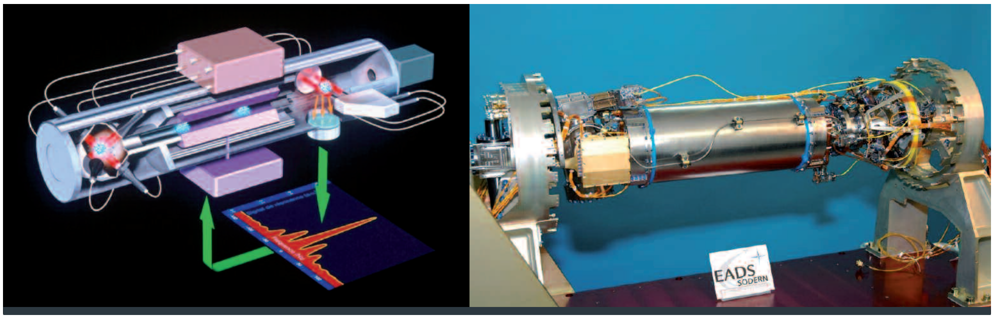
A pioneering step will take place in 2013, when the Columbus module will receive the Atomic Clock Ensemble in Space (ACES) payload [1], carrying ultra-stable atomic clocks and a high-precision time transfer system. Using this accurate time reference in space, the ESA-led ACES mission will perform new tests of general relativity, search for possible minute violations of Einstein's equivalence principle, and develop several applications in Earth observation and geodesy.

Clocks are basic instruments for science, technology and industry. For several decades, the most accurate and stable clocks have been atomic clocks using the hyperfine transition of the neutral Cs atom at 9.1 GHz as quantum reference. This transition also defines the unit of time. Every Europhysics News reader has played with a GPS receiver! In this global navigation system, each GPS satellite carries a set of precise atomic clocks. The orbiting satellites send electromagnetic timing signals to receivers on Earth that can determine their position with sub-meter accuracy by a simple triangulation method. Compared to GPS clocks, the time scale provided by ACES in space will have a hundred-fold increase in precision. Indeed in the PHARAO clock, developed by the French space agency CNES in the frame of the ACES mission, caesium atoms are cooled to a temperature of 1 μK, corresponding to velocities of about 7mm/s (Fig 1). For free-falling atoms, these low velocities cannot be maintained on the Earth surface because of the gravity acceleration. In space, there is no such limit and atoms in free expansion can be probed for several seconds. In this way, we expect the space clock to reach a relative frequency stability and accuracy of 1 part in 10^{16}, which corresponds to an error of less than one second over 300 million years.

While the accuracy of cold Cs atom clocks is already very high, recent advances in laser and quantum technology have opened the way to the realization of even more accurate and stable clocks. In optical clocks, the reference oscillator is a laser whose frequency is continuously controlled by comparison with the atomic transition. It is expected that clocks operating in the optical domain of the electromagnetic spectrum rather than in the microwave domain (with a ~10^5 times larger frequency) will bring at least two orders of magnitude improvement, reaching the 10^{-18} stability and accuracy level.

Two development lines are currently investigated: optical clocks based on a single atomic ion in an electrodynamic trap and optical lattice clocks, based on ensembles of ~10^4 neutral atoms trapped in the periodic potential produced by an intense laser. Present accuracy of ion clocks reaches a few parts in 10^{17} [2], while lattice clocks have been evaluated to one part in 10^{16} [3]. Both laboratory clock types exhibit frequency instability significantly lower than that of Cs clocks, reaching levels as low as $1 \cdot 10^{-16}$ after few hours of averaging.

When operated in space, optical clocks can enable high-precision experiments, *e.g.* measurements of the gravitational redshift due to various solar-system bodies, of the Shapiro gravitational time delay, and accurate tests of the space-time independence of fundamental constants. One particularly attractive ▸



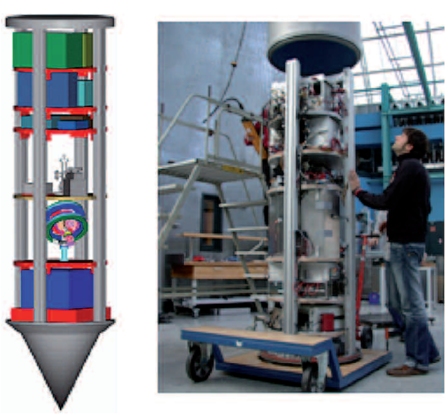
◀ FIG. 1: (Left) Working principle of the PHARAO clock (Projet d'Horloge Atomique à Refroidissement d'Atomes en Orbite); Cs atoms are launched in free flight along the ultra-high vacuum tube where they are probed on the clock transition by the resonant field in a microwave cavity. (Right) Engineering model of the clock interrogation tube; The clock is presently under test at CNES premises in Toulouse.

application of clocks in space is a high-precision mapping of the gravitational potential at the Earth's surface. This technique, which will be first demonstrated by the ACES mission, is based on the precision measurement of the gravitational red-shift between clocks on the ground, continuously compared via a master clock in space. Implementing optical clocks in space requires a concerted development effort of research groups, industry, and space agencies. Size, mass, power consumption, reliability, and performance of the clock shall reach a level compatible with the individual applications. The Space Optical Clock (SOC) project, supported by ESA and national space agencies, is developing this technology, currently focusing research efforts towards a transportable prototype of an optical clock based on Sr atoms.

Atom interferometry sensors

Atomic clocks are not the only instruments which benefit from weightlessness! Clocks belong to a larger class of inertial sensors based on ultra-cold atoms and on the interference of atomic matter-waves. Inertial sensors using atom interferometry provide a new tool for the precise measurement of acceleration, rotations, and faint forces [3]. According to the principle of these sensors, the measured physical quantity is converted into a frequency, which can be measured with the highest accuracy. Atomic gravimeters, gyroscopes, and gravity gradiometers have now reached on the ground a level of performance competitive with classical instruments and surpassing them in some cases. The most important features of these instruments are represented by the precisely known calibration factor and the good long-term stability, predestining these sensors for applications in inertial references, in the definition of SI units, and for precision measurements of tiny effects on long time scales (*e.g.* local gravity variations…). Under microgravity conditions, atom interferometry sensors benefit from the extended measurement time even more than clocks. Indeed, acceleration sensitivity improves with the square of the measurement time and thus a ten-time longer free flight will provide a hundred times higher sensitivity.

Inertial sensors are used nowadays in many experiments probing the rotation of the Earth, its gravity and gravity gradient, and for fundamental physics tests; recent studies are also investigating applications for the astronomy of gravitational waves sources. Future experiments in these domains are challenged by the aim to measure forces in the 10^{-15} range of terrestrial gravity.



◀ **FIG. 2:**
QUANTUS – a facility to produce degenerate quantum gases in the microgravity environment of the drop tower at the ZARM in Bremen. The robust and transportable set-up produces Bose-Einstein condensates of ^{87}Rb.

Experiments in space will exploit the full potential of these sensors. From this point of view, the Space Atom Interferometer (SAI) project coordinated by ESA intends to study applications of inertial matter-wave sensors in microgravity. SAI is pushing present performances, demonstrating this technology with a transportable sensor which will serve as a prototype for the space qualification of the final instrument. Further tests can be envisioned in drop towers or on parabolic flights, finally leading to experiments in orbit.

Bose-Einstein condensation

A leap forward in the field of atom optics has been the 1995 achievement of Bose-Einstein condensation (BEC). Cold quantum gases and, in particular, Bose-Einstein condensates are a new state of matter with very peculiar properties. BEC gives unique insights into a broad range of fundamental physics phenomena and offers prospects for novel quantum sensors [4].

The ongoing research on cooling and manipulation of atoms was and is to a great part motivated by reaching ever-new frontiers in low-temperature physics and achieving full control of these elementary quantum systems. With the current technology, atoms can be cooled to such low temperatures that Earth gravity represents a major perturbation. The present low temperature record is just below 500 pK, equivalent to the potential energy of a single Rb atom at a height of 5 nm, much smaller than the typical extension of its wavefunction.

Microgravity will set the stage for innovative studies. These include thermodynamics of systems at ultra-low temperatures (pK to fK regime); new phase transitions such as magnetism in the quantum domain where weak forces (long-range) govern the kinetics of the ultra-cold gas; physics of dilute gases and giant matter-waves; quantum gas mixtures unbiased by gravity; high-brilliance sources of ultra-cold atoms for atom interferometry.

A facility for studying BEC properties in microgravity has been developed with DLR support for the Bremen drop-tower experiment (Fig. 2). This apparatus routinely produces BEC during free-fall from a height of about 110 m, demonstrating an ability to well withstand decelerations that at the end of the drop can be as high as 40 g. The next frontier is now represented by space.

In conclusion, we have briefly described the fascinating and interdisciplinary applications of atomic quantum sensors in space. Atom optics is providing us with high-precision instruments to investigate the laws of physics and improve the perception of space-time surrounding us. ■

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TYPE II SUPERCONDUCTORS ARE 70 YEARS OLD

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It is already 70 years since the outstanding physicist L.V. Shubnikov together with his colleagues at the Ukrainian Physical - Technical Institute, Kharkov, have experimentally discovered the type II superconductors [1,2]. Their work has exerted a considerable effect on the development of current physics and engineering. This paper presents a short account of some historical events that accompanied the discovery and the appraisals given by prominent physicists of the world.

Although Lev Landau and Lev Shubnikov, two prominent physicists, were friends and the *"two Levs' tandem"* had been discussing from 1932 through 1937 all the works in progress at Shubnikov's Cryogenic Laboratory, Landau did not assist Shubnikov in "pushing" the work in question through, and so it has been published no sooner than 3 months later. The reason for that is set forth in V.L. Ginzburg's Nobel lecture [3]: as regards superconducting alloys *"an understanding of the situation was lacking*". The prevailing concept of that time was the influence of composition/structure inhomogeneities (including the "Mendelssohn sponge" model) and internal stresses on the alloy properties. It is worthy of note that type II superconductors have found significantly wide application (in this connection, it should be enough to mention the development of large-scale magnetic systems for charged-particle accelerators and thermonuclear reactors).

Not long ago, the centenaries of births of Lev Shubnikov (1901-1937) and his first postgraduate student Georgiy Shepelev (1905-1942) were celebrated. They both died at the age of 36. Shubnikov died on November 10, 1937, at the time of Stalin's Terror, the horrors of which were described as soon as in 1951 by such well known scientists as F.Houtermans, K.F. Shteppa and A.Weissberg-Cybulsky [4]. Shepelev was drafted into the army as a volunteer the day after fascist Germany attacked the USSR. He became one of the officers of the 928th Antiaircraft Battery of 61st Artillery Regiment of the Black Sea Fleet. And he was killed on April 21, 1942 during the defense of Sevastopol.

Shubnikov had been working for 4 years at the Kamerlingh Onnes Laboratory and revealed together with W.J. de Haas the first quantum oscillation effect, which now bears their names. In 1931, while based at the Ukrainian Physical - Technical Institute in Kharkov (UPhTI or National Scientific Center "Kharkov Institute of Physics and Technology" nowadays), he organized the first Cryogenic Laboratory in the USSR, where he obtained together with his colleagues a number of results of world-wide significance, which included such a pearl as the experimental discovery of type II superconductors [1]. Besides which, they studied the magnetic properties of thoroughly prepared single-phase, single-crystal alloys, discovered and studied in detail the phases when a magnetic field penetrates into (H_{c1}) and destroys the superconductivity (H_{c2}) of such alloys, as well as the changes in H_{c1} and H_{c2} in the case of a doping-level increase (in modern language, the increase of κ, the so called Ginzburg-Landau parameter, entails a corresponding change in the algebraic sign of the surface energy emerging between the superconducting phase and the normal phase that causes the superconductor magnetization curve to change completely). Making reference to this work, the members of International Conference on the Science of Superconductivity (Colgate Univ., Hamilton, N.Y. August 1963) addressed IUPAP to *"advise the use of the symbols H_{c1} and H_{c2} to express the limits of the mixed state in Type II superconductors. H_{c2} is taken to be the upper field limit while H_{c1} is reserved for the lower field limit. This notation (in the Russian version, H_{k1} and H_{k2}) is that introduced by Shubnikov in 1937, who was the first to give names to the critical fields."* [5].

After Shubnikov was groundlessly arrested on August 6, 1937 and subsequently executed, Shepelev was put in charge of the Cryogenic Laboratory from September 1937 until November 1938. In November 1938, by virtue of the Order of People's ►

▼ L.V. Shubnikov

► Commissariat of Heavy Industry, he was appointed, in place of M. Ruhemann exiled from the USSR together with other foreign specialists, as the Head of the Deep Freezing Experimental Station (DFES) being at the same time the Deputy Director of UPhTI. In November 1939, due to a critical defense assignment given to UPhTI by the Navy, Shepelev concentrated on this work together with V.I. Khotkevich (appointed subsequently to the position of Rector of Kharkov State University).

What happened to the above-mentioned experimental work, the theoretical explanation of which, as well as the analysis of its experimental results, was made by Abrikosov [6] 20 years later, is as follows. While the first experimental demonstration of Shubnikov and his colleagues' work was performed, as we know, by J.D. Livingston [7] at GE Research Labs. in 1962, Abrikosov's work was brought to attention by B.B. Goodman [8] at the IBM Conference on Fundamental Research in Superconductivity (T.J. Watson Research Lab., Yorktown Heights, N.Y.) as early as June 1961. The break-through in understanding the significance of Shubnikov and his colleagues' work [1] seemed to take place in 1963 at the International Conference on the Science of Superconductivity (Colgate University, Hamilton, N.Y.), which fact was noted by J. Bardeen, the Chairman of the Conference, the only doubly-nominated Nobel Laureate in Physics, and by R.W. Schmitt, the Conference Secretary [10]: *"It should be noted that our theoretical understanding of type II superconductors is due mainly to Landau, Ginzburg, Abrikosov, and Gor'kov, and that the first definitive experiments were carried out as early as 1937 by Shubnikov"*. The significance of the work [1] was also noted in the reports of such authoritative scientists as C.J. Gorter, K. Mendelssohn, B.B. Goodman, and T.G. Berlincourt. Besides, of great importance was the definition of the materials in which superconductivity remained sustainable in very large magnetic fields (the first publication [9]). P.G. De Gennes [10] was the first to introduce the notion *"Shubnikov's phase"* to describe the state of a superconductor between H_{c1} & H_{c2}, and after that this notion has come into use in the literature.

At the Superconductivity in Science and Technology Conference (University of Chicago, May 1966) J.Bardeen indicated in his presentation of the history of type II superconductivity [11]: *"The phenomenon was discovered experimentally by the Russian physicist, Schubnikov, around 1937"*. K.Mendelssohn [12], a classical scholar, estimated the 1937 work as follows: *"The real trouble here is that it is extremely difficult to make a homogeneous alloy, containing no lattice faults. Of the laboratories engaged in low temperature research in the thirties, Shubnikov's group in Kharkov had evidently the best metallurgical know-how"*. By the way, when Mendelssohn met A.G. Shepelev at the 10th International Conference on Low Temperature Physics (Moscow, 1966) and looked at his badge, he exclaimed at once: *"Schubnikow, Chotkewitsch, Schepelew, Rjabinin"* - although 30 years had passed! So, it was necessary to explain to him that it was Shepelev-the son, and that Shepelev-the father was killed when defending Sevastopol. Mendelssohn expressed his deep regret and continued by speaking of his high estimation of the 1937 work and of Shubnikov's scientific achievements. He also said that his book [12] describing that work was about to come out.

The situation relating to the McCarthy Era, *"The Iron Curtain"*, and superconductivity studies was described with great humor by P.W. Anderson, the Nobel Laureate who noted that A.A.Abrikosov's theory *"as well as the data of Schubnikov[1] together founded and almost completed the science of type II superconductivity"* [13]. At the H.Kamerlingh Onnes Symposium on the Origins of Applied Superconductivity – the 75th Anniversary of the Discovery of Superconductivity (Baltimore, MD, September 1986) T.G.Berlincourt estimated [1] as follows: *"Shubnikov et.al. had done the crucial experiment and had interpreted it correctly"* [14]. Presenting his report at the Fundamental Problems in High-Temperature Superconductivity Conference (Moscow, 2004), V.L. Ginzburg [15] has clearly stated: *"Shubnikov and his students and colleagues accomplished a lot within only a few years, and I should specially mention his studies of superconducting alloys and the factual discovery of type II superconductors... I am sure that Shubnikov would have achieved even greater success in science, and one cannot but feel bitterness about his untimely (at the age of only 36!) and quite guiltless death under the axe of Stalin's terror"*. ■

Acknowledgements

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PHYSICS IN DAILY LIFE: DRINK OR DRIVE

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For most of us, the small revolution went unnoticed. When we drive our car these days, our gasoline engine is no longer running on fossil fuel, i.e., on the solar energy harvest of millions of years ago. For a few percent, it is running on the solar energy harvest of last year: on bio-ethanol, that is. For Diesel engines, it may be even more than just a few percent. In Germany, for example, up to 200 000 cars have been running on pure biodiesel lately. And the European Commission's goal is that 10 % of all transport fuel be biofuel by the year 2020.

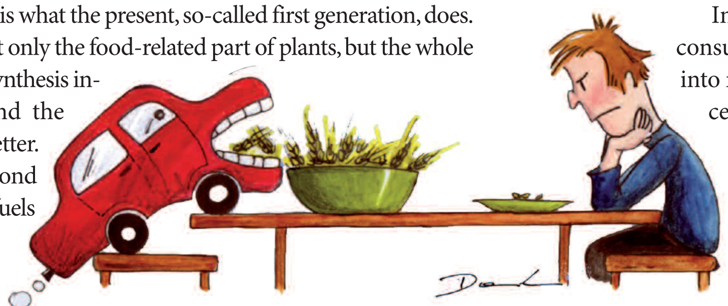
The EC may have been ill advised to set that goal. We have witnessed a dramatic increase in food prices world wide over the last years, and part of that is due to biofuels. Is the whole idea of biofuels just a hype, then?

Let us do a back-of-an-envelope calculation. Our daily food amounts to about 10 000 kJ/day. In terms of oil or gasoline, that is ¼ liter per day, only a small fraction of what our cars needs as a daily diet. In other words: If adopted on a world wide scale, this idea is bound to run into problems, if we assume that the biofuel competes with food. Which is what the present, so-called first generation, does.

If we utilize not only the food-related part of plants, but the whole harvest of photosynthesis including straw and the like, we can do better. But even this 'second generation' of biofuels has its limits. The reason, of course, is that the overall efficiency of natural photosynthesis is low. In a typical European climate, it is somewhat below 1 % as an average over the yearly solar energy influx. Which is bad news for densely populated and energy-intensive countries. Take the Netherlands, for example. Even with an optimistic photosynthesis efficiency of 1 %, the area needed for the total energy consumption to be based on biomass on a sustainable basis would be more than twice the total area of the country.

Granted: sooner or later we will have to rely on the sun for an appreciable part of our energy supply. But can't we do better than good old photosynthesis? Think of photovoltaic cells, for example. Crystalline silicon cells routinely have an overall efficiency of 10 to 15 %, while multi-junction concentrator cells achieved a record 43 % in the summer of 2007. This suggests that we may be better off relying on high-tech solutions, rather than trying to meet the energy demand of the modern energy-intensive society with methods of the Middle Ages.

In any case: Should we base our future fuel consumption on bio-ethanol, we sure would run into nasty dilemmas. For example, during the reception of the 50th anniversary of the EPS in 2018, we would face questions like 'Shall we have another glass, or shall we drive our car for another 300 meters?' ■



Comment/Addendum to L.J.F. Hermans, "Refueling", *Europhysics News* 39/1 (2008)

I much enjoyed reading L.J.F. Hermans' article "Refueling" in the last issue of *Europhysics News*. It highlights how simple physics reasoning can inform us on the fundamental constraints that new (and old) technologies face. I would like to add how after identifying stumbling blocks by back-of-the-envelope estimates, it is often important to think "out of the box" (or the "box" out of the car, in this case, as we will see).

Hermans' article points out a problem with electric cars. A car driving on the highway uses about 15 kW (see [1] for an instructive order of magnitude estimate of the energy that a car uses). This rate of energy usage is larger than the maximum rate of recharging of 3.5 kW from a standard electricity outlet. Even if we build a network of high-power charge stations, it is unclear whether batteries can ever be charged at 21 MW, the rate at which we pour gasoline into our present day cars. Therefore, electric car travel is potentially plagued by long stops for charging on trips that exceed the capacity of one battery cycle. Luckily, there is a simple potential solution: Electric cars (at least on long trips) should not be refueled by charging a car-mounted battery, but by simply swapping empty batteries for full ones! The empty batteries can then be slowly recharged in a fueling station. In fact, battery exchange is at the heart of a recent proposal to build up an electric car infrastructure in Israel [2, 3].

Another back-of-the-envelope calculation can inform us about the required infrastructure. Cars drive on average 20 000 km per year (this is the value that used car-sites use). If we assume an average speed of 50 km/h, cars drive about 400 hours per year, or a little more than 1 hour per day. From the above it follows that the average recharging time would then be about 4 hours per day, considerably less than the 24 hours per day available. The conclusion would be that, in principle, we would even need fewer batteries than cars. ■

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THE FAIRY TALE OF ELECTRICITY IN MUSEUMS IN SERBIA

>>> MUSEUM REVIEW

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▼ **FIG. 1:** Tesla Monument at Niagara Falls unveiled in 2006. Tesla is standing atop an AC motor. www.teslasociety.com

People in Serbia adore the Nikola Tesla Museum. In 2006, during the celebration of the 150th anniversary of his birthday, the airport in Belgrade was named after his name. The same year a Tesla monument was unveiled at Niagara Falls (Fig. 1), where the first major hydroelectric power plant, designed by Tesla, started producing electrical power in 1895.

Nikola Tesla Museum in Belgrade

Nikola Tesla Museum in Belgrade (www.tesla-museum.org) is the most important science museum in Serbia. After Tesla's death in 1943, his documents, original writings, correspondence and personal belongings were transported from New York to Belgrade, where the Nikola Tesla Museum was opened in 1955.

Tesla's *Fairy Tale of Electricity* [1] was illustrated and exposed in the museum exhibition (Fig. 2), emphasizing Tesla's appreciation of the history of electricity, expressed so nicely at the beginning of his tale : *"Whoever wishes to get a true appreciation of the greatness of our age should study the history of electrical development. There he will find a story more wonderful than any tale from Arabian nights. It begins long before the Christian era when Thales, Theophrastus and Pliny tell of the magic properties of* ***electron*** *– the precious substance we call* ***amber*** *– that came from the pure tears of the Heliades, sisters of Phaeton, the unfortunate youth who attempted to run the blazing chariot of Phoebus and nearly burned up the earth. It was but natural for the vivid imagination of the Greeks to ascribe the mysterious manifestations to a hyperphysical cause, to endow the amber with life and with a soul."*

Continuing in his poetic style Tesla's mentions most important discoveries and their discoverers ending with an ode to technological applications of the science of electricity: *"In 1831, as the crowning achievement of all, Faraday announced that he had obtained electricity from a magnet, thus discovering the principle of that wonderful engine – the dynamo, and inaugurating a new era both in scientific research and practical application. From that time on, inventions of inestimable values have followed one another at a bewildering rate. The telegraph, telephone, phonograph and incandescent lamp, the induction motor, oscillator transformer, Roentgen ray, Radium wireless and numerous other revolutionary advances have been made and all conditions of existence profoundly modified. In the eighty-four years which have since elapsed, the subtle agents dwelling in the living amber and loadstone have been transformed into cyclopean forces turning the wheels of human progress with ever increasing speed. This, in brief, is the fairy tale or electricity from Thales to the present day. The impossible has happened, the wildest dreams have been surpassed and the* ***astounded world is asking, What is coming next?"***

From the Fairy Tale section visitors enter into a section showing Tesla's main inventions: the induction (ac) motor (Fig. 2, in front) and the generator of poly-phase currents. Then follows the model of his system of production, transmission and distribution of electrical energy. The plaque from one of the generators of the hydro-power plant at Niagara Falls (1899), containing the list of Tesla's patents, is placed next to the model of the hydro-energetic system.

In addition to being a great inventor Tesla was a genius in teaching to the public the electromagnetic principles of his inventions. Tesla's egg of Columbus (Fig. 3) has attracted a lot of interest ever since it was first shown at the 1893 Chicago Columbian Exposition, when Tesla and George Westinghouse first introduced the

American public to the alternating current electrical power system. Tesla's Egg of Columbus performed the feat of Columbus with a copper egg in a rotating magnetic field. It was used to explain the principle of the rotating magnetic field and the induction motor.

One of Tesla's dreams was to harness lightning as a source of free energy. If he could not harness it entirely, he hoped at least to duplicate the tremendous voltages in his own laboratory. To enable himself to work with high voltages Tesla invented the only machinery that bears his name-the Tesla coil. It consists of an air core transformer with a spark gap and a capacitor. It is capable of generating extremely high voltages at very high frequencies.

Visitors may perform in NTM the experiment that Tesla carried out with the Tesla coil. This experiment was an early demonstration of radio waves. He stood several feet away from his coil holding a Geissler tube. This tube is a forerunner of the modern fluorescent tube. When the switch to the coil was closed, the coil sparked and the tube, unconnected in any way to the coil began to glow.

A decade ago an initiative was launched by physicists and the former director of NTM Marija Šešić to build an annex hall to house an interactive exhibition with models reproducing the historical experiments on electricity and magnetism. Unfortunately, the complex social situation in Serbia has not permitted yet the realization of this project. But, miraculously, an independent initiative by archaeologists have made it possible to set up in Belgrade an exhibition devoted to the magic properties of amber.

The exhibition "The magic of amber" in the National Museum in Belgrade

During summer and autumn 2006, the National Museum of Belgrade organized an exhibition "The magic of amber", which attracted a lot of visitors. On this occasion, a very well written and illustrated monograph was published [2].

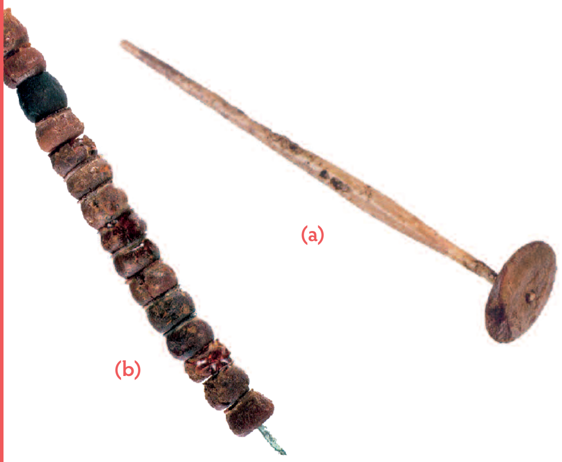
Amber is the fossilized resin which oozed down the sides of trees in some parts of the world millions of years ago. As geologic time progressed the forests were buried and the resin hardened into a soft warm, golden gem. The modern name amber is thought to come from the Arabic word, amber, meaning ambergris. Ambergris is the waxy aromatic substance created in the intestines of sperm whales. Ambergris and amber both wash up on beaches.

Amber from coastal erosion is transported along the shores of all the countries around the southern Baltic Sea. Its weight is slightly heavier than the water in the Baltic Sea. It floats like soap on the bottom, following the streams until it comes up on the shore or sinks in shallow water. One special chapter in the book "Magic of amber" is devoted to the routes of amber from the Baltic Sea, through Central Europe, to the Adriatic and Balkan region (Fig 4).

One interesting object of the exhibit is the distaff shown in Fig. 5. A distaff is a tool used in spinning. It is designed to hold the unspun fibers, keeping them untangled and thus easing the spinning process. It is most commonly used to hold flax, and sometimes wool, but can be used for any type of fiber. In the monograph [2] one ▸

▲ **FIG. 2:** Illustrated Fairy Tale of Electricity and poly-phase induction motor.

▼ **FIG. 3:** A reproduction of Tesla's egg of Columbus in NTM.



▲ **FIG. 5: (a) Pin with amber head [2]. (b) Pins with amber beads – distaff. End of the 1st – beginning of the 2nd century AD [2].**

▸ reads that "on the amber road, these pins (Fig. 5) are characteristic of the end of the 1st and beginning of 2nd century AD". This reminds us of a legend about the discovery of electricity, recorded by Boris Fomin in the book "Pokorennaja plazma" (Tamed plasma).

Amber spindle of Thales' daughter

According to the legend mentioned in Fomin's book, Thales' daughter had a spindle made of amber. While she was spinning the spindle, a lot of wool fibers stuck to it. She tried to remove them but as she rubbed the spindle, more and more down wool sticked to it. Lighter fibers even jumped from the table towards the spindle.

The girl told her father about the "miracle" After verifying the phenomenon he ascribed to *amber* the particular property of attracting down wool and called this special attraction force amber force. Since amber means in Greek *electron*, this mysterious force has been since named electrical force.

In Fomin's book there is no reference to the source of this legend. Most historians of the science of electricity do not mention this legend. But the legend is so nice and looks authentic. Other sources and facts about "amber distaff", were searched for in the Internet and two interesting articles [3, 4] were found:

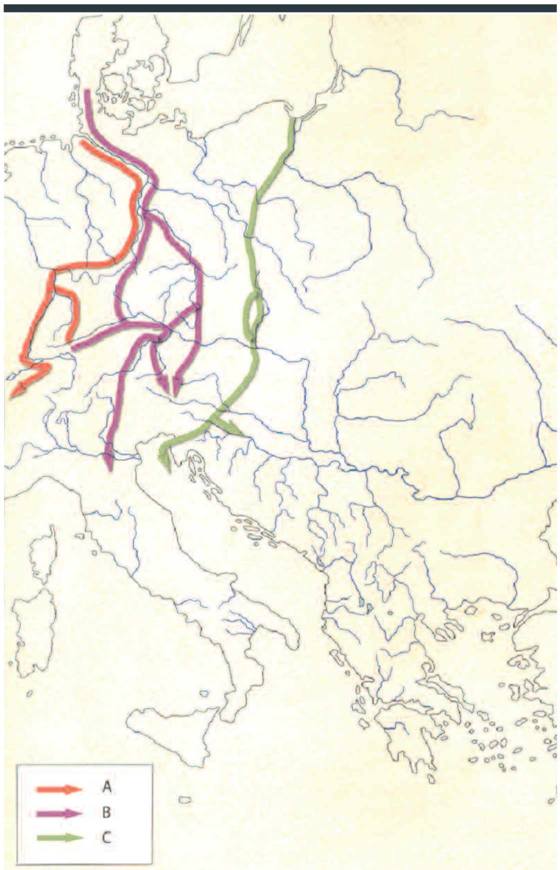
Anna Binnie in [3] writes: *"The Ancient Greeks are credited with the discovery of the basic properties of electrically charged objects. It is believed that the phenomenon presented a nuisance to the spinners of Ancient Greece who used amber distaff on their spindles when spinning wool. Dust and fluff was attracted to the distaff"*.

In another article [4] the authors report on their excavation and chemical-physical analyses of the object, similar to the one at Fig. 5, which they also call distaff. This object was found during the archeological survey in view of an urban project in the ancient Tenuta Boccone D'Aste (north-eastern area of Rome). The authors write [4]: *"…The function of these objects has not always been unequivocally defined…According to recent studies, the most reliable hypothesis assimilates this kind of artefact to the distaff widely used in the spinning process"*.

This hypothesis, made in 1947 by Haberey, has been investigated and supported later by Pirling and other researchers. They gave various comparative arguments based on findings in the Apennine peninsula and northern parts of Europe in the AD period. We would expect that similar research and findings along the Shkoder-Prizren route, shown at the exhibition *"Magic of amber"*, will be continued towards Greece in the BC period. The continuation of research along these lines would eventually reveal more facts related to the amber distaff of Thales daughter and throw light on the role of amber in antiquity. It would also contribute to better understand and explain the use and role of amber distaff in Roman and later time.

Hopefully, physicists, engineers, archeologists, historians, writers, philosophers and stack holders will join in the future their efforts to create in Belgrade an interactive museum exhibition telling to youngsters and the public an exciting story of electricity and magnetism.

▼ **FIG. 4: Amber routes according to Jose Maria de Navarro (1925). A. Early Bronze Age, B. Middle Bronze Age, C. Iron Age [2].**



Acknowledgments

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