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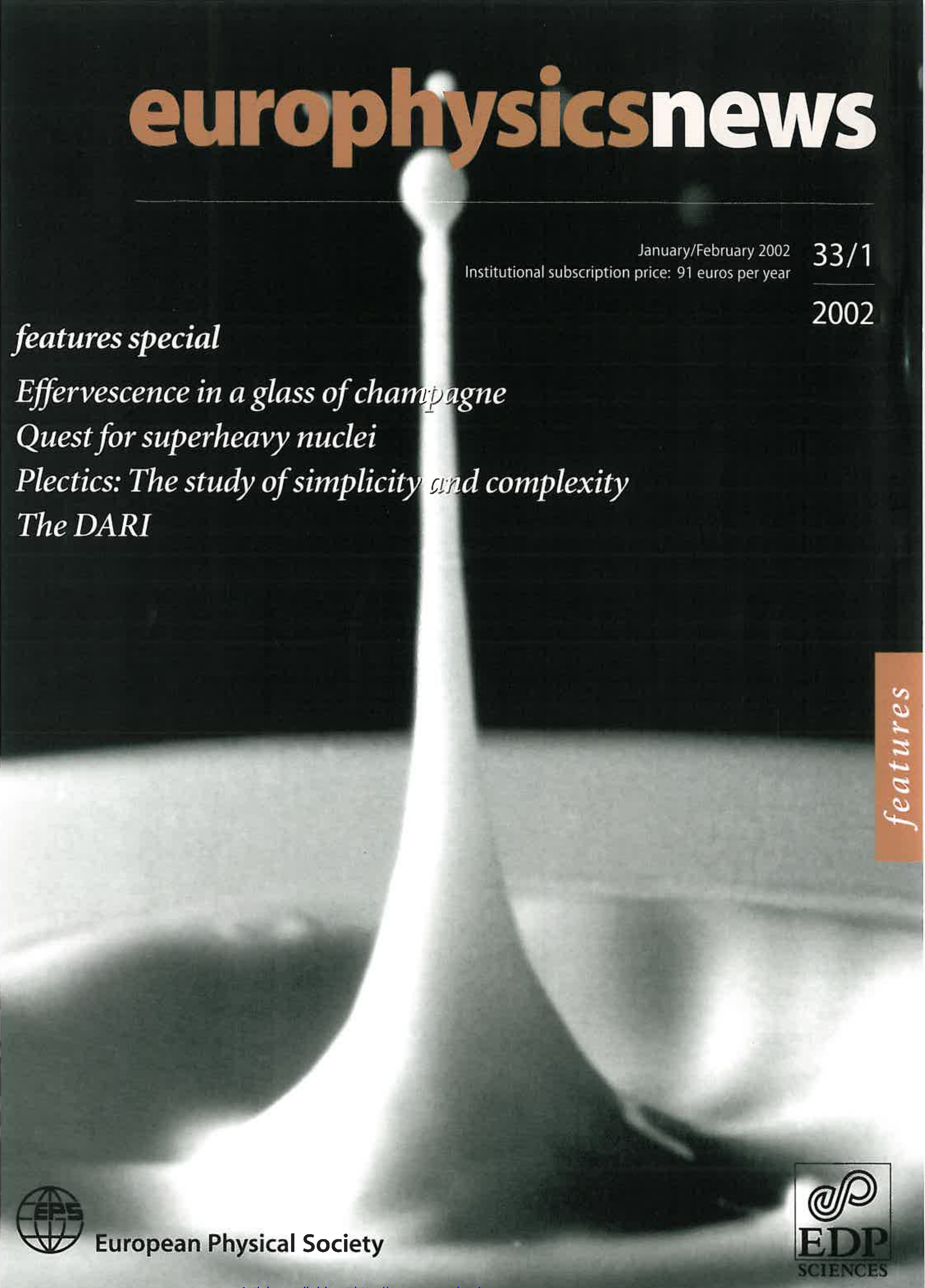

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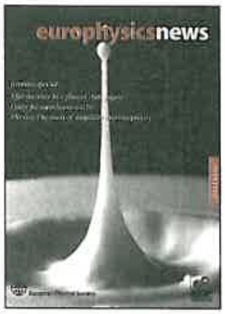

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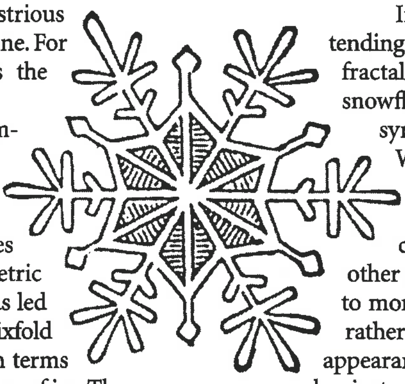
Snowflakes and seaweed

Denis Weaire, Trinity College, University of Dublin, Ireland

Sometime around 1609 Johann Kepler caught what he described as a star from heaven, an individual snowflake. Its elegant shape inspired him to write *A New Year's Gift or the Six-Cornered Snowflake* for his benefactor, Counsellor Wackher of Regensburg. It was a minor divertissement in his illustrious career, but a remarkable one. For some it even represents the origin of crystallography.



In his essay Kepler rambled amusingly from the seeds of the pomegranate to the cells of the honeybee, picking up clues to the origin of symmetric natural structures. He was led to a theory for the sixfold shape of the snowflake in terms of the packing of tiny lumps of ice. These were not described as atoms, but played the same role of simple, primary constituents, out of which a complex pattern was to arise.

The same indescribable beauty was admired by the Irish physicist John Tyndall in the 19th century. *How imperfect seem the productions of human minds and hands when compared with those formed by the blind forces of nature! But the blindness is ours*, said Tyndall, although he correctly attributed the sixfold shape to the way in which molecules of H_2O are arranged in the crystalline structure of ice. In his book on *Forms of Water*, largely drawn from his mountaineering experiences in Switzerland, he also gives an account of *flowers of ice* in frozen lakes, which have a similar sixfold shape. They are formed when sunlight melts the surface of the ice.

Only in recent times was the snowflake adopted as the universal icon of a white Christmas. The earliest example of its use in art is said to be on a 19th century Japanese sword-guard, but the ancient Chinese certainly knew all about snowflakes, so this assertion may well be wrong by some thousands of years!

The snowflake's star poses a further question. Why does it branch out, in a manner reminiscent of plants? Today we can understand this too, as a consequence of the growth process in which water vapour freezes on the growing flake. Depending on the precise conditions, such processes may lead to compact rounded objects, or branching feathery ones, in so-called dendritic growth. If several generations of branches are involved, we may even approach the mathematicians ideal of a *fractal* structure, one in which detail is contained with detail, indefinitely.

In branching out and tending towards towards a fractal structure, the snowflake maintains its symmetry, more or less. When similar patterns were first found in metals they were called *iron snow*. But other growth processes lead to more random structures, rather like seaweed in appearance. Treasa Meegan has just completed a PhD in the TCD Physics Department, modelling these structures and comparing her computer simulations with patterns found when metals are electrodeposited. These patterns are found to swirl clockwise or counter-clockwise when magnetic fields are applied, and the research group of Michael Coey hopes to exploit these magnetic effects. They may have important implications for the practical use of electrodeposition in industry.

electrodeposit pattern

Treasa is currently starring as Snow White in Ireland's leading Christmas pantomime (a traditional form of popular seasonal entertainment), and may be lost to science if her budding acting career prospers. One wonders what Grumpy's remark would be, on being told that his guest is a computational physicist.

[Adapted with permission from an article in the Irish Times]

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Quest for superheavy nuclei

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The discovery of new superheavy nuclei has brought much excitement to the atomic and nuclear physics communities. Hopes of finding regions of long-lived superheavy nuclei, predicted in the early 1960s, have reemerged. Why is this search so important and what new knowledge can it bring?

Not every combination of neutrons and protons makes a stable nucleus. Our Earth is home to 81 stable elements, including slightly fewer than 300 stable nuclei. Other nuclei found in nature, although bound to the emission of protons and neutrons, are radioactive. That is, they eventually capture or emit electrons and positrons, alpha particles, or undergo spontaneous fission. Each unstable isotope is characterized by its half-life ($T_{1/2}$) - the time it takes for half of the sample to decay. Isotope half-lives range from less than a thousandth of a second to billions of years. Many radioactive nuclei may have half-lives comparable to or longer than the age of the Earth (4.5 billion years). Examples are the actinide nuclei ^{232}Th ($T_{1/2}=1\cdot10^{10}$ years), ^{235}U ($T_{1/2}=7\cdot10^{8}$ years), or ^{239}U ($T_{1/2}=4\cdot10^{9}$ years). Short-lived isotopes cannot be found naturally on Earth because they have long decayed since our planet was formed. Yet, thousands of short-lived isotopes are continually created in the cosmos. Their existence may be fleeting, but they play a crucial role in the ongoing formation of the elements in the Universe. The properties of most rare isotopes are unknown and can be only inferred, with considerable uncertainty, from theoretical calculations.

Figure 1 shows bound nuclear systems as a function of their proton number Z (vertical axis) and their neutron number N (horizontal axis). The black squares represent the stable or very long-lived nuclei. They form the so-called "valley of stability". The yellow region indicates shorter-lived nuclei that have been produced and studied in laboratories. By adding either protons or neutrons, one moves away from the valley of stability, finally reaching the drip lines where nuclear binding ends because the forces between neutrons and protons are no longer strong enough to hold these particles together.

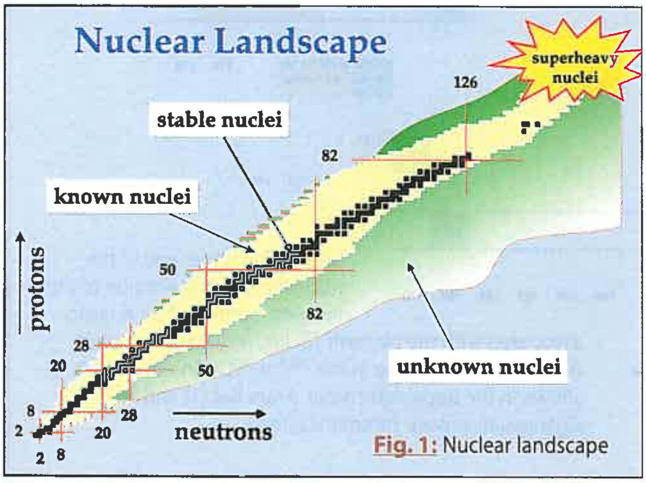


Fig. 1: Nuclear landscape

The superheavy elements mark the limit of nuclear mass and charge; they inhabit the upper right corner of the nuclear landscape, but the borderlines of their territory are unknown. The stability of the superheavy elements has been a longstanding fundamental question in nuclear science. How can they survive the huge electrostatic repulsion? What are their properties? How large is the region of superheavy elements? We do not know yet all the answers to these questions. This short article presents the current status of research in this field.

Historical Background

The quest for superheavy nuclei began in the 1940s with the synthesis of atomic nuclei with a number of protons greater than uranium (Z=92). In 1940, neptunium (Z=93) and plutonium (Z=94) were discovered. This was followed by the synthesis of americium (Z=95) and curium (Z=96) in 1944, berkelium (Z=97) in 1949, californium (Z=98), einsteinium (Z=99) and fermium (Z=100) in 1952, and mendelevium (Z=101) in 1955. All these elements were produced by intense neutron irradiations or by proton, deuteron, or helium (alpha particle) bombardment in a cyclotron. Some of these isotopes have been produced in sizable amounts. Einsteinium and fermium were discovered in the debris from the thermonuclear explosion conducted at Eniwetok Atoll in the Pacific Ocean. Amazingly, the fermium nucleus was made through the capture of 17 neutrons by ^{238}U followed by the subsequent beta decays. In nature, a similar process (the so-called r-process, believed to be taking place in supernova) is responsible for the synthesis of heavy elements.

Still heavier elements (transuraniums) were produced in heavy-ion accelerators by fusing heavy actinide targets (plutonium-californium) with light ions of carbon (nobelium, Z=102, 1958; ruthefordium, Z=104, 1969), boron (lawrencium, Z=103, 1961), neon (dubnium, Z=105, 1967), and oxygen (seaborgium, Z=106, 1974). In order to go heavier, to compensate the decrease of the proton-to-neutron ratio with mass, fusion of nuclei with the largest possible surplus of neutrons had to be used. In the 70s, "cold fusion" reactions involving medium-mass projectiles with $Z \geq 24$ and lead or bismuth targets were introduced and replaced "hot fusion" reaction with actinide targets. This enabled the discovery of bohrium (Z=107, 1976), hassium (Z=108, 1984), meitnerium (Z=109, 1982), ununnilium (Z=110, 1994), unununium (Z=111, 1994), and ununbium (Z=112, 1996). The last three elements are still unnamed. So far, they carry temporary names derived directly from the atomic number according to the systematic nomenclature of the International Union of Pure and Applied Chemistry (IUPAC).

Most of the heaviest elements were found in three "heavy element factories": Lawrence Berkeley Laboratory in Berkeley (USA), Joint Institute for Nuclear Research in Dubna (Russia), and Gesellschaft für Schwerionenforschung (GSI) near Darmstadt (Germany). After much discussion about the priority for their synthesis, IUPAC 1997 has accepted names up to Z=109. At that time, nuclei with Z=110, 111, and 112, discovered at GSI, were already known. The lifetimes of the heaviest elements were found to be very short. For instance, element Z=112, investigated using the reaction ^{70}Zn + ^{208}Pb → ^{277}Uub + 1n, turned out to have a half life of only about 280 μsec. The corresponding fusion cross section is extremely small, 1 pb. Since the production cross section was found to be rapidly decreasing with the atomic number, see Fig. 2, it was then concluded that it would be very difficult to reach still heavier elements.

As far as theory is concerned, major advances were made in 1966, when the first realistic theoretical calculations for the superheavy nuclei were carried out. These early calculations were based on the shell correction (or: macroscopic-microscopic) method in which the total binding energy was decomposed into a smooth part (approximated by a macroscopic liquid drop model) and a microscopic quantal shell correction term strongly oscillating with the number of nucleons and reflecting the energy stabilization due to the presence of nucleonic shells. Such calculations predicted the nucleus with Z=114, N=184 ($^{298}_{114}$Uuq) to be a doubly magic center of an island of long-lived superheavy nuclei. This result stayed practically unchallenged until the late 1990s where more refined models, based on self-consistent mean-field theory and realistic effective nucleon-nucleon interactions, started to be systematically applied to superheavy nuclei. In another frontier of superheavy element research, in quantum chemistry, relativistic effects in molecules containing heavy elements have been studied intensively since the mid 1970s, when it became apparent that they have to be included in the description of compounds containing heavy elements.

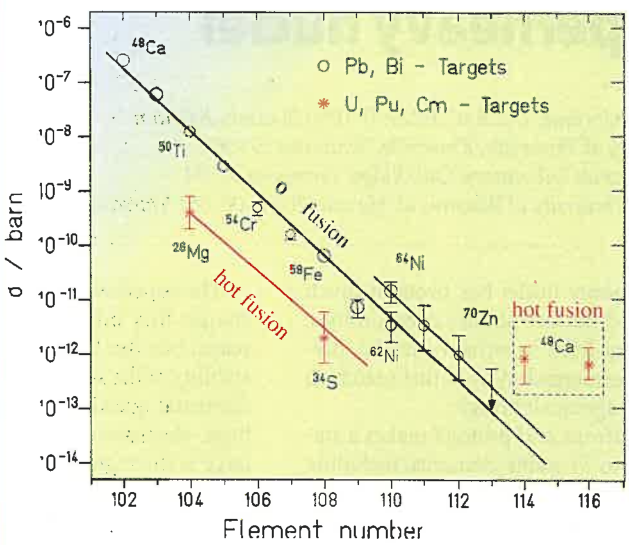


Fig. 2: Cross sections for the production of the heaviest elements. The results of recent hot fusion experiments with the ^{48}Ca beam and actinide targets carried out in Dubna are also shown in the box. (From Ref. [1] and Yu.T. Oganessian, private communication.)

New discoveries

The last three years (1999-2001) have brought a number of experimental surprises which have truly rejuvenated the field [1]. In January 1999, scientists from Dubna reported the synthesis of one atom of element 114 ($^{298}_{114}$Uuq) in a "hot fusion" reaction between a ^{48}Ca beam and a ^{244}Pu target. This discovery was followed by three other reports, also from Dubna. First, using the ^{242}Pu (^{48}Ca,3n) reaction, they produced ^{287}Uuq. In 1999, the synthesis of yet another isotope of Z=114, the even-even ^{288}Uuq, was reported. The two α decay sequences were confirmed afterwards (July 2000, May 2001) by the observation of three α chains associated with the element Z=116 ($^{292}_{116}$Uuh) in the ^{248}Cm (^{48}Ca, 4n) reaction. According to the Dubna analysis, the resulting a-decay chain goes through ^{288}Uuq, ^{284}Uub, and ^{280}Uun, which subsequently fissions. In neither of these cases do the a chains end up at a known isotope so a firm assignment could not be made. Considering the exponential trend seen in Fig. 2 for $Z \leq 114$, it actually

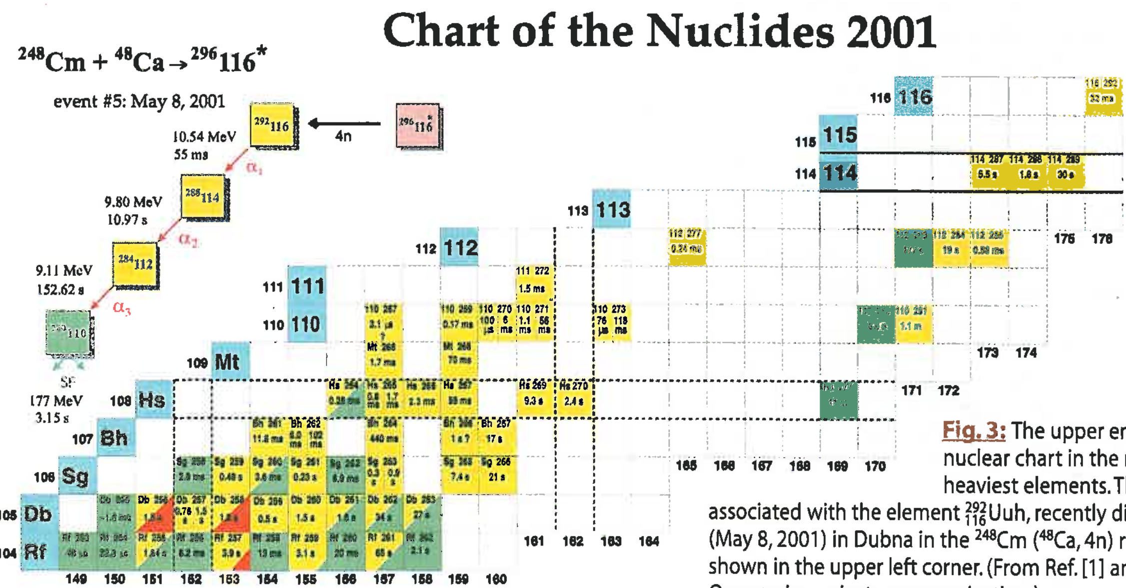


Fig. 3: The upper end of the nuclear chart in the region of the heaviest elements. The α chain associated with the element $^{292}_{116}$Uuh, recently discovered (May 8, 2001) in Dubna in the ^{248}Cm (^{48}Ca, 4n) reaction, is shown in the upper left corner. (From Ref. [1] and Yu.T. Oganessian, private communication.)

came as a great surprise that hot fusion reactions with a ^{48}Ca beam could produce a significant number of events. Another surprising (and exciting) result of the Dubna experiments was that nuclei which were produced have fairly long lifetimes. For instance, the lifetimes reported for the elements ^{284}Uub and ^{280}Uun are many orders of magnitude longer than those of the isotopes with $Z \leq 112$ previously discovered at GSI.

Progress has also been made in the region previously explored by GSI. The GSI group found a new even-even isotope of ^{270}Uun, and also ^{272}Uuu and ^{277}Uub. A group led by scientists from the Paul Scherrer Institute (PSI) observed the ^{269,270}Hs decay chains at GSI, thus convincingly confirming the data on ^{277}Uub for which ^{269}Hs is a member of the decay chain. New isotopes of ^{266,267}Bh have been found at Berkeley. As far as chemistry is concerned, a tremendous achievement and a true tour-de-force were the first chemical studies of seaborgium, bohrium, and hassium (see below). Figure 3 shows the upper end of the nuclear chart as of 2001.

Physics at the limit of cross sections is difficult and challenging. The synthesis of the new element Z=118 (^{293}Uuo), announced in 1999 by the Berkeley group, has been retracted two years later. The history of heavy element research remembers other cases of elements discovered and gone, and sometimes discovered again. A team working in Stockholm at the Nobel Institute of Physics reported in 1957 an isotope with atomic number 102. The group proposed the name Nobelium in honor to Alfred Nobel. In 1958 a group at Berkeley reported that they were unable to reproduce this work, findings agreed by a Russian group at Dubna. But the name stuck...

Structure of the superheavy nuclei

The structure of superheavy elements results from the interplay between the strong and electromagnetic forces. Unlike in lighter nuclei, the Coulomb interaction cannot be treated as a small perturbation atop the dominating nuclear interaction; it does influence significantly proton and neutron distributions[2].

The stability of heavy and superheavy elements has been a longstanding fundamental question in nuclear science. Theoretically, it has been shown that the mere existence of nuclei with $Z > 102$ is entirely due to quantal shell effects. Indeed, in the classical liquid drop picture, the shape of a nucleus is governed by an interplay between surface tension (proportional to $A^{2/3}$, trying to make the nucleus spherical) and Coulomb repulsion (proportional to $Z^2/A^{1/3}$, trying to make the nucleus deformed). At large values of Z^2/A, the Coulomb force is so strong that the nuclear liquid drop becomes unstable to surface distortions and it fissions spontaneously. It is the stabilization brought by quantal shell effects that is responsible for the superheavies.

In spite of an impressive agreement with experimental data for the heaviest elements, theoretical uncertainties are large when extrapolating to unknown regions of the nuclear chart. In particular, there is no consensus among theorists with regard to the center of the shell stability in the superheavy region. Since in these nuclei the single-particle level density is relatively large, small shifts in the position of single-particle levels (e.g., due to the Coulomb or spin-orbit interaction) can be crucial for determining the shell stability of a nucleus. While most macroscopic-microscopic (non-self-consistent) approaches predict Z=114 to be magic, most self-consistent calculations suggest that the center of the proton shell stability should be moved up to higher proton numbers, Z=120, 124, or 126. For the neutrons, most non-relativistic calculations predict magic gaps at N=184 while the relativistic mean-field theory yields N=172 - due to a slightly different spin-orbit interaction. The experimental determination of superheavy nuclei from this region will thus be of extreme importance for pinning down the fundamental question of the spin-orbit force.

Does it actually make sense to talk about "magic superheavy nuclei"? A recent theoretical work [3] sheds a new light on this question. According to calculations, the patterns of single-particle levels are significantly modified in the superheavy elements. Firstly, the overall level density grows with mass number A, as $\propto A^{1/3}$. Secondly, no pronounced and uniquely preferred energy gaps appear in the spectrum. This shows that shell closures which are to be associated with large gaps in the spectrum are not robust in superheavy nuclei. Indeed, the theory predicts that beyond $Z = 82$ and $N = 126$ the usual localization of shell effects at magic numbers is basically gone. Instead the theory predicts fairly wide areas of large shell stabilization without magic gaps. This is good news for experimentalists: there is a good chance to reach shell-stabilized superheavy nuclei using a range of beam-target combinations.

Some of the observed α-decay chains attributed to elements 112 and 114 are believed to link odd-N nuclei. The presence of an odd neutron adds to a theoretical uncertainty. Since the single-particle level density of transactinides is large, there are many candidates for low-lying one-quasiparticle states in parent and daughter nuclei. Moreover, many alpha transitions are structurally forbidden since the properties of one-quasiparticle excitations in parent and daughter nuclei often differ dramatically. As an example, Fig. 4 shows the predicted a-chains for the nucleus ^{277}112 found at GSI. The Hartree-Fock-Bogoliubov calculations explain two observed a branches, attributed experimentally to ^{273}110, in terms of transitions between negative parity and positive parity single-neutron orbitals.

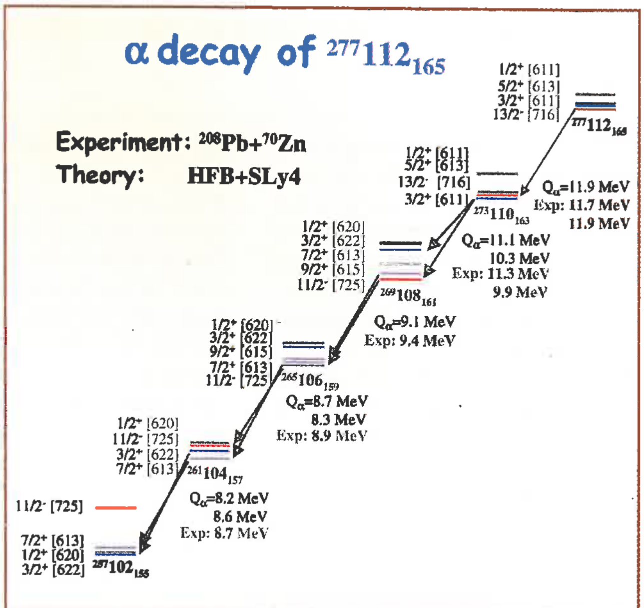


Fig. 4: α-decay chain of $^{277}112_{165}$ predicted in the HFB calculations with the SLy4 Skyrme interaction. The individual one-quasineutron states are labeled using the asymptotic Nilsson quantum numbers. The allowed alpha transitions are indicated by arrows. Calculated Q_α values are compared to experimental data from GSI. (Taken from S. Ćwiok *et al.*, private communication.)

Chemical properties of superheavy elements

Since atomic relativistic effects scale approximately with Z^2, chemical properties of transactinides cannot be properly described by non-relativistic quantum mechanics. However, experimental tests of relativistic effects and of anticipated deviations from the periodic table of the elements in the superheavy region are extremely difficult because the single atom chemistry requires half-lives of the order of one second, i.e., much longer than those of the heaviest elements found so far. Another obstacle is very small production rates: a few events per day for hassium and less for heavier elements. In spite of these difficulties, there has been major progress in the chemical characterization of transactinides. Special techniques, such as gas phase separation, have been devised to perform one atom-at-a-time chemistry and to deduce thermodynamical properties of new elements [4].

In 1993, chemical studies of dubnium demonstrated that it does not behave like tantalum, the element from the group to which dubnium was supposed to belong. On the contrary, the following chemical studies of Sg (year 1997), Bh (2000), and Hs (2001) confirmed relativistic calculations predicting their behavior to coincide with that expected on the basis of their positions in the periodic table. Hassium, for instance, forms a gaseous oxide similar to that of osmium, which places it in group 8. As of today, the periodic table has been experimentally established up to element 108. However, preparations are under way to carry out gas chemistry of element 112, which instead of behaving like its lighter transition metal homologs (Zn, Cd, Hg) is expected to have properties of a noble gas like Rn or Xe; a first attempt to chemically identify element Z=112 has recently been carried out in Dubna. Still heavier elements, predicted to be noble volatile metals, are also excellent candidates for gas chemical studies, provided that their half-lives are sufficiently long. In particular, there is hope of employing chemical methods for the firm identification of the alpha-chains of long-lived isotopes of Z=114 and 116 observed in Dubna.

First predictions of the chemistry of superheavy elements were made in 1971, and the first relativistic molecular calculations for systems involving transactinide elements were published in 1977. Since then, calculations based on the relativistic quantum theory have been considerably improved and applied to many atoms and molecules [5]. Relativistic effects in transactinides are crucial and show up in several ways. Most importantly, s and $p_{1/2}$ atomic orbitals contract relativistically. The shrinking of the inner shells results in an increased screening of the nuclear charge, and this gives rise to an expansion of the $p_{3/2}$ and of higher angular momentum orbitals. Another relativistic effect is a change in the spin-orbit coupling. Both can produce drastic rearrangements of orbital levels. That is what is predicted to happen for element 112. Recent calculations indicate that the 7s orbital should be shifted below the $6d_{5/2}$ orbital due to relativistic effects. It is the large relativistic stabilization of its valence 7s orbital, combined with its closed shell electron configuration, that has led to the prediction that element 112 is chemically inert.

Chemistry of the superheavy elements with $Z > 118$ is believed to show relativistic effects that are so large that comparison with lighter elements or nonrelativistic results is meaningless.

Borders of the superheavy region

Where are the borders of the superheavy region? What are the properties of the heaviest nuclei that can be bound (at least, in theory), in spite of the huge disruptive Coulomb force?

As a consequence of their saturation properties, nuclear forces favor values of the internal density close to the saturation density of nuclear matter. On the contrary, since the Coulomb interaction tends to increase the average distance between protons, the Coulomb energy is significantly lowered by either the creation of a central depression or by deformation, or by both. Based on this general argument, one expects the formation of voids in heavy nuclei. Recently, the subject of exotic (bubble, toroidal, band-like) configurations in nuclei with very large atomic numbers has been revisited by self-consistent calculations.

Box 1: The nucleus is a complicated many-body system. The strong forces describing heavy nuclei are strongly affected by the in-medium effects; they are usually approximated by phenomenological effective density-dependent interactions fitted to a few key nuclear properties. This strategy, well known in condensed matter physics, turned out to be extremely successful. The self-consistent density functional theories (relativistic and non-relativistic) describe bulk nuclear properties such as masses, radii, shapes, as well as nuclear excitations. A number of effective interactions have been introduced and their capability to describe properties of exotic radioactive nuclei is one of the major challenges in present-day nuclear structure.

Any theoretical model aiming at making predictions in an unknown territory should first be tested in known regions of the chart of the nuclides. Since the main decay mode for the known heaviest elements is α decay, one of the crucial quantities determining lifetimes of the heaviest and superheavy elements is the α-decay energy. The Q_α values for the heaviest elements calculated with the self-consistent model with the SLy4 effective interaction are displayed in Fig. 5. They are compared with known α-decay energies. It is seen that the agreement with experimental data (including the recent data shown in Fig. 3) is very good, and this suggests that calculations such as those shown on Fig. 5 can be used to predict properties of unknown superheavy nuclei.

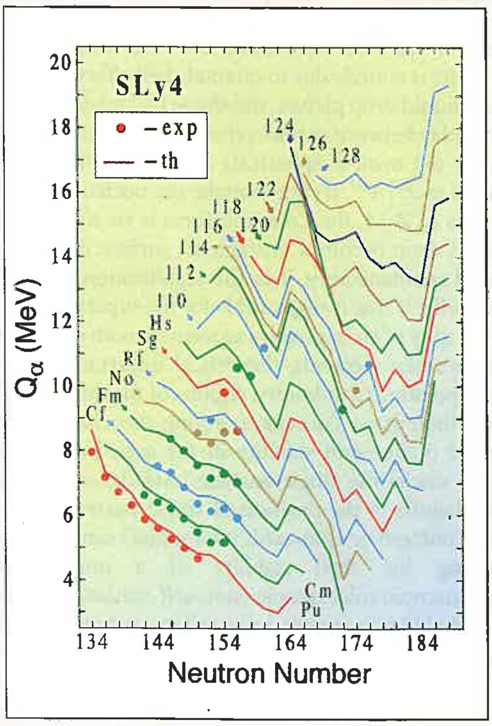
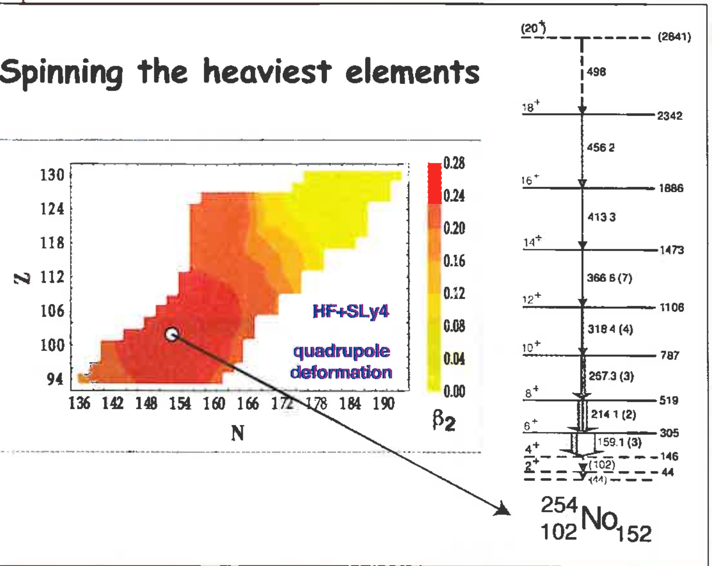


Fig. 5: Q_α values for even-even nuclei with $96 \leq Z \leq 118$ obtained in the self-consistent calculations. They are compared to experimental data (closed symbols) including the recent data for Z=114 and 116. (Taken from S. Ćwiok *et al.*, Phys. Rev. Lett. **83**(1999) 1108, and to be published.)



Box 2: In spite of the fact that the number of protons and nucleons in the nucleus is rather small, and nucleonic velocities are fast, atomic nuclei exhibit collective modes such as rotations and vibrations. Many nuclei emit photons characteristic of the sequential de-excitation of rotational bands. In quantum mechanics, collective rotation can only arise for systems that have a deformed shape, i.e., nonspherical distribution of the nucleonic density. It has been only recently that rotational photons could be detected in spectroscopic studies of the transactinides. First results on the collective properties of nobelium isotopes ^{252,254}No have been obtained at Argonne (USA) and Jyväskylä (Finland). It has been found that the ground state rotional band of ^{254}No, the best deformed nucleus above ^{208}Pb, resists fission up to a spin of at least 20 $\hbar$ (see Fig. 6). Detailed microscopic calculations have shown that the fission barrier of this nucleus changes very weakly with angular momentum, thus explaining this amazing stability of the nobeliums as a combined effect of the Coulomb and Coriolis-plus-centrifugal forces.

Fig. 6: Experimental confirmation of the role of deformation in transactinides was recently obtained for ^{254}No. The figure (right portion) shows a cascade of transitions characteristic of the rotation of a deformed nucleus. From the precise energy difference between successive states, it is inferred that ^{254}No has a football-like shape with an axis ratio of 4:3, in agreement with theory. The fact that states with angular momenta as high as 20 $\hbar$ were detected underscores the remarkable resilience of the shell effects against the centrifugal force and fission. Modern nuclear structure calculations – such as the one labeled HF+Sly4 (left) – tell that stability comes in specific cases from the ability of the nucleus to deform. Here, the deformation parameter β_2 characterizes the elongation of the nuclear shape (for β_2=0 nucleus is spherical).

The calculations predict the competition between several of these forms for the central nuclear density due to the huge electric charge. It is difficult to say at present whether these exotic topologies can occur as metastable states. Will the spherical bubble minimum undergo the shape transition to the "band-like" configuration? What is the stability of all these shapes to reflection-asymmetric and triaxial deformations? It is possible that there exist isolated islands of nuclear stability, associated with very exotic topologies of nuclear density, stabilized by shell effects.

Perspectives

The heavy element research has been traditionally concentrated in three laboratories: Berkeley, Dubna, and GSI. But the exciting new discoveries brought new players to the "superheavy" community: RIKEN (Japan) and GANIL (France). Chemical studies of transactinides are also being carried out at PSI and JAERI (Japan).

One of the most important and urgent tasks facing experimentalists will be to confirm the new elements found in Dubna. This will not be easy, since these nuclei form an isolated island, disconnected from the known region of the nuclear chart. In order to identify the elements beyond Z=112, new tools, such as direct mass measurements or chemical studies must be developed. How to reach even heavier nuclei? The new-generation high-current stable-beam accelerators will certainly be helpful in making new discoveries at a picobarn level. However, in order to explore new, more neutron-rich superheavy regions, accelerated beams of radioactive neutron-rich nuclei will have to be utilized. It is hoped that the new high-powered ISOL facilities will enable us to explore the theoretically crucial region of nuclei between the deformed N=162 shell and the spherical N=184 shell.

There are also many challenges facing nuclear theory of superheavies. The currently highly phenomenological models used to describe heavy-ion fusion are not reliable when extrapolating outside the regions of known nuclei. The situation is not better for the description of static fission barriers and of dynamics of fission. Slightly better is the situation in the theoretical modeling of nuclear structure of transactinides, where the microscopic self-consistent models can make quantitative predictions. Here, the main problem is how to extrapolate density-dependent effective interactions to the superheavy "terra incognita" and how to describe exotic forms of nuclear existence created thanks to the huge Coulomb force and the borders of the superheavy region. The advances in computer technology and in numerical algorithms will certainly be crucial for the success of this task.

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Effervescence in a glass of champagne: *A bubble story*

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People have long been fascinated by bubbles and foams dynamics, and since the pioneer work of Leonardo da Vinci in the early 16th century, this subject has generated a huge bibliography. However, only very recently, much interest was devoted to bubbles in champagne wines [1]. Small bubbles rising through the liquid, as well as a bubble ring (the so-called collar) at the periphery of a flute poured with champagne, are the hallmark of this traditionally festive wine, and even if there is no scientific evidence yet to connect the quality of a champagne with the fineness of its bubbles, people nevertheless often make a connection between them. Therefore, since the last few years, a better understanding of the role played by each of the numerous parameters involved in the bubbling process has become an important stake in the champagne research area. Furthermore, in addition to these strictly enological reasons, we also feel that the area of bubble dynamics and especially the area of collapsing bubble dynamics could benefit from the simple but close observation of a glass poured with champagne.

In this paper, our first results concerning the close observation of the three main steps of a champagne bubble's life are summarised, i.e. the bubble nucleation, the bubble ascent and the collapse of a bubble bursting at the free surface of the liquid. Our results were obtained in real consuming conditions, in a classical crystal flute poured with a standard commercial Champagne wine.

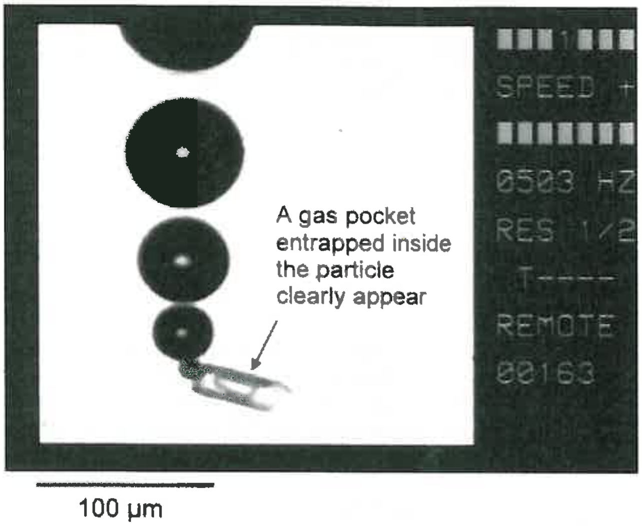

Fig. 1: Close-up of a particle acting as a nucleation site on the wall of a glass poured with champagne. Most of these particles are hollow elongated and roughly cylindrical fibres.

Bubble nucleation

In the case of Champagne wines, the main gas responsible for bubble production is carbon dioxide, which is produced by yeasts during the second fermentation in the closed bottle. According to Henry's law, equilibrium progressively establishes between the gas dissolved into the wine and the gas into the vapour phase in the headspace under the cork. At the end of fermentation, the CO_2 pressure under the cork is around 6 atm., and the wine may contain up to 12 g/L of dissolved CO_2. When the bottle is opened, the CO_2 pressure in the vapour phase suddenly falls. The thermodynamic equilibrium of the closed bottle is broken, and the wine becomes supersaturated with CO_2 molecules. To recover a new stable thermodynamic state corresponding to the atmospheric pressure, champagne must degas. When champagne is poured into a glass, two mechanisms enable dissolved CO_2 molecules to escape from the supersaturated liquid medium: diffusion through the flat free surface of the liquid, and bubble formation. As soon as a liquid medium is supersaturated, the bulk free energy per unit of volume, Δg_v, associated with the transfer of dissolved gas molecules into the vapour is negative, and therefore thermodynamically favourable. But the bubble production process also results into the production of interfacial free energy. Below a critical radius r_c depending on some physicochemical parameters of the solution, the bubble embryo formation results in a net increase of the total free energy of the system. Henceforth, classical nucleation is characterized by an energy barrier to overcome [2]. Therefore, homogeneous bubble nucleation within the liquid bulk or heterogeneous nucleation on smooth surfaces requires very high supersaturating ratios, which are totally unrealistic in the case of Champagne wines [3,4]. In weakly supersaturated liquids, such as champagne, sparkling wines and carbonated beverages in general, bubbles need pre-existing gas cavities with radii of curvature greater than the critical radius in order to overcome the nucleation energy barrier and grow freely. In this type of non-classical heterogeneous nucleation, dissolved gas molecules spontaneously diffuse through the meniscus of pre-existing gas cavities.

Contrary to a generally accepted idea, nucleation sites are not located on irregularities of the glass itself. The length-scale of glass and crystal irregularities is far below the critical radius of curvature required for the non-classical heterogeneous nucleation. Most of nucleation sites are located on hollow and roughly cylindrical exogenous cellulose fibres coming from the surrounding air or remaining from the wiping process. Because of geometrical and hydrophobic properties, such particles are able to entrap gas pockets during the filling of a flute and thus to start up the bubble production process. A typical nucleation site is displayed in figure 1. The gas pocket entrapped into the particle and which starts-up the bubble production process clearly appears. Such particles are responsible for the clockwork and repetitive production of bubbles that rise in-line into the form of elegant bubble trains [5-7]. This cycle of bubble production at a given nucleation site is characterised by its "bubbling" frequency. The time needed to reach the moment of bubble detachment depends on the kinetics of the CO_2 molecules transfer from the champagne to the gas pocket, but also on the geometrical properties of the given nucleation site. Now, since a collection of particle shapes and sizes exists on the glass wall, the bubbling frequency may also vary from one site to another. Three minutes after pouring, we measured frequencies ranging from less than 1 Hz up to almost 30 Hz, which means that the most active nucleation sites emit up to 30 bubbles per second.

Bubble rise

A short examination of the typical regular bubble train presented in figure 2 is already very instructive. It appears clearly that bubbles grow during ascent. Moreover, as the distance between two successive bubbles increases, and since bubbles are released from the nucleation site with clockwork regularity, it can be guessed that a bubble accelerates when rising through the liquid. In order to better analyse hydrodynamic and physicochemical parameters that control bubble ascent, let us write the equation of motion of an expanding spherical gas bubble, rising in a low viscous fluid, as in the case of champagne bubbles. After release from its nucleation site, a bubble experiences, in addition to the buoyancy

$$F_B = \rho g \frac{4}{3}\pi R^3$$

a viscous drag force exerted by the surrounding fluid. This drag force is classically expressed by

$$F_D = C_D \frac{\rho U^2}{2}\pi R^2$$

where C_D is a dimensionless drag coefficient†. Inertia of bubbles can obviously be neglected, but during the rise, bubbles induce a displacement of the surrounding fluid in their vicinity, which leads to an added-mass force. The added-mass of a bubble is

$$M_0 = C_{AM}\,\rho \frac{4}{3}\pi R^3$$

where the added-mass coefficient C_{AM} is the ratio of the surrounding volume of liquid displaced during ascent to the bubble volume. The equation of motion of champagne rising and expanding gas bubbles can therefore be written under the form,

$$\frac{d}{dt}(M_0 U) = \frac{4}{3}\rho g \pi R^3 - C_D \frac{1}{2}\rho U^2 \pi R^2 \qquad (1)$$

Since the bubble radius expands during the rise, this equation reduces to,

$$C_{AM}\,\rho \frac{4}{3}\pi R^3 \left(\frac{dU}{dt} + \frac{3U}{R}\frac{dR}{dt}\right) = \frac{4}{3}\rho g \pi R^3 - C_D \frac{1}{2}\rho U^2 \pi R^2 \qquad (2)$$

It was nevertheless found that the added-mass effect of a bubble approaching the free surface never exceeds 2-3 % of its buoyancy [5-7]. As a result, it will be neglected in the following. Thus, the

† R is the bubble radius, U is the rising velocity, ρ is the liquid density, and g is the acceleration due to gravity.

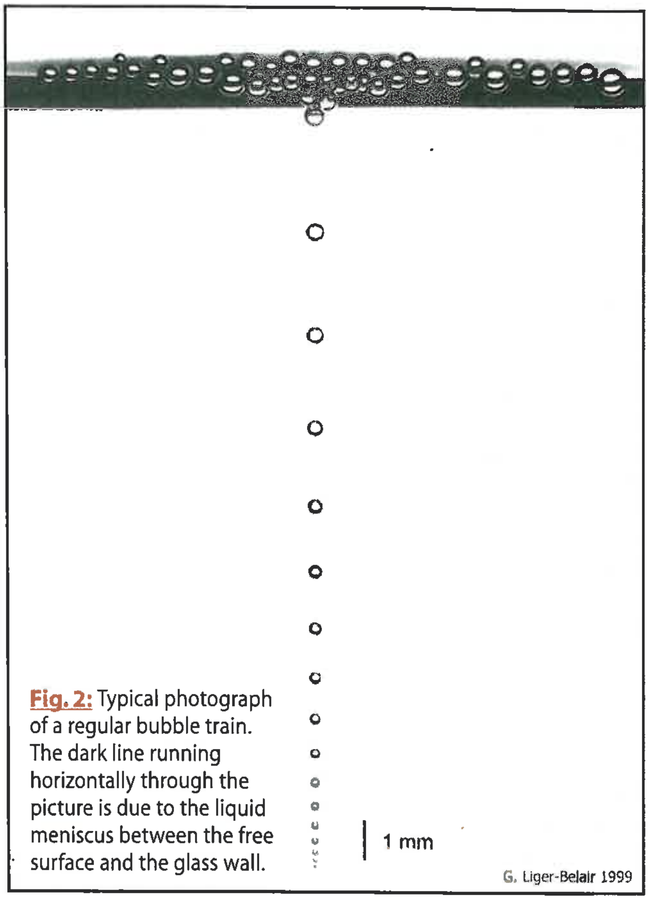

Fig. 2: Typical photograph of a regular bubble train. The dark line running horizontally through the picture is due to the liquid meniscus between the free surface and the glass wall.

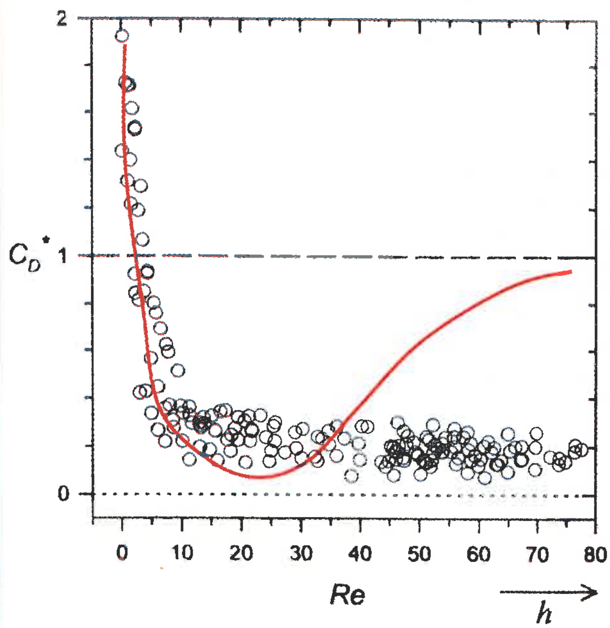

Fig. 3: Normalised drag coefficient experienced by champagne bubbles during ascent as a function of the Reynolds number *Re* (and indirectly as a function of the travelled distance *h* from the nucleation site); fluid sphere limit (- - - -); rigid sphere limit (– –); normalised drag coefficient that a bubble of fixed radius would experience (—).

equation of motion (2) reduces itself to the classical balance between drag force and buoyancy. Now, for each bubble of a given bubble train, the experimental determination of R and U leads to the experimental determination of the drag coefficient C_D along the rise, through the expression,

$$C_D = \frac{8gR}{3U^2} \tag{3}$$

During the last decades, many empirical or semi-empirical equations have been proposed to approximate C_D for bubbles in free rise. Some of the most popular are listed in the book of Clift *et al.* [8]. Our measurements were compared with two of them, respectively C_{RS} and C_{FS}, available in the whole range of Reynolds numbers Re covered by champagne bubbles. C_{RS} concerns rigid spheres, and is applicable for rising bubbles completely covered with surfactants, whereas C_{FS} was obtained for fluid spheres, i.e. bubbles with a fully mobile interface free from surface-active materials.

In order to indirectly access the bubble surface state during the rise, the normalised drag coefficient C_D^* defined as follows was used,

$$C_D^* = \frac{(C_D - C_{FS})}{(C_{RS} - C_{FS})} \tag{4}$$

Bubbles with a fully mobile interface behaving hydrodynamically as fluid spheres will exhibit values of C_D^* close to zero, whereas polluted bubbles behaving hydrodynamically as rigid spheres will have values of C_D^* close to one. In figure 3, the normalised drag coefficient of champagne bubbles was plotted as a function of Re, for bubbles of various bubble trains. After a first regime attributed to both inertia and wall effects where $C_D^* > 1$, it appears clearly from figure 3 that bubbles reach a quasi-stationary stage intermediate between that of a rigid and that a fluid sphere (but nevertheless closer to that of a fluid sphere). This result drastically differs from the result classically observed with bubbles of fixed radii rising in surfactant solutions. Actually, surfactants progressively adsorb at the surface of a rising bubble thus increasing the immobile area of the bubble surface. Therefore, the drag coefficient experienced by a rising bubble of fixed radius progressively increases, and inexorably reaches the rigid sphere limit when the bubble interface gets completely contaminated. Strictly speaking, the complete immobilisation of the interface of a bubble rising in a surfactant solution is reached before its complete coverage, as demonstrated by Ybert and di Meglio [9]. In the case of a champagne bubble, since the bubble expands during its rise through the supersaturated liquid, the bubble interface continuously increases, and therefore continuously offers newly created surface to the adsorbed surface-active materials (around 5 mg/L, mostly composed of proteins and glycoproteins). Expanding bubbles experience two opposing effects. Figure 3 suggests that the bubble growth during ascent approximately balances the adsorption rate of surface-active compounds on the rising bubble.

We also compared the behaviour of champagne bubbles with that of beer bubbles. It was found that beer bubbles showed a behaviour, very close to that of rigid spheres [5-7], thus confirming a previous study [10]. This is not a surprising result, since beer contains much higher amounts of surface-active macromolecules (of order of several hundreds mg/L) likely to be adsorbed at a bubble interface than champagne. Furthermore, since the gas content is lower in beer, growth rates of beer bubbles are lower than those of champagne. As a result, the dilution effect due to the rate of dilatation of the bubble area may be too weak to avoid the rigidification of the beer bubble interface.

Bubble collapse at the free surface

We report now results concerning bubbles collapsing at the free surface of champagne. A reconstructed time sequence illustrating four stages of the collapse of a single bubble is presented in figure 4. Photographs reproduced here were taken immediately after the rupture of a bubble cap [11]. A brief description of each frame follows.

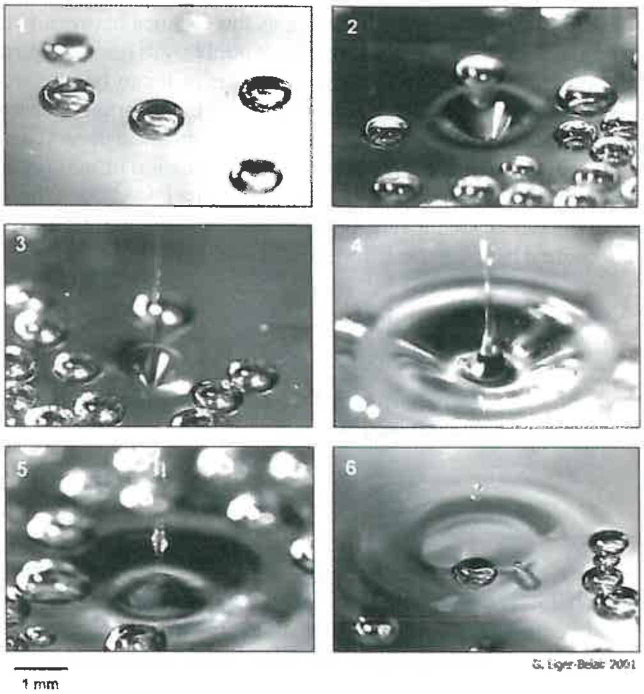

Fig. 4: Reconstructed time sequence illustrating six stages of the collapse of a single bubble at the free surface. The time interval between each frame is around 1 ms.

Between the frame 1 and 2, the thin liquid film, which constitutes the emerged part of the bubble, has just ruptured (on a time-scale of 10 to 100 μs). During this extremely brief initial phase, the bulk shape of the bubble has been frozen. A nearly millimetric open cavity remains at the free surface. While collapsing, the bubble cavity gives rise to a high-speed liquid jet above the free surface (frames 3 and 4). Near the base of the liquid jet, one can distinguish an extremely small bubble (around 100 μm), probably entrapped during the collapsing process. Due to its own velocity, this upward liquid jet becomes unstable and breaks up into droplets called jet drops (frame 5). The combined effects of inertia and surface tension give droplets various and often amazing shapes. Finally, droplets ejected by the parent bubble recover a quasi spherical shape (frame 6). Due to surface excitations following bubble collapse, capillary wave trains centred on the bursting bubble are propagating at the free surface. On the right side of the central bubble, the tiny bubble entrapped during collapse can be observed.

The liquid jet that follows a bubble collapse strikingly resemble, in miniature, that one can observe as a drop impacts the surface of a pool of liquid. In his book "A Study of Splashes", Worthington, presented remarkably sharp photographs of drops impacts [12]. Shape details of two various liquid jets, produced during a bubble collapse and during a drop impact are displayed in figure 5. Hydrodynamic structures arising after a drop impact are clearly very close to those which follow a bubble collapse. Since hundreds of bubbles are bursting every second during the first minutes of champagne-tasting, one can conclude that the free surface of a glass of champagne is literally spiked with such cone-shaped liquid structures, unfortunately too short-lived to be observed to the naked eye.

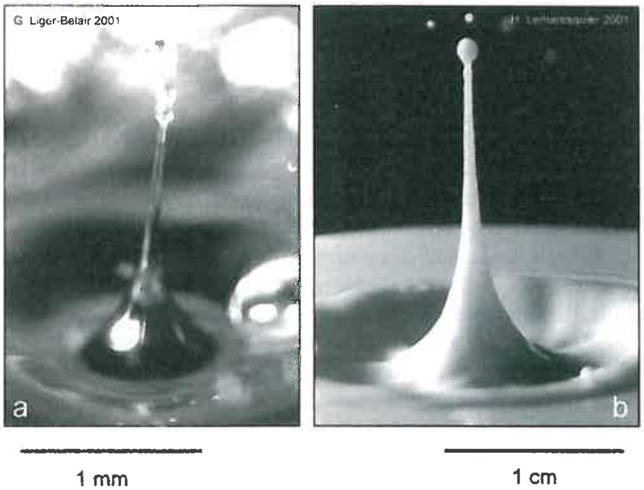

Fig. 5: Close-ups of two liquid jets that follow respectively, a bubble collapse (a), and a drop impact (b).

At a millimetric scale, such a violent hydrodynamic phenomenon which leads to the projection of a high-speed liquid jet is driven by the capillary pressure gradients arising in the layer around the open cavity left by a bursting bubble. Immediately after the rupture of the bubble cap, the sides of the open cavity becomes a region of positive curvature. It ensues a ring of high pressure on the sides of the open cavity. At the same time, due to a negative curvature, a low pressure zone exists around the underside of the cavity. As a result, fluid is rapidly drawn from the sides to the axis of symmetry. The underside of the cavity becomes a region of high pressure. This pushes fluid upward and downward to produce two liquid jets.

Since the first photographic investigation published about fifty years ago [13], numerous experiments have been conducted with single bubbles collapsing at a free surface. But, to the best of our knowledge, and surprising as it may seem, no results concerning the collateral effects on adjoining bubbles of bubbles collapsing in a bubble monolayer have been reported up to now. Actually, effervescence in a glass of champagne ideally lends to a preliminary work with bubbles collapsing in a bubble monolayer. For a few seconds after pouring, the free surface is completely covered with a monolayer composed of quite monodisperse millimetric bubbles collapsing close to each others. Photographs displayed in figure 6 were taken immediately after the rupture of a bubble cap. Adjoining bubble-caps are literally sucked toward the lowest part of the cavity left by the bursting bubble, leading to unexpected and short-lived

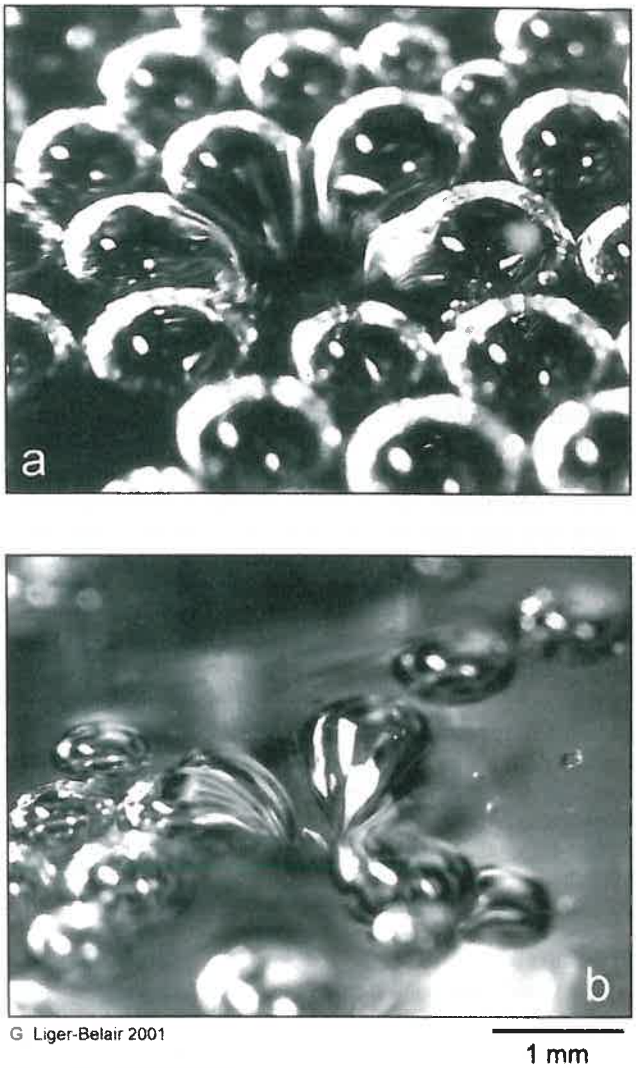

Fig. 6: Oblique view of the collateral effects on adjoining bubbles of a bubble collapsing at the free surface.

flower-shaped structures [14]. During the stretching process, energy is supposed to be mainly stored as surface free energy. A systematic image analysis of numerous time sequences conducted with an high-speed video camera demonstrated an average increase ΔA of 15 % within approximately 300 µs of bubble areas adjacent to collapsing bubbles. During the stretching process, stresses in a distorted bubble-cap (one petal of the flower-shaped structure) can be evaluated as shown below in equation 5.

By comparison, in a previous study, a numerical model conducted to stresses of the order of 10^4 dyn cm^{-2} in the boundary

Equation 5††:

$$\left[\frac{\Delta E}{V}\right]_{\text{bubble-cap}} \approx \frac{2\gamma\Delta A}{Ae} \approx \frac{0.15\times 2\,\gamma}{e} \approx 10^4 - 10^5\ \mathrm{J/m^3} = 10^5 - 10^6\,\mathrm{dyn/cm^2}$$

†† ΔE is the corresponding surface energy in excess during the stretching process, V is the volume of liquid in the emerging bubble-cap, γ is the champagne surface tension ($\approx$ 50 mN/m), A is the emerging bubble area, and e is the thickness of the thin liquid film of the bubble-cap (of order of 10^{-6}-10^{-7} m) [15].

features

layer around an isolated millimetric collapsing bubble [16]. This is a brand-new and slightly counter-intuitive result. While absorbing the energy released during collapse, as an air-bag would do, adjoining bubble store this energy into the thin liquid film of emerging bubble-caps, leading finally to stresses higher than those observed in the boundary layer around single millimetric collapsing bubbles. Further investigation should be conducted now, and especially numerically, in order to better understand the relative influence of each pertinent parameters (bubble size, liquid density and viscosity, effect of surfactant...) on bubble deformation.

Contrary to what could have been thought at first glance, effervescence of champagne turned out to be a fantastic tool to investigate a first approach of the physical chemistry of rising and collapsing bubble dynamics. As we do, we hope that the reader will now look at the effervescence in this traditionally festive wine, not only as a nice visually appealing phenomenon, but also as a very instructive one in terms of bubble dynamics study. It would have been regrettable not to have a closer look at such a daily phenomenon, before considering a more academic approach under certainly better controlled, but also less seducing conditions.

Acknowledgments

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The DARI

A unit of measure suitable to the practical appreciation of the effect of low doses of ionizing radiation

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A clearer understanding by a wider public of the health effects of radioactive materials arising in the nuclear industry is essential if the public interest is to be served. Even clear and continuous information provided to the public about radiation dose from industry is inadequate to an intuitive and correct understanding of relative risk— in part because radiation exposure is expressed in units that non-specialists find difficult to comprehend.

We propose the establishment of a unit of irradiation dose to the individual that is equal to that provided to a human being by the naturally occurring radioactivity of human tissue: the "DARI," from the French for "Dose Annuelle due aux Radiations Internes"— annual dose from internal radioactivity.

To the extent of 90%, this radiation is due to potassium 40, of half-life 1.3 billion years, which was present in the cosmic dust from which the Earth was formed about 4.5 billion years ago.

The DARI amounts to less than 10% of the natural radiation to which the body is subject, arising from external irradiation from rocks and from cosmic rays. The use of this unit for expressing the individual's radiation dose from an incident or an accident involving radioactive materials would facilitate a proper judgment of its impact, and would avoid unwarranted concerns.

In the physical sciences an important role is played by units of measure that permit an easy appreciation of the order of magnitude of the items measured.

The metre, the kilogram, and the second were thus adopted in engineering. In fields in which the order of magnitude of the object studied are much smaller or much larger, it has been necessary to introduce auxiliary units adapted to daily practice. It is thus in astronomy or in microscopy, where one uses the light-year, or the angstrom and the nanometer.

Over the last few decades there has been a massive increase in use of ionizing radiation. There has been a corresponding evolution of units for the measurement of the intensity of sources emitting radiation and for evaluating their effect on the human being.

The extreme sensitivity of instruments to measure radioactivity, detecting even the disintegration of a single atom, has led practitioners, in their particular fields, to deal with figures that have a substantial number of zeros. Thus the becquerel (Bq) is the intensity of a source in which one atom on the average disintegrates each second; it is used for weak sources, while the megacurie is often used by an engineer dealing with nuclear wastes— the curie (Ci) being the intensity of a source in which 37 billion atoms disintegrate each second— hence 3.7×10^{10} Bq.

Evaluating the effect of radiation on the human body involves more complex questions. The nature of the ionizing radiation— alpha particles, betas, gammas, heavy ions— makes it necessary to take into account the great variation in the deposit of energy along the trajectory of the particle and on its effectiveness in disturbing the genetic material of living cells. The mechanisms involved in these effects are still a matter of debate, and the existence or not of a threshold for harm gives rise to argument.

Current units of irradiation

The accepted units, which are employed by various individuals and groups needing to make decisions regarding the acceptable doses of radiation, both for the public at large and for workers in the field, are based on the energy deposited by the ionizing radiation. But they are hardly helpful in providing an intuitive estimate of the nature and hazards of radiation. In this regard, let us just note that the lethal dose of radiation for a human involves the deposition of energy that raises the temperature of the body by a mere thousandth of a degree.

The gray (Gy) corresponds to the deposition of 1 joule per kg of living tissue. One takes into account the different sensitivity of the various human organs by weighting the deposit of energy by a coefficient of effectiveness, which leads to the definition of the sievert (Sv). Finally, although it is a matter of reasonable agreement that the lethal dose is four or five Sv for a human being, regulatory authorities interpret the available facts on the induction of lethal cancer by low doses of radiation as giving a probability of cancer linear with the dose, without a threshold of harm for a human being. Specifically, that estimate is 0.04 lethal cancers per Sv of whole body irradiation. Such a coefficient permits the prescription of permissible levels of irradiation to have an acceptable risk for the various populations, when weighed against benefits to the economy or to the public health in the use of radiation, for instance for the diagnosis or treatment of disease.

Proposal for a new unit linked to the irradiation of the human body by its own natural radioactivity—the DARI

We suggest an approach that may lead to a more intuitive estimation of the impact of low doses of radiation. The unit that we propose provides a much more immediate idea of the risks run by a given level of irradiation. It is as rigorous as the units used thus far, to which it can be related in a precise fashion. We suggest the "DARI," for "Dose Annuelle due aux Radiations Internes—(annual dose due to internal radiation)". This is close to the irradiation experienced during a single year by an individual, due to the radiation emitted by the radioactive materials present in the human body that have nothing to do with any line of work. The DARI is to be defined as 0.2 millisieverts, precisely, although the annual dose itself is about 10% less.

The two principal radioactive substances that contribute to this internal irradiation are potassium-40 (a natural isotope that is a permanent component of living tissue), and carbon-14 produced in the air by cosmic rays and which is present in all living organisms.

We prefer this standard of internal radiation to one representing the average human irradiation from all natural sources that corresponds to a level about ten times larger than the unit proposed. This total varies too much with geography and altitude to serve as a reasonable standard.

Our interest in a standard such as the DARI arises from the fact that even much weaker irradiations than this internal exposure give rise to futile controversy and can distort crucial choices such as those that concern energy supply for centuries to come.

First we discuss more extensively the origin of this internal irradiation, which will permit us to estimate readily the scale of certain incidents or accidents related to nuclear power.

Natural sources of internal and external irradiation

Our planet was formed by the aggregation of the dust from dead stars. All of the chemical elements that compose the Earth were synthesized through the nuclear reactions that take place throughout the life of such stars. Certain elements are radioactive with a mean life in hundreds of millions or billions of years and are always present.

Uranium, thorium, and potassium play an important role in creating the molten core of the Earth. The energy of their radiations has melted and maintains the molten sphere of iron-nickel, some 3500 km in radius, which constitutes the core of our planet.

These primordial radioactive wastes are present everywhere on Earth. Potassium-40, which is a natural isotope of potassium, has a half-life of 1.3 billion years. It pervades living organisms, and the human body of 70 kg mass is host to about 6000 Bq—i.e., 6000 disintegrations per second.

Uranium is widely distributed on Earth and constitutes about 3 millionths by weight of the Earth's crust. Its presence in rocks contributes a significant portion of the natural irradiation to human beings. It also contributes to this total by the radioactivity of one element in its decay chain— radon-222 (of half life 3.8 days), which is a noble gas emitting alpha particles. Radon is responsible on average for more than half of the natural irradiation of humans; the U.S. government recommends effective ventilation of homes in order to reduce the level of radon from building materials or from seepage from the underlying rock.

Nuclear energy and public health

Uranium has a special importance since the discovery of nuclear energy. By use of uranium fission in a nuclear reactor, as much energy could be extracted from the uranium of any given portion of the Earth's crust as if it were pure coal.

Of course, because of the cost of extraction of uranium from such lean deposits, it is currently obtained from the much smaller deposits of higher grade ore— ranging from 0.1% to 14% uranium by weight. But studies show that it is possible to obtain uranium from seawater (where it constitutes only about 3 billionths by weight) with a cost that is a mere 15 times larger at the moment than that required to obtain uranium from the deposits that now serve to feed nuclear power plants. Uranium from seawater thus gives an affordable and practically unlimited supply of fuel for fission power.

In the future, which in the more or less long term is threatened by the exhaustion of the energy resources based on fossil fuel, it is thus legitimate to consider the major role that can be played by nuclear energy. This is particularly true considering the enhanced greenhouse effect from the carbon liberated to the atmosphere by the normal combustion of coal, oil, or even natural gas. However, the enormous amount of radioactivity produced in the course of releasing energy from fission, raises inevitable questions and anxieties about the danger for our generation and those to come, by the massive deployment of nuclear power.

The degree to which nuclear power is accepted depends upon the resources of the individual countries, but also upon a realistic evaluation of the dangers and problems the various alternative energy sources present to the human species. Decisions are rendered more difficult by the sometimes irrational character of the debates concerning the effects on humans of ionizing radiation of various origins, to which we are exposed, voluntarily or not.

A major problem right now for the nuclear industry is to show that it is capable of caring for radioactive waste from nuclear power plants in a satisfactory fashion for generations to come, and is able practically to eliminate the possibility of a major catastrophe like that at Chernobyl in 1986.

To make a proper judgment of various proposed courses of action, it is helpful to take into account the irradiation to which humans are exposed independently of nuclear energy.

Relative importance of natural sources of irradiation, internal or external

Radiation from internal sources is an absolute floor below which it is impossible to sink. Natural radiation overall, about ten times larger, represents a level to which we should refer to evaluate the limits imposed on exposure from the nuclear industry, and in order to evaluate the seriousness of incidents or accidents. We will now examine several sources contributing to natural radiation, using as the unit of irradiation the sievert or the thousandth of a sievert— millisievert (mSv). Cosmic rays shower the Earth and provoke nuclear reactions in the upper atmosphere, caused by the energetic protons of the cosmic rays. At sea level the cosmic rays contribute an annual irradiation about 0.5 mSv. The intensity increases with altitude, which on average contributes more irradiation in a year to airline crews than is legally permitted for workers in the nuclear industry— 20 mSv per year.

In the atmosphere, cosmic rays transmute nitrogen into radioactive carbon— carbon-14, with a mean life of 5000 years; C-14 is present in the form of carbon dioxide within the atmosphere. Incorporated by plants into their tissues, carbon-14 pervades all living things, and along with potassium-40, present since the beginning of the Earth, contributes the most important and least avoidable part of internal radiation. For a person of 70 kg weight, carbon-14 contributes about 4000 becquerel; together with the 6000 Bq from potassium-40, one has thus an activity of 10,000 Bq in the average human being. Taking into account the relative biological effectiveness of this radiation on different organs, this source of 10,000 Bq contributes about 0.17 mSv per year. Incidentally, it is the same 0.17 mSv per year for a child and for an adult of whatever weight, since it is the energy deposited per kg that is measured by the Sv— 1 joule per kg.

Now we compare this level to the total irradiation experienced by humans from other natural sources, totalling, as indicated, about 2 mSv per year. One needs to take into account the radioactivity of the soil containing more or less radioactive material— notably potassium and uranium. In France itself, there is a variability of a factor 3 from 1 mSv in the environs of Paris to 3 mSv in Brittany. On our planet, there are vast populated regions where the natural radioactivity is much greater. Added to the exposure from rocks, there is the radioactivity due to radon, and the cosmic ray intensity that varies with altitude.

Natural irradiation of the average American citizen, like that of the French, amounts to about 2.5 mSv per year, to which must be added the irradiation due to medical diagnostics— on the order of 1 mSv per year on average. The variation in natural radioactivity within France, about 1 mSv per year, exceeds the limit imposed by the law on the exposure of the civil population by the nuclear industry. At this level, it has not been possible thus far to demonstrate any impact on public health; there is no direct evidence of harm caused by irradiation of this magnitude.

It seems to us instructive to choose as a practical unit of irradiation close to that due to the unavoidable K-40 and C-14 in the body, amounting to 0.17 mSv per year, which is quite uniform among the world's population. We have rounded this to 0.20 mSv per year and called it the DARI, for "Dose Annuelle due aux Radiations Internes (annual dose due to internal radiation)". According to the International Commission on Radiation Protection (ICRP), exposure to a DARI conveys a probability of incurring lethal cancer of ten parts in one million. If a lethal cancer corresponds to 20 years of life shortening, each DARI then costs the individual one hour of life expectancy. This calculation is rejected by some who believe in the existence of a threshold, below which there is no harm from radiation. In either case, one hour is little enough to pay for the gift of a body inherited from the stars and the cosmic rays.

The natural variability from place to place amounts to five DARI or more. Nevertheless, we should not countenance the addition of even one DARI to the individual's radiation burden without considering the benefits to that individual and to society.

Table 1 demonstrates the relative importance of various widespread sources of irradiation.

Table 1. The relative importance of various widespread sources of irradiation

0.1 DARI	Dose received in France on average from the nuclear power industry
5 DARI	The soil in the environs of Paris on average
10 DARI	The soil in Brittany on average
5 DARI	Cosmic rays at sea level (increase of 1 DARI per 50 m at altitude).
5 DARI	Average diagnostic radiography*
5 DARI	Limit established for the irradiation of the public by the nuclear industry.
40 DARI	Single CAT scan
500 DARI	Annual maximum dose, for 5 successive years, for a worker in the nuclear industry.
25,000 DARI	Lethal dose for the average human
300,000 to 500,000 DARI	Dose delivered as local irradiation to treat a cancer.

* The DARI is intended to represent an effective dose. If 2 milligray of gamma radiation is delivered to the left side of the body, the equivalent (and effective) whole-body dose is one millisievert or 5 DARI. According to the linear hypothesis for the effects of low doses of radiation, the same probability of cancer will result as if one millisievert were delivered to the whole body — although any tumour will appear only on the left and not the right side of the body. A similar approach applies to the effect of a small diagnostic dose of radioactive iodine — effects of which would be limited to the thyroid but which could be expressed in equivalent whole-body dose in microsieverts or DARI.

The exposure limit of 500 DARI imposed on a worker in the nuclear industry corresponds to a reduction in life expectancy (500 hours) equal to that produced by the smoking of ten cigarettes per day during that same year.

This risk of cancer to a worker receiving the maximum permitted dose in the nuclear industry should be compared with the occupational risks associated with other industrial or commercial activities. For example, driving an automobile in traffic exposes the driver to carcinogenic exhaust fumes (especially particulate matter) with a greater risk of cancer.

Recently one has seen in France polemics over accidental releases of radiation whose impact is less than one hundredth of a DARI, exposing only a local population to this tiny augmentation in irradiation.

The DARI puts in perspective these polemics, of which the impact on the political scene and in the media is disproportionately large compared with the substance. The debate should centre on the following problems as regards future energy:

- What are the real and comparative hazards of various sources of energy now available to humanity?
- After the exhaustion of the fossil energy supplies, what are the options then?

We are expecting 9 billion humans in the middle of this century, compared with 6 billion at this moment. In the industrialized countries, about 20% of the population die of cancer. Among the sources of cancer about half have been identified as due to life style— tobacco, alcohol, obesity, diet—and seem avoidable. About 2% of cancers are thought to arise from carcinogenic materials used in industry, or from automobile exhaust fumes.

One must be alert to reduce to a minimum all of these hazards—especially the more important ones. Those that are due to radioactivity are among the easiest to measure, and they must be maintained at an acceptable level. A unit of measure which takes into account the unavoidable natural self-irradiation of a human being seems appropriate, bearing in mind that it has not been directly demonstrated to have an effect on health.

According to the severe criteria used by regulatory authorities to evaluate the impact of radiation on public health, the DARI shortens life by about one hour per year. And the French accordingly lose six minutes per year because of their dependence on nuclear power—assuredly less than the hazard of the coal alternative. The table shows, however that there is substantial merit in reducing the exposure to the average individual from diagnostic X-rays, which by the same calculation shortens life by an average of five hours per year.

Georges Charpak received the Nobel Prize for Physics 1992 and is Membre de l'Academie des Sciences. Richard L. Garwin is a member of the US National Academy of Sciences.

Plectics: *The study of simplicity and complexity*

Murray Gell-Mann, Santa Fe Institute, Santa Fe, USA

The subject that I call plectics is the study of simplicity and complexity. At the Santa Fe Institute, which I helped to start, we deal to a great extent with matters of simplicity and complexity. I arrived at the name, plectics, in the following way. The word "complex" comes from *plexus*, originally meaning braided, and *com-*, meaning together, hence braided together. "Simple" comes in a similar way from roots meaning once folded; and the Latin words for "braided" and "folded" both owe their ultimate origin to the Indo-European root **plek-*. In Greek, that root gives rise to *plektos*, meaning braided. So, in using the word plectics we are describing the subject of simplicity and complexity without committing ourselves as to whether we are talking about something simple (once folded) or something complex (braided together).

What do we mean by complexity and its opposite, simplicity? It would take a great many concepts, a great many quantities to capture all the various meanings implicit in our use of the word complexity. But there is one concept — what I call effective complexity — that represents most closely what we usually mean in everyday conversation and also in scientific discourse when we use the word. A non-technical definition of effective complexity would be the length of a highly compressed description of the regularities of the entity under consideration. Compression — the elimination of redundancy — is very important; otherwise the length of the message would be of very little concern to us.

In my book "The Quark and the Jaguar" I describe the elementary school teacher who assigned to her class a 300-word essay to be turned in on Monday. One pupil, who spent the weekend playing around outdoors (as I would have done as a child), hastily scribbled the following on Monday morning: "Yesterday the neighbours had a fire in their kitchen, so I leaned out of the window and yelled "FIRE, FIRE, FIRE, FIRE,..." Of course he could have compressed that description by saying "I leaned out of the window and yelled FIRE 282 times", but the teacher insisted on a 300-word essay. Now, one way to discuss compression is to make use of the concept of algorithmic information content. It is defined for a string of bits, that is a string of zeros and ones, or an entity that is described by that string of zeros and ones. The algorithmic information content is the length of the shortest program that will cause a given universal computer U to print out that bit string and then stop computing.

Any kind of definition that utilises the length of description, even the length of a very concise description, will still involve a certain amount of arbitrariness or context dependence. We are describing a certain entity and the description is coded into a bit string. The level of detail at which we are describing the entity obviously matters. In physics that is called the *coarse graining*. The language in which the original description is expressed may also matter, and certainly the assumed knowledge and understanding of the world are important. All of these things help to determine the length of description. When the description is then coded into a string of bits to be printed out by a computer, we have additional context dependence, through the coding convention and also the choice of the universal computer. But if we put up with all that context dependence, we can give a more technical definition of effective complexity: the algorithmic information content of the regularities of an entity. That means that the entire algorithmic information content of the entity is split into two terms — one describing the regularities and the other describing the remaining features, which are regarded as incidental or random

Ties and bits

Let me use neckties as an example. The length of description of regular ties is trivial — you just give the colours, widths, and spacings of the stripes and the background colour of the tie, and you have it. But, of course, we are making a distinction here between the regularities in the pattern and various other features of the tie that we are treating as random or incidental, for example soup stains or little irregularities in the weave, and so on and so forth... Those are not included in the description.

If we are just concentrating on the regularities in the pattern of other ties, this by contrast, is quite complex. For a hand-painted tie from Austin, Texas, describing the regularities of its pattern would take a long time. It has a high effective complexity.

features

Let us consider a bit string consisting entirely of ones. It is obviously simple, since describing its regularity is so easy. It has a very low effective complexity as well as a very low algorithmic information content.

At the other end of the scale of algorithmic information content we would have a long bit string with almost no regularities — an incompressible or "random" string of zeros and ones, with no regularities except the length. Its algorithmic information content is very high, in fact maximal for the length of the string. The shortest program to describe it would be one that says "Print" followed by the string. Even though it has the greatest possible algorithmic information content, its effective complexity is again very small, because there are no regularities except the length.

So at both extremes, for the very simple string and for the very messy one, we have low effective complexity. Effective complexity can be large only in between, for something that lies between the extremes of order and disorder, something that has lots of different regularities.

Now, there can be no well-defined mathematical procedure that is guaranteed to find all the regularities of a bit string or of an entity described by it. In general we identify regularities by means of shared information, known technically as mutual information. If we process a bit string in certain ways and find that after processing it we can divide it into two or more parts and those parts share a lot of information, then we conclude that there is regularity present. While mutual information is diagnostic of regularity, it does not supply a measure of the algorithmic information content of the regularities that are present, and so mutual information is quite distinct from effective complexity.

Although there are mechanisms for identifying regularity, there is, as I indicated already, no mathematical procedure that will guarantee finding all the regularities. Thus the effective complexity, the algorithmic information content of the regularities, depends to some extent on who or what is describing the entity.

Let's go back to the necktie, when we were discussing the effective complexity of the pattern and ignoring the various kinds of stains. However, suppose that we are dry-cleaners. We wouldn't care so much about the pattern; we would concentrate instead on the soup stains, the blood stains, the wine stains, and so on. Those are the regularities that are most important for the dry-cleaner.

> For a hand-painted tie... describing the regularities of its pattern would take a long time. It has a high effective complexity.

What are the systems that identify perceived regularities and then compress their description into a brief message? They are what I call complex adaptive systems, ones that learn or adapt or evolve as living things do. Each of us is such a system, capable of identifying perceived regularities in the data stream reaching us and distinguishing them from what is perceived as random or incidental, and then compressing the description of those regularities into a brief message.

We can give a description of how a complex adaptive system functions. It takes in a stream of data about the world, including itself. Certain regularities are identified in data that it has already taken in, and those regularities are then compressed into a very brief message, which I call a schema. This schema can be used, in combination with further data from the stream, to describe features of the world, predict the behaviour of things in the world, or prescribe behaviour for the complex adaptive system in the world. But then there are consequences in the real world: the description is better or worse; the predictions come true or they fail; the prescription for behaviour in the real world results in success or failure, survival or disappearance. Those consequences in the real world then feed back to exert selection pressures on the competition among various candidate schemata. (A schema, although it has to have some degree of stability or robustness, must also be capable of changing, of undergoing mutation or replacement by another schema.)

Complex adaptive systems and life

All of the examples on Earth of complex adaptive systems, at least all the ones we know of, are connected in some way with life, although they are not necessarily alive or even parts or aggregations of living systems. Also, they have a tendency to give rise to other complex adaptive systems.

Among the complex adaptive systems on our planet were the prebiotic chemical reactions that led to life in the first place. Then biological evolution is a complex adaptive system, and so is the behaviour of each individual organism resulting from biological evolution. Parts of organisms can also function as complex adaptive systems — for example our immune system. The functioning of the human brain, giving individual learning and thinking, is also a complex adaptive system. Then we may look at the behaviour of organised groups of people: human cultural evolution in general is a complex adaptive system, and human organisations, such as business firms, evolve as complex adaptive systems.

There are also non-living complex adaptive systems. Our computers are now sophisticated enough so that complex adaptive systems can be established on computers, usually by the use of software. Where is the connection with life? It's generally agreed that the nerds who perfect the software for these complex adaptive systems on computers are actually living things.

Now, what are the schemata? Well, let's take a very familiar complex adaptive system involving many human beings, namely the scientific enterprise in which most of us are engaged. The schemata are theories. The theories are robust and when they have success in predicting properties of the real world they generally survive. When observations that are done carefully and are repeated over and over again disagree with the theory, then the theory is likely to be modified or have another one substituted for it.

Besides the scientific enterprise, where the schemata are theories, we may consider biological evolution, where the schemata are genotypes, and the evolution of a human society, where the schemata are laws, traditions, myths, customs, and so forth. Those schemata are composed of units that Richard Dawkins has christened memes, analogous to the genes in biological evolution. Sets of memes are the cultural DNA for societal evolution.

Let's return to the complex adaptive systems on computers. There are genetic algorithms, based on a very crude analogy with biological evolution. There are the so-called neural nets on computers, which are based on a very crude analogy with the way that the human nervous system - in particular the brain — is thought to operate. But there could be many more. We might have dozens of different kinds of adaptive computation methods, and they don't have to be based on analogies with ideas about the brain or biological evolution. There must be a wide class of possible complex adaptive systems on computers. What is that class? Which members of that class are suitable for solving which problems? We know that there are some problems for which genetic algorithms are suitable, while for others they are not. The same for neural nets — there are certain optimisation problems, for example, for which neural nets work very well, while there are others for which they don't. It can be shown that there is no complex adaptive system on computers that would be good for all optimisation problems. Each one has its domain of applicability, and it is a great challenge to theory to understand the whole class of complex adaptive systems on computers and figure out which one is good for which kind of problem.

Now I should point out, as a warning, that not everyone uses my notation. John Holland, who was the original inventor of genetic algorithms and a colleague and friend, uses a different terminology. What I call a complex adaptive system is something like what he calls an adaptive agent. What I call a schema he calls an internal model. Also, he uses the term complex adaptive system to mean what I would call a loose aggregation of complex adaptive systems that are modelling one another. (Examples include a market composed of investors and an ecological system composed of organisms.) By using different terminologies, we are both illustrating the famous adage that a scientist would rather use another person's toothbrush than another scientist's nomenclature.

Sometimes apparent complexity does not reflect high effective complexity. Besides the length of the shortest program that will cause a fixed universal computer to print out a description of the regularities of the entity in question, we must also consider how long it takes that computer to go from a brief program to printing out the description. That is called the logical depth of the regularities, as discussed by Charles Bennett.

Apparent and effective complexities

Take, for example, the energy levels of atomic nuclei. The rules for those energy levels look, at first sight, as if they are very complicated, but we now believe that they are obtained from a couple of simple physical theories: quantum electrodynamics (the quantum field theory of electromagnetic interactions) and quantum chromodynamics (the quantum field theory of quarks and gluons). We believe that if you put these two together you will get a description of atomic nuclei in great detail, including the positions of all their energy levels. But the computations are extremely long and difficult on our existing computers, using known methods, and most of them haven't even been done yet. So here is a case where we are looking at something apparently complex that has in fact low effective complexity, but a lot of logical depth. In other words, a short program is involved, but that program is associated with a very long computation time.

Consider a case where we are still not sure whether apparent complexity reflects effective complexity or logical depth. Do the universal features of biochemistry on Earth constitute a unique system? Or are there many different kinds of possible biochemistries for systems resembling life that may flourish on other planets, orbiting other stars, in other parts of the universe? It doesn't look as if there is anything particularly special about our solar system or our planet or, for that matter, life, which appeared soon after the heavy bombardment of the Earth came to an end. It is most likely, therefore, there are very many planets in the universe with something like life, that is, complex adaptive systems with a chemistry resembling in some way the biochemistry on Earth. But do those chemistries have to be the same? Or is there a wide class of possible biochemistries? We don't really know and the experts disagree.

Some of them think that the fundamental constraints of physics limit biochemistries to just a very few possibilities. Other theorists believe that there are many possible biochemistries, of which we happen to have one example here on Earth. If we accept the ideas of the first set of theorists, then biochemistry has low effective complexity because it is derivable from the laws of physics. That derivation might be lengthy, however, implying a good deal of logical depth. If the other theorists are correct, then biochemistry on Earth could have some appreciable effective complexity, since it would depend as much on accidents of history as on fundamental physics.

This brings up the matter of how complexity arises in the universe. Where does effective complexity come from? We who work on the fundamental laws of physics mostly believe, as I do, that those laws are extremely simple. There are two of them. The first is a unified theory of all the elementary particles and all the forces of nature. It may be that we already have that theory, in the form of the wonderful candidate that has evolved from superstring theory into what is now called "M Theory."

The other fundamental principle of physics is the initial condition of the universe near the beginning of its expansion, some ten billion years ago. That may also be simple. In fact some specific ideas have been proposed about ways in which it could be simple.

A hundred years ago, we would have said that, given the fundamental theory and the initial condition, we could in principle predict the history of the universe. But today we know that is not the case. Our theories are probabilistic rather than fully deterministic. Thus the history of the universe is co-determined by these two fundamental principles and by an inconceivably long sequence of accidents — chance events - with various possible outcomes. In advance of each event, only probabilities for the different outcomes are available. A very simple example from the laboratory is the disintegration of a radioactive nucleus, emitting, for example, an alpha particle. The direction in which that alpha particle will come out is completely unknowable before it emerges; all directions are equally probable. When it does come out, then it is possible to discover the direction of emission.

We can think of the alternative, suitably coarse-grained histories of the universe as forming a branching tree, with probabilities at each branching. As time goes on and a given branching is reached, one of its branches is selected. Before the branching occurs, however, there are only probabilities for the different alternatives.

Frozen accidents and the history of the universe

The wonderful Argentinian writer, Jorge Luís Borges, wrote a short story called "The Garden of Forking Paths", in which somebody built a model of the branching histories of the universe in the form of such a garden.

Just think of all the accidents that have given rise to us in this discussion group: the little fluctuation that produced our galaxy; the accidents that were responsible for the formation of the solar system; the accidents that determined the character of the Earth; the accidents early in the history of the Earth that gave rise to life; all the accidents of biological evolution, which, together with natural selection, have produced the life forms on Earth today, including human beings; and then the accidents of sperm and egg, of sexual selection, of development in the womb and in childhood that led to the specific adults in our group.

Now, out of all the accidents in the history of the universe, some of them are more productive of mutual information, more productive of regularities than others. The fluctuation that gave rise to our galaxy, for example, might not be considered very important on a cosmic scale, but to everything in this galaxy it is of enormous significance that the galaxy came into being. Similarly, many events in human history represent branchings with huge effects on the future history of humanity on the Earth.

Historians nowadays like to talk about Annie Oakley, the famous female sharpshooter in Buffalo Bill Cody's Wild West Show, which travelled across Europe in 1889. One of the features of the show was that Annie Oakley offered to shoot part of a cigar out of the mouth of a volunteer from the audience. Typically, no man volunteered for this dangerous job and her husband, himself a famous marksman, would step forward with his cigar. Annie Oakley would shoot the ash off her husband's cigar and the audience would applaud. But in Berlin, in 1889, there was a volunteer from the audience — the Kaiser. He had been on the throne for just one year when he volunteered to be the victim of Annie Oakley's shooting stunt. She was worried about her aim — she had been drinking heavily the night before — but she had no choice. The Kaiser removed the band from his expensive Havana cigar, clipped off the end with his silver cigar cutter, put the cigar into his mouth and lit it. Annie aimed at the end of it and shot off the ash. She did not kill the Kaiser, but what if she had? History would probably have been quite different. The First World War might have been very different — indeed, it might never have happened — and so on and so forth. Here we have an example of a frozen accident, one that produces a great deal of future mutual information in a portion of the universe that is of interest.

We can now answer the question of why there is, in so many domains of experience, a tendency for entities of greater and greater complexity to come into being as time goes on. The fundamental laws of nature, we have said, are very simple, including the initial condition of the universe, but those laws are probabilistic. So we have a branching tree with probabilities, with accidents at the branchings. Some of these accidents — the frozen accidents — are more important than others. Now, as time goes on, more and more frozen accidents can accumulate, making possible the emergence of more and more regularities. If the accumulation of the results of frozen accidents outstrips the erasure or disappearance of the results of such accidents, then things of greater and greater complexity can come into being as time goes on. It is of course, not true that every individual thing becomes more complex. Far from it; for instance, organisms and civilisations die and become, naturally, much less complex in the process. But what we can say is that in many cases the envelope of complexity keeps getting pushed out as time goes on, so that more and more complex entities come into being.

Now, the appearance of more and more complex entities as time goes on is in no way incompatible with the famous second law of thermodynamics, which states that the average disorder, the average entropy, of a closed system has a tendency to increase with time. But that is *average* disorder — there is nothing to stop mechanisms of self-organisation from producing local order at the expense of greater disorder elsewhere. We know of many mechanisms of self-organisation, for example gravitational attraction, which has produced galaxies, stars, planets, rocks, etc. Likewise, low temperatures give rise to the beautiful, regular shapes of crystals or snowflakes.

Let me end by asking about the future. Will things of greater and greater complexity keep on appearing in the universe? Well, we don't know for sure, but we can speculate about it. Many theoretical physicists believe, although so far the experiments have not proved it, that the proton will ultimately be found to be unstable. If so, then atomic nuclei are all unstable, with lifetimes perhaps something like 10^{35} years (that's a one with 35 zeros after it – a very large number of years). After some such time, nuclei would mostly be gone, and atoms and molecules would disappear too. Most of the regularities with which we are familiar would disappear, and it may be that then entities of greater and greater complexity would no longer keep appearing. In fact, the envelope of complexity might start to shrink when most of the nuclei are gone.

However, that is not of immediate concern. We have many more pressing worries.

(talk delivered to the symposium "Frontiers of Science" held in Coimbra, Portugal, 1999)

European Group for Optics and Photonics (EGOP)

The Quantum Electronics and Optics Division of the European Physical Society (QEOD of EPS) and the European Optical Society (EOS) share a strong desire to establish one unique voice to speak for the optical science and engineering community in Europe.

As a first step towards greater integration, the Prof. Dr. Theo Tschudi (President of EOS) and Prof. Dr. Guenter Huber (President of QEOD-EPS) signed an agreement in November 2001 to create a European Group for Optics and Photonics (EGOP), as a coordination mechanism between the two societies.

EGOP is concerned particularly with those topics that benefit from a close collaboration between physicists and optical engineers. The QEOD and EOS will use EGOP to coordinate their relevant activities in optics and photonics, and to represent the two societies in discussions with outside partners when both societies wish to be represented as one. Especially, there is a strong wish of both societies to coordinate and collaborate in conferences. EGOP is an informal structure and has no consequence on the membership and structure of QEOD-EPS and EOS, or on their rules of operation.

Below is a list of EPS Europhysics Conferences, and EPS Sponsored Conferences. Europhysics Conferences are organised by EPS Divisions and Groups. Sponsored Conferences have been reviewed by experts in the field following application, and based on criteria such as timeliness and topical coverage, are considered to merit EPS sponsorship.

2002 EUROPHYSICS CONFERENCES

19th General Conference of the Condensed Matter Division of the European Physical Society held jointly with CMMP 2002 Condensed Matter and Materials Physics
7–11 April 2002 the Physics Congress, Brighton, UK
Contact: Conferences Dept.
The Institute of Physics,
76 Portland Place, London W1B 1NT
tel. +44 20 7470 4800 *fax* +44 20 7470 4900
email conferences@iop.org
web http://physics.iop.org/IOP/confs/CMD19/

European Particle Accelerator Conference EPAC 2002
03–07 June 2002 Paris, France
Cité de la Science, Centre des Congrès de la Villette, France
Contact: Prof. J. Le Duff
LAL Laboratoire de l'Accélérateur Linéaire
Université de Paris Sud, Bât. 34 F - 91898 Orsay Cédex
tel. +33 1 64 46 84 30 *fax* +33 1 69 07 14 99
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tel. +41 22 767 32 75 *fax* +41 22 767 94 60
email Christine.petit-jean-genaz@cern.ch
web http://epac.web.cern.ch/EPAC/

29th EPS Conference on Plasma Physics and Controlled Fusion
17–21 June 2002 Montreux, Switzerland
Contact: Dr. J.B. Lister or Dr. Y.R. Martin
CRPP-EPFL,
CH - 1015 Lausanne, Switzerland
tel. +41 21 693 3482 *fax* +41 21 693 5176
email eps2002@epfl.ch
web http://crppwww.epfl.ch/eps2002

34th Conference of European Group of Atomic Spectroscopy 2002 (EGAS 2002)
9–12 July 2002 Sofia, Bulgaria
Contact: Dr. K. Blagoev
72 Tzarigradsko, 1784 Sofia, Bulgaria
tel. +59 2 7144646 *fax* +592 9753226
email kblagoev@issp.bas.bg or 34egas@issp.bas.bg
web http://www.issp.bas.bg/egas34

Synchroton Radiation in Polymer Science II
04–06 September 2002 University of Sheffield, UK
Contact: Professor A.J. Ryan
University of Sheffield, Dept of Chemistry, Brookhill,
UK - Sheffield S3 7HF
tel. + 44 114 222 9409 *fax* + 44 114 222 9303
email tony.ryan@shef.ac.uk

5th Liquid Matter Conference
14–18 September 2002 University of Konstanz, Germany
Contact: Universität Konstanz, Fachbereich Physik
D - 78457 Konstanz, Germany
Conference Chairman: Prof. Rudolf Klein
tel. + 49 7531 88 2955 *fax* + 49 7531 88 3157
email rudolf.klein@uni-konstanz.de
Prof. Georg Maret
tel. +49 7531 88 4788 *fax* +49 7531 88 3864
email liquids2002@uni-konstanz.de
web www.Liquids2002.de

2002 SPONSORED CONFERENCES

Second International Meeting on Photodynamics
10–16 February 2002 Havana, Cuba
Contact: Prof. Jesus Rubayo Soneira
Instituto Superior de Ciencias y Tecnologia Nucleares
Ave. Salvator Allende y Luaces, Quinta de los Molinos, Habana 10600, A.P. 6163, Ciudad Habana, Cuba
tel.+53 7 785018
fax +53 7 785018 or +53 7 241188
email jrs@rsrch.isctn.edu.cu

IUPAP International Conference on Women in Physics
06–09 March 2002 UNESCO Headquarters, Paris, France
Contact: IUPAP International Conference on Women in Physics
c/o American Physical Society
One Physics Ellipse, College Park, MD 20740 USA
tel. + 1 301 209 3269 *fax* + 1 301 209 0865
email beamon@aps.org
web www.if.ufrgs.br/~barbosa/conference.html

5th International Topical Meeting on Industrial Radioisotope and Radiation Measurement Applications (IRRMA-V)
09–14 June 2002 Bologna, Italy
Contact: Professor Jorge E. Fernandez (Chairman)
University of Bologna Laboratory of Montecuccolino-DIENCA
via dei Colli, 16, I - 40136 Bologna, Italy
tel. +39 051 644 1718 *fax* +39 051 644 1747
email chairman@irrma.unibo.it
web http://www.irrma.unibo.it/

International Quantum Electronics Conference collocated
with the Conference on Lasers, Applications and Technologies - IQEC / LAT 2002
22–28 June 2002 Moscow, Russia
Contact: Institute of Laser Physics SB RAS
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Europhysical Conference on Defects in Insulating Materials (EURODIM 2002)
30 June – 05 July 2002 Wroclaw, Poland
Contact: Professor Maria Suszynska
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web http://www.int.pan.wroc.pl/ks/konferencje/eurodim2002/eurodim2002.asp

International Conference on Laser Probing (LAP 2002)
07–12 July 2002 Leuven, Flandres, Belgium
Contact: LAP Conference Secretariat
Celestijnenlaan 200 D,
B - 3001 Leuven, Belgium
tel. + 32 16 32 72 04 *fax* + 32 16 32 79 83
email lap2002@fys.kuleuven.ac.be
web http://www.fys.kuleuven.ac.be/vsm/lap2002

International Conference on Theoretical PhysicsTH-2002
22–26 July 2002 Paris - UNESCO, France
Contact: Prof. Daniel Iagolnitzer
tel. +33 1 69 08 81 15
email iago@spht.saclay.cea.fr
Prof. Jean Zinn-Justin
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F - 91191 Gif-sur-Yvette Cédex, France

Conference on the Elementary Processes in Atomic Systems (CEPAS 2002)
02–06 September 2002 Technical University of Gdansk, Poland
Contact: Brygida Mielewska Elzbieta Ptasinska-Denga
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email cepas@mif.pg.gda.pl
web http://www.mif.pg.gda.pl/cepas2002

International School of Nuclear Physics, 24th Course, "Quarks in Hadrons and Nuclei"
16–24 September 2002 Erice, Italy
Contact: Prof. A. Faessler
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meetings

The word from Brussels

Tom Elsworth

This is the sixth article in the present series and a year has passed. Have we made progress on Framework Programme 6? Yes we have as you will see below. Is thinking in Brussels moving in a sensible direction? Yes again, I think. Is everything well with the world in that case? Not really, not only are the horsemen of the apocalypse loose, except from the narrowest science oriented point of view, but also there is fear of recession and a frisson of concern about how things will pan out with the Euro.

For myself, I take a positive view and this is of course coloured by my own interests and experience. For example, a couple of weeks ago I attended two events in the European Week of Science and Technology. My company (Communqué PR) was involved in organising the events (called EuroPAWS) as part of a consortium working under the Framework Programme 5, "Raising Public Awareness" programme. More information about the events can be found at www.europaws.org or at www.alphagalileo.org or at www.cordis.lu.

Suffice it to say for this epistle that the events were intended to have two impacts, firstly to bring something professional, refreshing and new to the European Science and Technology Week (ESTW) and Raising Public Awareness (RPA) generally. Secondly and more importantly, they were directed at convincing writers, producers and broadcasters of TV drama that good science and technology is a viable, exciting and audience friendly topic. We did this by showing excerpts from real top quality TV drama material (e.g. "Longitude" from Channel 4 in the UK) and also presenting live dramatisations of new scripts with a science bent. The main idea behind all this being that science needs access to the immense communicating power of TV drama (including soaps because they obviously have the highest impact in terms of audience). We also feel that the easy approach to raising public awareness — putting on some sort of amateur direct public contact event that touches a few thousand people (usually school kids because it is easy to get a good turn out) at most is far from cost effective.

The EuroPAWS events, in particular the live renditions of future TV scripts, were judged a success by all those involved and the positive reaction received was such as to encourage the consortium to do more of the same in future years — so watch this space and if you are at all interested in this field please look at the www sites listed above or contact me directly (see box)! This then was an example of a real move in the right direction.

Turning now to Framework Programme 6, the most recent development (14th November) is a vote in the European Parliament. Gérard Caudron, the rapporteur presented reports from the Industry and Research Committee dealing with Euratom and FP6 (under the consultation procedure) and FP6 generally (under the co-decision procedure). The main point to note is that the proposed budget of Euro 16,270B was endorsed (unlike the awful budget row for previous Framework Programmes). Secondly, we have considered in these articles more than once the question of the so called "new instruments". The Caudron report contains some notes of concern about these; in that they are untried, but it generally accepts the logic of their application. However, Caudron proposes an additional instrument called, somewhat quaintly, the "stairway to excellence" essentially as an entry level instrument for candidate countries, SMEs, new research institutes and small scale projects. This seems a mild proposal and indeed I would characterise the whole report in that way.

The Euratom report was likewise on the whole, mild. On fusion research however there was an historic event; for the first time the Parliament voted for an increase in fusion funding, by Euro 100M to Euro 800M. The Caudron report says "Parliament agrees that controlled thermonuclear fusion is one of the long term options for energy supplies in conditions of sustainable development" — hoorah! The Parliament is to be congratulated on this sensible position.

The next question however, is how will the Commission and Council of Ministers react (it is the consultation process which applies so the decision lies with them in reality)? My own view for what it is worth, is that the time of fusion is coming and rapidly. All the signs are that UK Government is now a strong supporter and I should think France and Germany would be too. Indeed the time scale attached to energy security concerns strongly indicates an acceleration of fusion research — perhaps to enable a decision, post ITER, to build a demonstration power station in 25 years or so. Expect announcements on all this soon!

Calls for Proposals

Calls published to 16 November 2001

Promoting a User-Friendly Information Society

8th IST Call published on 16 November 2001
Opening date: 16.11.2001
Closing dates: variously 21st or 28th February 2002

Quality of Life and Management of Living Resources

4th Call for Proposals for RTD actions
Opening date: 31.10.2001
Closing date: 31.01.2002

Competitive and Sustainable Growth

Dedicated call Measurements and Testing, Infrastructures
Opening date:16.10.2001
Closing date: 15.02.2002

Research and Training in the field of Nuclear Energy

4th Call for Proposals for RT Actions under the Specific Programme for Research and Training (Euratom) in the Field of Nuclear Energy (1998 to 2002) Key Action 2; Nuclear Fission)
Call Identifier: NE-Fission Fourth Call
Opening date: 16.10.2001
Closing date: 21.01.2002

Open Call for Proposals for RT Actions under the Specific Programme for Research and Training (Euratom) in the Field of Nuclear Energy (1998 to 2002)
Call Identifier: NE Open 2
Opening date: 16.10.2001
Closing date: See evaluation cut-off dates in call text

Call for Proposals to extend Existing Contracts under the Specific Programme for Research and Training (Euratom) in the

Field of Nuclear Energy (1998 to 2002) to include Partners from the "Newly Associated States" (NAS) associated to the Euratom Programme
Call Identifier: NE Fission NAS
Opening date: 16.10.2001
Closing date: 21.01.2002

Quality of Life and Management of Living Resources
Competitive and Sustainable Growth
Energy, Environment and Sustainable Development

Joint call for proposals to support for the integration of "newly associated states"(NAS) in the European research area
Opening date: 20.09.2001
Closing date: 31.01.2002

Confirming the international role of Community research

Call for Proposal for Accompanying Measures
Opening date: 18.09.2001
Closing date: See Call text

Promoting a User-Friendly Information Society

An Initiative on 2.5-3G Mobile Applications and Services
Opening date:04.09.2001
Closing date: See Call text

Improving Human Research Potential and the Socio-economic Knowledge Base

The Archimedes Prize 2001
Opening date: 04.09.2001
Closing date: 15.03.2002

Competitive and Sustainable Growth

Call for proposals to extend existing contracts to include partners from the "Newly Associated States" (NAS)
Opening date: 01.09.2001
Closing date: 13.12.2001

A summary of one year in Brussels

It has been a year largely devoted to preparing future research activities and this work has yet to reach its climax. But the signs are I think, positive; Parliament and the Commission and Council seem in broad accord on the thrust of FP6 and the general objectives of enhancing quality and pushing forward with initiating the creation of a European Research Area to rival the capabilities of the United States. There is a very long way to go of course, on both FP6 in particular and ERA in general (I shall really believe we have one when Europe has a single body as influential on the AAAs!). The current president of the Research Council (at the time of writing late in November 2001) Francois-Xavier de Donnea proclaims himself confident that the 10th December meeting of his Council will "...bring together the final strands needed for agreement on the details of the next Framework Programme...". We shall soon see whether the EU institutions have grown up sufficiently that the hiccups of previous Framework programmes can really be avoided!

A happy 2002 to all readers of Europhysics News.

Communiqué PR is a communications consulting firm specialising in supporting organisations in the science, engineering and technology sectors. Areas of work that can be tackled include media relations, event management, video and print promotional material, public awareness activities, lobbying in Brussels or in relation to EU linked activities and strategic planning and integration of internal and external corporate communications, Public Relations and Public Affairs.

Tom Elsworth, one of the partners in Communiqué PR, has prepared this article (it reflects his own opinions on matters in Brussels). Tom has experience working in the external relations of major science based organisation extending over 25 years and in locations including London, Brussels and Washington DC. Recent customers of Communiqué PR include EPS, UK Atomic Energy Authority and the Commission of the EU.

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Simplifying Europe

Twelve European countries have adopted the Euro as the common currency. Fortunately, language and cultural differences remain.

	expressed as an amount	*********	with definite article	
language	one unit	several units	singular	plural
DA	1 euro 1 cent	100 euro 100 cent	euroen centen	euroene centene
DE	1 Euro 1 Cent	100 Euro 100 Cent	der Euro der Cent	die Euro die Cent
EL	1 ευρώ 1 λεπτό	100 ευρώ 100 λεπτά	το ευρώ το λεπτό	τα ευρώ τα λεπτά
EN	1 euro 1 cent	100 euro 100 cent	the euro the cent	the euro the cent
ES	1 euro 1 cent	100 euros 100 cents	el euro el cent	los euros los cents
FR	1 euro 1 cent	100 euros 100 cents	l'euro le cent	les euros les cents
IT	1 euro 1 cent	100 euro 100 cent	l'euro il cent	gli euro i cent
NL	1 euro 1 cent	100 euro 100 cent	de euro de cent	de euro's de centen
PT	1 euro 1 cent	100 euros 100 cents	o euro o cent	os euros os cents
FI	1 euro 1 sentti	100 euroa 100 senttiä	euro sentti	eurot sentit
SV	1 euro 1 cent	100 euro 100 cent	euron centen	eurorna centen

An interview with Charles Kleiber

Swiss State Secretary for Science

C. Rossel, Executive Secretary of the EPS and T. Jung, President of the Swiss Physical Society.

In a previous edition of EPN (32/3, May-June 2001), Philippe Busquin the European Commissioner for Research was interviewed and expressed his views on the issues facing European Science. In ordet to address the specific case of Switzerland, not a member of the EU, we asked a few questions to the Swiss State Secretary for Science, Charles Kleiber. In addition to his function as State Secretary, Dr. Charles Kleiber has also been director of the Swiss Science Agency since 1997. He was previously Chief Executive of the Association of the cantonal teaching hospitals in Lausanne, Head of the Public Health and Planning Services and visiting professor at the University of Lausanne.

The Swiss Science Agency that includes the Federal Office for Education and Technology, the Swiss Space Organization and the Council of the Swiss Polytechnic Schools (ETH) has several objectives: Promote the excellence and efficiency of research and education, reinforce competitiveness of Switzerland and encourage international scientific cooperation.

Mr. Kleiber, how do you see the integration and cooperation of Swiss Science in Europe? What are the problems raised by the fact that Switzerland does not belong to the EU?

Good science is international. Swiss Science cannot be excellent alone, we need cooperation within international networks, in particular with Europe for political and cultural reasons. While Switzerland is partly isolated, it is not easy to have our own national policies and to run different bilateral policies with European countries in parallel. This is a very complex relationship.
In fact we enter a time of a relationship that I call "ménage a trois" between Science, Democracy and Economy that are getting more and more intertwined. Science is and remains the pleasure of knowledge with no limits but has to take into account the rules of democracy and economy.

Within the European Research Community, it is often criticized that most national scientific communities do more actively collaborate with the United States, than with their European partners. Is this also the case for Switzerland, and what is your opinion on this matter?

Of course it is the case. Many Swiss scientists went to the USA or are part of the US science system. This is good for the internationality of Swiss science. We have to pick up the best of the American model based on competition. We also have to shape new ways of collaboration in Europe that are consistent with our European traditions and values.

What is your opinion on the 6th EU Framework Program?

This program is a necessary compromise between hundreds of actors, with no clear shape yet. It is like an 'auberge espagnole', you take out what you put in. Up to now over 700 propositions of changes have been made. I really hope that this program will put emphasis on basic research in science, social science and humanities.

Where do you see the strengths of Switzerland in Science in general and in Physics in particular? Do you think that Switzerland invests enough in expenses for research and development with 2.6% of its national growth product?

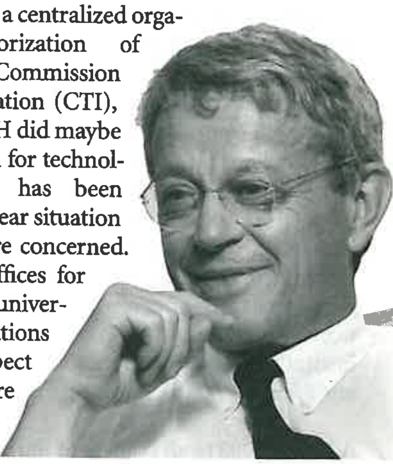
You are the scientists; the physicists and you know better where we are strong. Of course, there are several areas with traditional strength: for example, in high energy physics at CERN and more generally in condensed matter physics. Concerning the investment, 2.6% is certainly not enough. Other countries invest more. Equipment is getting older, people leave the country. If we do not increase our investment in science, we will be in danger, because in a small country like Switzerland the economy strongly relies on scientific achievements. To remain on the cutting edge and to keep or attract the good scientists, we have to take the right decisions and invest accordingly. Small countries, in proportion, must invest more than big countries, which can count on mass effect. They also have to choose their priorities, what is always risky.

If we had the same financial problem for Swiss science as Swissair recently encountered would the government help in a similar manner?

No, clearly not. Swissair is a symbol of identification for the population. This is not the case for Swiss research. We certainly need more information campaigns to raise public awareness on science. The program Science et Cité with public events in all major cities has been shaped for this purpose.

In the indicator for technology development published by the UNPD (United Nation Program for Development) in July 2001 Switzerland ranks very well between Germany and Austria in terms of number of patents. Nevertheless none of the Swiss Research Centers appears in the list of large world centers for technological innovation based on a study of the magazine "Wired". Why is it so?

This is indeed a problem. Scientific creativity and standards in our country are very high and in principle we should be better able to transform knowledge into products. There are two reasons for this problem: the first one is cultural; the scientists have to learn how to valorize their inventions. The second one is social. With the existence of a centralized organization for the valorization of knowledge, the so-called Commission for Technology and Innovation (CTI), the Universities and the ETH did maybe not feel responsible enough for technology transfer. Now this has been improved with a new and clear situation as far as property rights are concerned. Once the newly created offices for technology transfer within universities and research institutions get more established, I expect Swiss Science to create more technological innovation.



I might add that for the precise example of the WIRED study, there was also a technical problem: the indicators used in the study were not available for Switzerland.

What are your feelings about fundamental research? Do you think that the links between industry and research in Switzerland are strong enough?

Swiss firms invest more abroad. This means that they find better conditions outside Switzerland. In my opinion the situation is improving but we certainly have to work more on it. For example I believe that our country is a good place for investments in life science and we have to convince companies to do so. High salaries and social charges are not a major concern if investors find a high quality of services and a good cultural life. Firms are changing their strategies by establishing new partnerships with universities. In some cases they even install their own research groups within the universities, taking advantage of a creative and stimulating environment.

As proposed by Philippe Busquin, Europe needs to have centers of excellence. On December 18, 2000 the Swiss ministry of interior affairs announced the creation of the first National Centres of Competence in Research (NCCR) to promote scientific excellence in areas of strategic importance. Two of the projects are related to physics: "Nanoscale science" and "Materials with Novel Electronic Properties". What criteria were used for the final choice?

Out of 237 initial projects, the Swiss National Science Foundation retained 18 proposals and finally 14 have been financed. Three more are to come. The attribution of these significant funds to basic research is of course a political decision. With two projects in physics, I assume that the physicists are happy.

Over the past few years there has been a strong decrease of physics students in the Universities and fewer go today into research. From your point of view, what are the reasons and what can be done to reverse this tendency?

There is indeed a phase of concentration in physics. For example, and contrary to other universities, the last figures from the ETHZ show stability or even a small rise of the number of students, 30% in chemistry and 10% in all other sciences.

Is a migration of the students to the larger ETH schools not a danger for the smaller faculties that might collapse by lack of students?

No, the smaller universities are certain to remain but you cannot have a strong and sustainable institution with only a couple of professors and a handful of students. Are they strong enough to have a faculty of science? It depends on the creativity of their research teams and their international connections. Creativity thrives on debate but when you only have one of a few faculty members and students, controversies are hard to entertain! Therefore smaller (or all?) universities will have to concentrate their efforts on those disciplines where they are excellent. The support of small universities is a matter of cost. It would only be problematic if one directly links the funding a faculty or university to the number of students.

There has been lately a strong promotion for life sciences and biotechnologies as seen from the marked refocusing of the Federal Institutes of Technology. Isn't it a danger to over do it and weaken other sciences like physics, chemistry, electrical engineering or computer science?

Where is the balance? You have got two NCCR programs in physics out of 14! We have to look where the core business of the industry is and invest where we are strong. Basic sciences will be developed, as seen by the transfer of the mathematics, physics and chemistry departments from the University of Lausanne to the EPFL. Switzerland is a good place for life sciences, with clusters of strength in Science, education, medicine and biotech industry in Basel, Zurich and Geneva/Lausanne. The ongoing expansion of life sciences is not directed against physics: the old view of disciplinary kingdoms is outdated; interdisciplinary is wanted. In short, physicists will increasingly have to deal with life scientists, as already exemplified by the recently inaugurated Swiss Light Source.

You have organized the program "Science et Cité" to better communicate the image of Science to the public. Key manifestations took place in different Swiss Cities. The press and the public responded very well. What are your plans for the future in this field? Do you plan any activity at the Swiss National Exposition EXPO02?

I would like to say that Science et Cité is part of our science policy. This national manifestation has been very successful and takes place every 2 or 3 years, the next one will be in 2004. We organize also so-called scientific cafés to discuss new topics or have the questions of the public answered by specialists. Such an event is planned at Expo02. Next year the theme of "human embryos in research" will also be addressed. Another project is to build the future Houses of Science et Cité in the Cantons of Zurich, Ticino and Vaud so to decentralize our activities. The main issue is to bring knowledge out of the universities into the street by creating open debates on radio, TV, etc. The public, being the taxpayer, has to be convinced that science is important for the future of our society. If scientists do not succeed here, investment into science will further decline. Moreover, the taxpayer has to be convinced that science is not only a problem for specialists; he too, has his word to say.

The European Physical Society (EPS) and National Physical Societies represent a large body of European physicists. How do you see their role in influencing science politics and promoting the image of physics?

To my view, learned societies are needed to disseminate the scientific culture. They should also participate to political debates and decisions. As you say, all national institutions like the SPS and the Swiss Academy of Science should raise public awareness and also establish a better link between scientists and politicians. Science education at school could also start earlier to raise a larger curiosity among youngsters. Let me add that as science policy is concerned, this is too important to be left solely in the hands of scientific lobbies or only to politics, for that matter. Science policy is a collective endeavor.

At the World Congress of Physical Societies in December 2000 in Berlin, the EPS has launched the project "2005, World Year of Physics" to promote the image of Physics. This choice has been mainly motivated by the wish to commemorate the famous publications of Albert Einstein in 1905, its "miraculous year". Several manifestations are planned in Switzerland. What are your visions in this respect?

I shall be very happy to help with this project and would well see the Foundation Science et Cité involved in an action. Why not on a topic like "Physics and the Citizens"? The impact of physics on the society since 1905 has been enormous, and Einstein is certainly the most popular and best-known scientist.

Switzerland is a Federation of 'Cantons', which are running their Universities with independent science policies. To some extent, your role as State Secretary for Science is to orchestrate the actions of independent bodies. What have been your good and bad experiences on this job?

My role is first to create the good conditions for the development of science in our country so that young scientists feel that they have a future. This has to be done in collaboration with the cantons. One of my good experiences on the job is that the scientific cooperation between Cantons and Confederation works well, and might even be the best among all. The intensification of this cooperation follows a reform strategy started in 2000 and which should extend to 2007 with a new constitutional article. This is not enough, we have to reform, not suppress, the small universities and help them to reinvent themselves. They are the actors in a competitive world, where funding, like that provided by the NCCR program is attributed based on quality and scientific merit.

Bern, 23 October 2001

The science lecture: theatre in the round?

Denis Weaire, Trinity College, University of Dublin, Ireland

If you work at a university and want to provoke a really good argument, broach the question of the ideal shape of the lecture theatre. Opinions vary, and they are rarely understated.

There are two poles of disagreement. One the one hand there is the steeply raked, overbearing form of the traditional amphitheatre: the semicircular bowl where Faraday stood at the Royal Institution or the chemistry theatre of the old polytechnic university in Lisbon. At the other extreme is the more rectangular and shallow space of an auditorium or cinema.

In the planning committees of universities, battle is joined between the two factions. Surprisingly it is the scientists who favour the more antique and intimate design. Points at issue will include acoustics and efficiency (rectangles come cheap) but perhaps most importantly the "feel" of the theatre. The experience of both speaker and audience is quite different in the two cases.

In the flat design, the lecturer climbs to a lectern as a priest to his pulpit in a medieval cathedral, to *talk down* to his congregation. Received wisdom is to be dispensed from a book to the multitude by a privileged minority of the learned. Is not the arts lecturer, reading with such exactitude from a meticulously prepared script (the same as last year's, and the year before) in that position?

The scientist comes to his flock with uncertain and provisional conclusions about the workings of the world. Like one of Shakespeare's modest prologues, this is but a poor player, humbly inviting the attention of the audience to dissect a piece of nature's plan "within the girdle of these walls". The wonderful Globe Theatre, now reconstructed, places many of its customers in high balconies that seem to overhang the stage. Aristocratic patrons who arrived late in the best of these could ask for the play to be restarted.

Sir Robert Ball at the bench in the Royal Institution, in the early years of the 20th century.

In the old science lecture theatres that give the audience such a privileged position, the ghosts of great masters of the demonstration lecture prowl about the bench. Their art, which had its heyday in the 19th century, is now largely defunct. But the physics lecturer still does well to dance around upon his stage, lay out some props upon the bench and call out from time to time: "Hey, look at this!" The convergent focus of attention of the awakened onlookers gives a dramatic punch to the experience. It can stick in the mind for decades. A good *coup de theatre* is worth ten thousand words. If Hamlet had not held up the skull, who would remember Yorick?

But perhaps you do not agree? You prefer the lectern to the bench? And disciples at your feet to inquisitive eyes ranged about and above you? Ah well, wise was that person that first said: "An academic is one who thinks otherwise."

Do you have any examples of good and bad practice in theatre design, or established guidelines? If so, send them to Europhysics News.

East-West collaboration in nuclear science

Wolfram von Oertzen, Chairman of the NPD
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The Sandanski-2 meeting on East-West collaborations in Nuclear Science was held in May 2001 in the town of Sandanski (Bulgaria), about 6 years after the first meeting of this kind with 115 scientists from 17 European countries, the USA, Japan and the Joint Institute for Nuclear Research in Dubna participating in the meeting. The scientific programme included 66 oral contributions. This meeting has provided the chance to look at the recent progress in the field of nuclear science. 2001 also marked the 10-year period, over which substantial political and economic changes have taken place in Eastern Europe. These changes have had a decisive impact on the scientific community in these countries, because the support for basic and applied science has decreased dramatically due to the collapse of their economic systems. Nevertheless educational institutions in Eastern Europe have continued to attract motivated young students and have produced well-trained young scientists. It should be also noted that, in spite of the difficult economic situation in the East, there are still good resources — experimental installations, technical and scientific manpower, and a well trained human intellectual reserve. At the present meeting the excellent results from this region were presented. Evidently, the conditions vary in the different Eastern European countries, and they differ strongly from one institute or laboratory to another. Improving their working conditions is not easy. This statement holds true especially for university laboratories and smaller institutes. Everyone is aware that the future working conditions may become rather unattractive, which in turn is likely to discourage the next generation of students to embark on the study of science.

Collaborations in nuclear science existed in many fields before and at the Sandanski-2 meeting it was demonstrated that scientific contacts have been developed considerably in the last 5 years. Many national and European institutions, having realised the difficult situation of scientists in the East, have set up support programmes for the funding of local activities for scientists in their Eastern institutions (e.g. The Soros Foundation), or more extensively to fund collaborations between Eastern and Western scientists (by NATO Science, INTAS, WTZ-Germany, CNRS-France, INFN-Italy, etc.). Many highly experienced scientists working in basic nuclear science now spend time working in Western Europe, the United States and in Japan. It cannot be overlooked that brain drain from the poorer Eastern European countries is a real problem. These people are of course very welcome in Western institutions, however, in the mid-term a collapse of the scientific community in the East can be anticipated. On the other hand, we must admit that the situation in the West is also disturbing. There, few young people adopt a career in physics, and many of those who do go to industry.

The EPS and the Nuclear Physics Board therefore have created action committees and "task forces" studying issues of East-West collaboration. At the Sandanski-2 meeting the majority of the large collaborations were present. The scientific program was organised to cover the following major fields of basic science:

- Nuclear reactions at low and intermediate energies
- Radioactive beams and exotic nuclei
- Heavy and super-heavy nuclei
- Nuclear spectroscopy
- Fundamental aspects in nuclear physics
- Accelerator applications of nuclear physics
- Public awareness of nuclear science

Although this list of themes does not cover all collaborations, the subjects illustrate the main directions of research in basic nuclear science, which will also play a major role in the future. With this selection, the strength of European nuclear science has been made visible, but also lines of research for the further development can be defined on the basis of the very successful work being performed in strong East-West collaborations. The future development of these fields is covered in the separate scientific summaries of the conference (www.sandanski.ru/s_summ.html). The high level of research done in these collaborations is documented in the complete slide report to be found on the web-site. Their quality is reflected in the fact that the results presented also appear in the first ranks of international research conferences. The contributions of the partner institutions and scientists from the Eastern European countries are very important and are well documented in the corresponding presentations.

These presentations show the impact of several very successful national (mostly bilateral) programmes for support of research

in collaborations with scientists from Eastern European research institutions. These have played a major role in stabilising the scientific communities in the East. There are also recent trans-national European programmes directed to support East-West collaborations. Programmes such as INTAS (www.intas.be), and NATO Science (www.nato.int/science) have been supporting research in nuclear science for the past ten years. It is understandable that this support has been only a part of the total resources needed for any investigation. However, the grants given within these programmes have been of great moral importance for the participants. They have been a way to make specific investigations more visible, and have highlighted their importance. They have helped to give this research a higher priority in the respective home institutes, etc.

The documentation of the excellence of the research presented at the Sandanski-2 meeting is not a reason to rest on our laurels. It has to be taken as a basis and a signal to make all efforts to coordinate and support the future activities on a European scale so as to prevent a possible collapse of the scientific communities in the Eastern countries. This gains importance through the pending entries of many Eastern countries into the European Union.

Scientific excellence in Europe has been achieved with a large contribution by the scientists from Eastern Europe. European science needs the scientists from these countries as strong partners in the future. Thus another very important conclusion from the Sandanski-2 meeting is obvious, that these collaborations improve the use of the available European infrastructure resources in a very effective way. The national and European institutions have to therefore increase their funding of collaborations with Eastern Europe, existing successful collaborations have to be further developed and, new ones must be created according to the needs of science. This is also essential to achieve a balance in Europe between East and West.

As another possible conclusion from the Sandanski-2 meeting, we forward the recommendation to create European structures for the support of scientists in their Eastern home institutions in such a way that they can return and continue to work at home in conditions which will allow them to collaborate in European projects and to attract young people into their home institutions.

East-West Coordination meeting on Nuclear Science was a Europhysics Conference held in Sandanski (Bulgaria) from 5 – 9 May 2001. The Conference was organised by: EPS, Nuclear Physics Board; Joint Institute for Nuclear Research, Dubna; Bulgarian Academy of Sciences — Institute for Nuclear Research and Nuclear; Energy, Sofia; The Committee of Peaceful Use of Atomic Energy, Bulgaria.

European Journal of Physics

Alastair I.M. Rae, Honorary Editor, European Journal of Physics

Physicists working in Universities and other higher-education institutions world wide generally spend a similar fraction of their time teaching physics as they do conducting research. As a result, many valuable insights and new ways of understanding are developed. From the student point of view, the success of their introduction to university level physics often determines not only their academic commitment to physics but also their future career. It is therefore important that the teaching of physics at university level be treated as a professional skill that needs reinforcement and recognition. The European Journal of Physics aims to assist and stimulate the teaching of physics in universities and to emphasise its importance for the successful long-term future of undergraduate physics, by publishing relevant papers and encouraging discussion.

The European Journal Physics is a journal of the European Physical Society, which has been published by the U.K. Institute of Physics for over 21 years, its papers covering a wide spectrum of physics. The Editorial Board is drawn from universities throughout Europe and includes representatives of both the EPS and the IOP. The journal's main focus is on topics that are of particular interest and use for teachers of undergraduates and aimed at enriching their understanding of new and developing fields of physics. Papers featuring developments in the teaching of experimental physics are often of particular interest. Also of primary importance are papers covering the historical, social and technological implications of physics in a wider context. Discussion of the theory and practice of teaching physics is also encouraged, along with contributions on education policies and their implementation.

The European Journal of Physics has, over the years, published special sections with papers concentrating on particular topics. These include "Unsolved problems in physics"; "The electron: discovery and consequences"; "Quantum physics in solids" and "The Life and work of Hendrik Casimir". A special feature on Environmental Physics is planned for 2002.

A glance at any recent issue of the journal shows that the authorship of the papers is truly international, and this is reflected in a reader circulation that spans not only the major physics departments of Europe but also North America and the rest of the world. A full electronic version of the journal plus ten years' archive is available at no extra cost to all institutional subscribers, thus increasing the level of exposure for papers published in the journal. The potential readership of the journal has also been doubled by the Institute of Physics Publishing's many consortia agreements (including four national site licenses) that give electronic access to Institutions that do not have print subscriptions.

The Editorial Board of European Journal of Physics would like to encourage members of the European Physical Society with an involvement in educational matters to contribute their papers for publication. All papers are peer reviewed and the journal is abstracted in ISI (SCIE; Research Alert and Current Contents: CC/PC&ES).

For further information on submitting your work go to the online version of our Notes for Authors at www.iop.org/Journals/nfa or the European Journal of Physics page at www.iop.org/journals/ejp

noticeboard

EPS QEOD Prizes

Nominations are now sought for the following prizes

- **EPS Quantum Electronics and Optics Prize**, sponsored by NKT, for outstanding contributions to quantum electronics and optics. One prize is awarded for fundamental aspects, one for applied aspects.
- **EPS Fresnel Prize**, for outstanding contributions to quantum electronics and optics from younger scientists, for work performed before the age of 35.

Details of the nomination procedure, which must be followed, will be given on the EPS web page www.eps.org. Deadline for receipt of applications at the EPS office is March 28, 2002 for both prizes. The Awards will be announced at the IQEC 2002, meeting in Moscow, June 22 – 28, 2002.

EGAS 34 conference

The European Group of Atomic Spectroscopy will organize its 34th Conference (EGAS 34) from 9 to 12 July 2002 in Sofia, Bulgaria. The scientific program of EGAS 34 will cover all aspects of spectra of simple and complicate atoms, ions (including highly charged) and small molecules; atomic constants and application in astrophysics. The Conference will be focused to the rapid progress of quantum optics, laser manipulation of atoms, cooling and trapping of atoms and molecules, Bose-Einstein condensate, atomic lasers, laser spectroscopy, generation of ultrashort EM pulses, and application of quantum optics in metrology. Special attention will be paid to the atomic spectroscopy aspects of low and high temperature plasma and application to light sources. The experimental methods and instrumentation will be discussed. For more information, see the Conference site at www.issp.bas.bg/egas34

In memoriam

On 14 December 2001 Prof. Eduard Nagaev died unexpectedly. Until the last moment he was full of energy and defended his ideas eagerly. He was born in Penza (Russia) in 1934 and graduated at the Moscow State University in 1956. For almost 30 years he was Head of laboratory at the Institute of Current Sources (Moscow), and during last decade he worked in the Institute for High Pressure Physics and Institute of Radioengineering and Electronics of the Russian Academy of Sciences as the Head scientific researcher. Among many Distinctions and Honours he was USSR State Prize in 1984. During his wide scientific career he made relevant contributions. One of the most important was the developing of the theory of "spin polarons". He was a charismatic person and the scientific community in the field of magnetic semiconductors and magnetic oxides will miss him.

Prof. M.R. Ibarra
Chairman of the Magnetism Section
CMD Division of the EPS

Workshop

The Wojciech Paszkowicz Institute of Physics will organize a Workshop on New Methods of Low Dimensional Structures Characterization: VUV and X-ray Free Electron Lasers from June 15 – 17, 2002, in Ustroń-Jaszowiec, Poland. Since the first meeting, in 1992, the ISSRNS is organized as a biennial event. It is a traditional forum for discussing fundamental issues of application of the synchrotron radiation and related methods in natural science (physics, chemistry, materials science, molecular biology, biomedicine). The scientific programme of the School includes invited general lectures, poster sessions and panel discussions. The deadline for submission of abstracts of the other contributed papers is 15 March 2002. For more information, please visit the workshop's site at http://info.ifpan.edu.pl/celdis/wp5/

Elections to the Board of the EPS–IGA

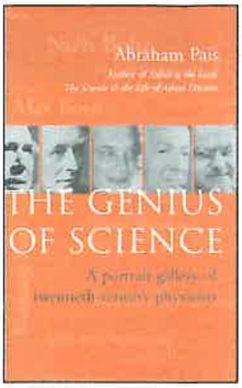
The Statutes of the European Physical Society Interdivisional Group on Accelerators stipulate that one third of the members of the Elected Board has to be renewed every two years. Nominations must be supported by 3 Members of the Group. Members are elected for 6 years (3 conferences). Six vacancies are announced herewith. Nominations should be made on the appropriate form available from the Budapest Secretariat, together with a short c.v. and description of the activities of the candidate, should be addressed to M. Lazar, Nador Utca 7, H 1051 Budapest, Hungary

The deadline for receipt of nominations is: 8 March 2002. The resulting list of candidates and ballot papers will be mailed to EPS-IGA Members who will be invited to vote by the deadline of 26 April 2002. Newly elected Members of the Board of the EPS-IGA will be notified of the result of the election in writing by mid-May 2002.

Elections to the Board of the NPD

The Board of the EPS Nuclear Physics Division is organising elections to replace outgoing members. Three vacancies are announced herewith. Nominations must contain a short c.v. and a statement from the candidate, and should be addressed to M. Lazar, Nador Utca 7, H 1051 Budapest, Hungary. The deadline for receipt of nominations is: 28 February 2002. The resulting list of candidates and ballot papers will be mailed to EPS NPD Members who will be invited to vote, if necessary by the deadline of 30 April 2002. Newly elected Members of the Board of the will be notified of the result of the election in writing by mid-May 2002.

BOOK REVIEWS



The Genius of Science

A portrait gallery of twentieth-century physicists

Abraham Pais
Oxford University Press, 2000
487 pages

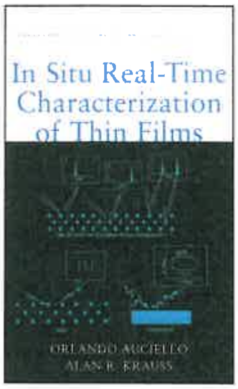
The late Abraham Pais (1918-2000) has led an extraordinary fruitful life, filled with history, physics and history of physics. *The Genuis of Science* is, and will remain, his last fruit and, apart from Pais' autobiography *A Tale of Two Continents* (1997), the most personal one. Pais paints portraits of eminent physicists and of one universal genius (Von Neumann) of the 20th century, all of whom he came to know personally; some of them became intimate friends (Bohr, Einstein, Jost, Uhlenbeck). Some of these "microbiographies", as Pais calls them, are superficially sketchy, such as the ones of Weisskopf, Yang and Lee (they occupy a few pages only). Others display more depth and are at times moving, such as the ones of Bohr, Einstein, Dirac, Kramers and Uhlenbeck, who was Pais' teacher in Utrecht before Pais went into hiding during the war. Needless to say there is a lot of history of elementary particle physics too scattered over these pages, the branch of physics Pais contributed too for over a period of about twenty years, after he emigrated to the USA.

Occasionally the detached historian in Pais takes over, such as when he severely criticises Max Born's claim, made in his Nobel lecture of 1954, that Einstein's photon hypothesis guided him to his famous probabilistic interpretation of the quantum-mechanical wave-function. But most of the time Pais never forgets to make clear that most of these brilliant physicists were his buddies. Pais gladly spills over autobiographic morsels on his microbiographies whenever he deems it appropriate.

One cannot help noticing that of the seventeen portraited men, thirteen are Jewish: Bohr, Born, Einstein, Feigenbaum, Jost, Klein, Von Neumann, Pauli, Rabi, Serber, Uhlenbeck, Wiesskopf and Wigner, the non-Jews being Dirac, Kramers, and the Chinamen Lee and Yang. I personally cannot help noticing that in the previous century the Jewish people have suffered as well as excelled in such an extraordinary disproportion. It seems as if in the past century theoretical physics was an almost entirely Jewish enterprise — I mention that Weinberg and Witten are not even among the portraited physicists, but also portraits of Oppenheimer, Feynman and Schwinger are absent, all three men whom Pais knew. In particular a portrait of Oppenheimer, with whom Pais led the Insitute of Advanced Studies in Princeton after the war, is felt as a sad ommision, because together with Heisenberg (understandably not portraited) Oppenheimer is the most tragic figure of 20th century physics. In comparison to Heisenberg, Oppenheimer stands out as a morally superior being, but whereas Heisenberg never encountered any serious obstacle in his professional career before, during and after the war, Oppenheimer was shamelessly shattered by the government of the USA during the McCarthy period. Despite this omission, Pais' portrait gallery makes fine leasurely reading, because Pais has managed to find a balance between the detached historian of physics and the passionate physicist he never ceased to be. Admittedly, in most portraits Pais is prominently present too. But this goyem does not dare to deny him that right.

F.A. Muller, Faculty of Physics and Astronomy, Utrecht University, The Netherlands

In Situ Real-Time Characterization of Thin Films



Orlando Auciello & Alan R. Krauss
John Wiley & Sons, 2001
266 pages + xiv

The Editors of *In Situ Real-Time Characterization of Thin Films*, Orlando Auciello and the late Alan R. Krauss - both established Senior Scientists at the Argonne National Laboratory, Argonne, Illinois – have successfully selected fifteen known experts in the field of in situ real-time monitoring and analysis of evolving growth and concurrent surface and iterface phenomena of thin films for providing eight (two of which strengthened by their own participation) extensive, thorough, didactic, and research – illuminating Contributed Chapters covering attested methods for on the spot dynamic characterisation of technologically and application-wise important epitaxial materials in several different environments.

In sequence, Time of Flight Ion Scattering and Recoil Spectroscopies (TOF - ISARS), Reflection High Energy Electron Diffraction (RHEED), Ellipsometry, Reflectance Spectroscopies and Transmission Electron as well as Atomic Force Microscopy (TEM & AFM), LASER Reflectance Interferometry (LRI), X-Ray Reflectivity (XRR), Curvature – Based Techniques (especially the Multibeam Optical Stress Sensor – MOSS – LASER Deflectometry Method), and Photo-Electron Emission Microscopy (PEEM) are the in situ real-time characterisation approaches laboriously studied, each enriched with an admirably and fruitfully vast Reference alphabetical Literature.

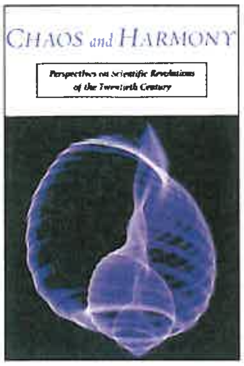
The Subject of direct dynamic analytical characterisation of thin films whilst being grown lies truly in the forefront of the needs, the interests, and the ongoing research of Solid State and advanced Optoelectronic Devices Science and Engineering; as such it places the Book at the priority level of Library updating for the related University , Research Centre, and Dedicated High Technology Industry Working Groups – despite its unavoidable not being all-inclusive:

The characterisation techniques focused on in the Book have been preferred on the basis on the one hand of their functionality in vacuum and in the presence of ambient gases, either resulting from the deposition process or serving as a requirement for the production of the desired chemical phase, and on the other of their employing sufficiently compact and non-luxuriously expensive instrumentation, thus permitting incorporation of its as a dedicated analytic tool within a thin film epitaxial deposition chamber.

The Volume itself is aestetically beautiful and , apart from a small percentage (including those on the front cover) of its sketches being hurriedly drawn, is supported by numerous clear and exact graphs and several genuinely interesting diffraction, dark field , and electron microscopy images; the appearance of a literally negligible amount of grammatical errors not at all impeding the ease and enticement of reading and learning.

The Reviewer's enthusiasm for both the mentally pleasant and scientifically rigorous minuteness of the wealth of information compiled and the motivating justification of effective applicability produced, for all characterisation methods outlined throughout the Book, has been admittedly even more heightened by Chapters 3 on Ellipsometry by Eugene A. Irene of the University of North Carolina and 8 on Photoelectron Emission Microscopy by Martin E. Kordesch at Ohio University.

Professor Emmanuel A. Anagnostakis, Hellenic Army Academy, Hellenic Centre for the Study of Optoelectronics, Athens, Greece



Chaos and Harmony

Perspectives on Scientific Revolutions of the Twentieth Century

Trinh Xuan Thuan
Oxford University Press, 2001
P14 + 366 pp. + 70 figs.
Translated from French by Axel Reisinger

The book is about the main developments of science, basically of physics, during the 20 century and about their reflections upon the philosophical understanding of the world. Both the title and the subtitle are quite pleasing and raise high expectations. The contents, the subject index, the glossary, the well chosen illustrations and even the number of pages give the first impression that the book meets the challenge to comprehensibly present modern science to the layman. In fact this is what the author states in the Foreword and his promise is readily supported by the observation that there is more poetry than mathematics.

The book offers a rich variety of topics: from big bang, black holes and wormholes to quarks and superstrings reaching up to the mind-body problem, the self-referential systems and Goedel's theorem. All this is wrapped accurately up in the dichotomies of chance and necessity, chaos and harmony, creativity and conservatism, holism and reductionism, yin and yang.

The book is a challenge to interdisciplinarians, to philosophers and historians of science. They will be stimulated to reveal numerous lapses and discrepancies. In most cases these are quite subtle which makes them even more risky for the layman. The book resembles a collage, or a parquette (to keep to the French accent of the translation) in which most of the pieces seem to be all right but their arrangement is rather awkward.

A few extracts to illustrate this (all italics are mine).

The "electrons may have left the electron gun as particles, but they have turned to waves before reaching the slits" (p. 211).

"Integers are not a product of our mind" (p. 314)... "why do abstract entities forged in the minds of mathematicians..." (p.322).

"The behavior of a collection of electrons is not haphazard but is perfectly well determined by the laws of probability" (p.329).

Let the potential reader volunteer to make out this: "Even though we cannot predict the weather a month from now, we have every reason to expect that, for a long time to come, the Sun will rise every morning and spring will return every year to reawaken Nature and signal trees to bloom. Chaos is thus a powerful ally to quantum indeterminism in liberating matter from its deterministic shackles." (p.330).

Forgive me, Shakespeare, for paraphrasing your lovely Sonnet 116:

> If this be errorless, and upon me prov'd,
> I never writ, nor no man ever read.

Michael Bushev
Institute of Solid State Physics, Bulgarian Academy of Science

activities

Books for review

From Nonlinearity to Coherence
Dixon, Tuszynski, Clarkson
Oxford

Experimental Techniques in Condensed Matter Physics at Low Temperatures
R. C. Richardson, E. N. Smith
Addison Wesley (Advanced Book Classics)

Introductory Nuclear Physics
Hodgson, Gadioli, Gadioli-Erba
Oxford

Large Facilities in Physics
J. Schopper, M. Jacob
World Scientific

Neutron and Solid State Physics
L. Dobrzynski, K. Blinowski
Ellis Horwood Series

Numerical Simulations in Astrophysics
Franco, Lizano, Aguilar, Daltabuit
Cambridge

Philosophical Reflections and Syntheses
E.P. Wigner
Springer Verlag

Physically Speaking. A dictionary of quotations on physics and astronomy
C.C. Gaither, A.E. Cavazos-Gaither
IOP Publishing

If you are interested in reviewing one of the above books, or in receiving books for review in general, please send us name, and contact co-ordinates, along with the your field(s) of specialisation to:

Book Reviews, EPS Secretariat
BP 2136, 68060 Mulhouse Cedex, France

Letters

In his letter published in EPN 32/5, Dr. R. Joern S. Harry questions whether CO_2 emissions associated to the whole nuclear fuel cycle, from ore extraction to waste disposal, are as low as expected. He refers to an article (http://home.trouweb.nl/stormsmith) in which "the authors claim that in the end nuclear emits about as much CO_2 as the burning of natural gas for an equivalent amount of electricity production" . If this were indeed found to be the case, nuclear power would hardly be worthwhile!

Three independent studies quoted below conclude, on the contrary, that CO_2 emissions associated to nuclear power, considering the whole cycle, are quite low, comparable to those of hydroelectricity:

In Sweden, a Vattenfall study entitled "Certified Environmental Product Declaration of Electricity from the Nuclear Power Plant at Forsmark" (http://www.environdec.com) finds **2.90 g/KWh** where the whole cycle is considered, and the quantity measured is the Global Warming Potential (green house gases), given in CO_2 equivalents. This quantity actually breaks up into:

Pre-nuclear Production Phase (Pre-NPP)	2.17 g/kWh
Nuclear Production Phase (NPP)	0.556 g/kWh
Post-Production Phase (Post-PP)	0.178 g/kWh

A paper entitled "Energy Analysis of Power Systems" (http://www.uic.com.au/nip57.htm), by the Uranium Information Centre Ltd. (UIC) finds somewhat larger numbers: for France, where enrichment is done by diffusion but most of the electricity comes from nuclear plants, the greenhouse contribution for nuclear power is found to be less than **20 g/kWh.** A supplement to this paper discusses the "stormsmith" paper at some length expressing strong disagreement with its content. One of the problems with the "stormsmith" paper is that it assumes all the electricity used in the nuclear fuel cycle comes from fossil fuels. Other problems are underestimated plant life duration and overestimated pre production greenhouse gas emissions and post production waste related energy demands.

In a paper entitled "Bois, charbon, pétrole, gaz, nucléaire et autres, même problèmes?" which could translate to: "Wood, coal, oil, gas, nuclear and others, same problems?" published in "La Jaune et la Rouge" N° 555 (May 2000), Jean Pierre Bourdier, Director of environment at EdF, gives **6g/kWh** CO2 emissions for the whole nuclear fuel cycle in France.

For a comparison of greenhouse gas emissions related to the whole cycle for various energy sources, we would like to quote Vattenfall numbers (data take from the UIC paper):

Energy source	g/kWh CO_2 (approx)
Hydro	3
Wind	5.5
Nuclear	6
Solar (PV)	50
Gas combined cycle	450
Coal	980

Finally, according to the work in progress at ISN (Institut des Sciences Nucléaires de Grenoble) and elsewhere, there are good grounds to claim that converter and/or breeder reactors, because they convert essentially 100% of the Uranium or Thorium fuel, would yield a considerably improved energy balance, thus further reducing greenhouse gas emissions per unit energy produced. In our view, it is only with such converters (or breeders), based on the Uranium or, better, the Thorium cycle, that it will be possible to justify classifying nuclear energy as sustainable. Meanwhile, during the time needed to design and test these new reactors, and develop or improve other environmentally clean energy production technologies, we feel that PWRs can fill the gap and help reduce greenhouse gas emissions to the atmosphere, as stated in our paper "Global Warming or Nuclear Waste – Which Do We Want" published in EPN 32/2.

H. Nifenecker and E. Huffer

Acknowledgments

Martin C.E. Huber, the Editor of the Special Issue on 'Physics and the Universe' would like to express his thanks to his colleagues. He was able to rely on the expert advice of the Board of the Joint Astrophysics Division, as well as on the guidance by the EPN astronomy correspondent, Frank Israël. He is deeply indebted to them and, likewise, to the authors of the individual articles, who all provided their manuscripts in time and at the requested length.

M.C.E. Huber, 65, has worked in laboratory astrophysics and extreme-ultraviolet solar spectroscopy. He was Head of ESA's Space Science Department, and currently spends most of his time in the International Space Science Institute (ISSI, Bern) and the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass.

EPN would also like to take this opportunity to publish some of the biographical details omitted from the last issue.

Luigi Piro is senior researcher at Istituto Astrofisica Spaziale of C.N.R. in Rome and Mission Scientist of BeppoSAX for the Italian space agency (ASI). His main research areas are Gamma-Ray Bursts and Active Galactic Nuclei, as well as the development of instrumentation for high energy astrophysics. He has led several observing programs with X-ray satellites since 1980.

Letters, opinions, comments... please send them to:
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