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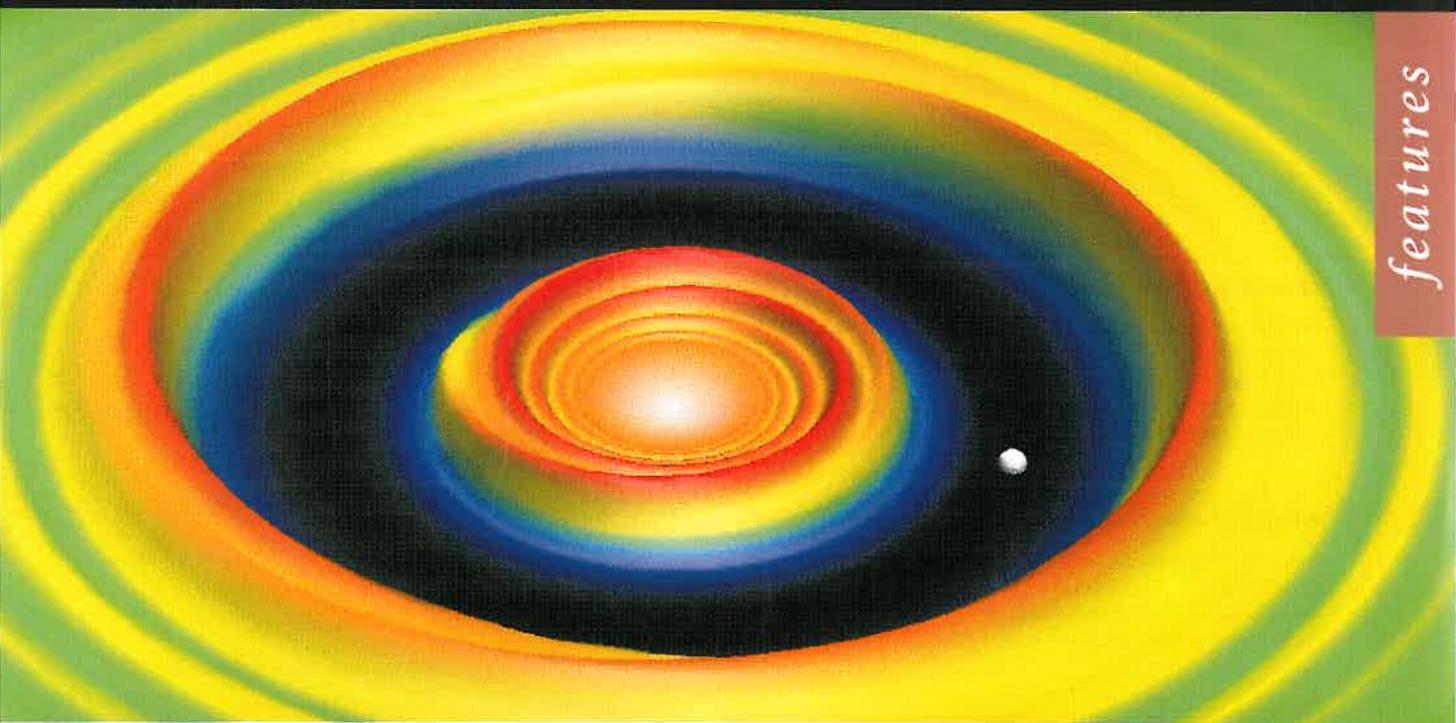
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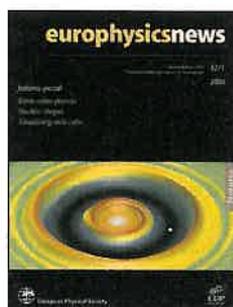
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Simulation of the formation of a planetary system.
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The EPS European Physicists Biographies Project

EDITOR: DR. SVETLANA ERYKIN
 Graphics: Pauline A. Russell
 Svetlana Erykin

The venture is aimed at increasing the interest in physics of 12-17 year old students by way of a brief description of the personal as well as the scientific aspects of those famous physicists, whose names are mentioned in school text books

Pauli showed that no two electrons with the same quantum numbers could be in the same orbit



Kamerlingh Onnes studied liquefied gas at very low temperatures



Laplace developed game theory



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Santa Claus and Science

There are approximately 2 billion children on earth (not older than 18). However, as Santa Claus does not visit members of the Muslim, Hindu, Buddhist or Jewish religions, this reduces the workload on Christmas Eve by about 15%, leaving around 378 million children. Using on average 3.5 children per household, assuming that there is at least 1 good child per family, this leaves 108 million houses for Santa to visit. Santa Claus has around 31 hours to effectively work on Christmas eve, taking into account the Earth's rotation and different time zones on the hypothesis that Santa works from east to west, which seems logical.

The resulting calculation leaves Santa with 967,7 visits per second. This means that for each eligible household, Santa has just more than 1/1000th of a second to park his sleigh, jump out, fill the stockings, distribute the rest of the presents under the Christmas tree, eat some of the cookies on the plate, climb back up the chimney, get back into the sleigh and move on to the next house.

Assuming that there is an even distribution across the surface of the Earth of the houses (which we know is incorrect from the outset, but will accept it as a first approximation), Santa travels about 1.4 kilometres between each house. This means that Santa travels around 150 million kilometres on Christmas eve, without counting pit stops. This means that Santa's sleigh travels at approximately 1,170 kilometres per second (3000 times faster than the speed of sound). By way of comparison, the fastest man made vehicle, the space probe Ulysses, travels at a pokey 49 kilometres per second. An average reindeer, at top speed, only manages 27 kilometres an hour.

The maximum load that the sleigh can carry is also an interesting subject. Supposing that each child receives only one box of Lego, weighing 1 kilo, the sleigh has to carry 500,000 tons, without the weight of Santa Claus or the reindeer. The average reindeer (on Earth) can carry up to 150 kilos. Even supposing that the famous flying reindeer can carry 10 times more, Santa Claus could not tow the load with a measly 8 or 9 reindeer. He would need 360,000. Which would increase the maximum weight by another 54,000 tons making the sleigh heavier than the USS enterprise (the aircraft carrier, not the Starship). Close to 600,000 tons moving at 1,170 kilometres per second creates enormous air resistance. The reindeer would heat up, just like the space shuttle entering into the Earth's atmosphere.

The 2 leading reindeer would absorb 14,300 million joules of heat energy per second. To make a long story short, they would burst into flame almost instantaneously, leaving the two following reindeer dangerously exposed. The entire pack would be completely vaporised in 4.26/1000th of a second, or in other words, just in time for Santa to have visited 5 houses.

Don't worry about being one of the lucky 5 though, because just as a last piece of information, lets suppose that Santa weighs 125 kilos (which seems particularly trim). Passing from a standing stop to 1,170 kilometres per second in 1/1000th of a second, Santa would be subject to g force from the acceleration of 17,500 times his normal body weight. A Santa Claus weighing in at 125 kilos would find himself smashed against the back of the sleigh with the force of 2,157,207.5 kilos. We can only hope that Santa lives in another space/time dimension.

Merry Christmas and Happy New Year from the team at Europhysics News.



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Nuclear shapes

Renée Lucas

The naive picture of spherical nuclei is far from reflecting the reality of nuclear structure. Indeed a variety of different shapes have been observed and/or predicted that depend on the neutron to proton ratio and on the conditions of excitation energy or spin of nuclei. Thanks to the impressive technical developments of γ -ray detector arrays, the interest of nuclear physicists in nuclear structure related to the study of nuclear shapes, in particular at high angular momenta, has become more and more important.

Indeed, very few nuclei have a spherical shape in their ground state and a variety of shapes can be observed, often in the same nucleus. The deformed nuclei can be schematically subdivided into prolate, oblate and triaxial deformed nuclei depending on the relative axis values of the ellipsoid. Other shapes can also be encountered (fig.1). The low lying part of the energy spectrum of spherical nuclei can be interpreted in terms of surface vibrations. Magic or semi-magic nuclei (see box 1) have very few excited states at low excitation energy, their low transition probabilities indicating a low collectivity of these states and the dominance of single particle degrees of freedom. In contrast, the energy spectrum of a deformed nucleus has excited levels at energies which obey the typical relation of the angular momentum I for a rigid quantum mechanical rotor: $E \sim I(I+1)$. The measured quadrupole moments ($I(I+1)/2\hat{J}$ where \hat{J} is the dynamical moment of inertia) for these nuclei characterise their deforma-

tion. As nuclear rotation also modifies the microscopic structure of the nucleus, the shapes favoured by a particular nucleus will change with increasing spin. Of course, many nuclei have a transitional character involving both vibrational and rotational features.

Near closed shells spherical shapes prevail, while between closed shells the large number of valence nucleons in orbits with large single particle angular momentum leads to nuclei with large deformations. It is also possible to observe both a deformed and a spherical shape in the same nucleus at different excitation energies and spins. Fig 2 gives an overview of the different shapes encountered or predicted presented over the chart of nuclei. One has, however, to remember that theoretical predictions and recent measurements indicate that very far from stability, for large N/Z ratios (number of neutrons over number of protons), there might be a quenching of shells changing the representations on the chart of deformed nuclei.

Nuclear structure research with exotic as well as stable nuclear beams is in an exciting and evolving challenge. By choosing a stable or exotic beam one can reach nuclei far from the stability line and at different excitation energies. This indicates the importance of access to different and complementary facilities. In Europe such facilities are GSI (Darmstadt Germany), JYFL (Jyväskylä Finland), Vivitron (Strasbourg France) for the stable beams, or GANIL (Caen France) and CRC (Louvain

la Neuve Belgium) for radioactive beams. One of the main tools used to determine nuclear properties is γ -ray spectroscopy and the impressive improvements made in detector instruments during the last decade have lead to an extensive range of new results. New γ -ray detectors, such as EUROBALL and GAMMASPHERE, are being used either alone or in association with other instruments such as detectors for conversion electron, charged particle or fission fragments, or recoil spectrometers, or velocity filters.

To show how lively and diversified this research domain is today, some examples of nuclear shapes encountered in the different regions of the chart of nuclei and for different experimental conditions are given below. This cannot be an exhaustive presentation of the recent results and this article should be considered only as an attempt to give a flavour of the field.

Deformed ground state of nuclei

Light nuclei

In light nuclei it is possible to explore an isotopic chain from the most neutron rich elements to the proton drip line. By Coulomb excitation one has gained access to nuclear parameters such as the energy of the first excited state and its excitation probability. For example, the large excitation probability for the first excited 2^+ state found for $^{44}_{16}\text{S}$ indicates that this nucleus has not the spherical shape expected from the $N=28$ magic number of neutrons [ref. 1]. Neutron-rich magnesium isotopes have been extensively investigated from both theoretical and experimental points of view. According to microscopic calculations their structure fluctuates very rapidly from one isotope to the next and the $^{32}_{12}\text{Mg}$ ground state is deformed, in spite of the $N=20$ shell closure. Indeed the low energy of the first excited 2^+ state and the large transition probability are in agreement with such a deformed shape. Experiments have been recently carried out to determine more precisely the deformation parameters.

Heavy nuclei

The rotational character of the ground state bands of deformed nuclei have been intensively studied. As far back as 1981, a Coulomb excitation experiment of $^{238}_{92}\text{U}$ was made at GSI (Darmstadt) [ref. 4]. Coulomb excitation was pre-

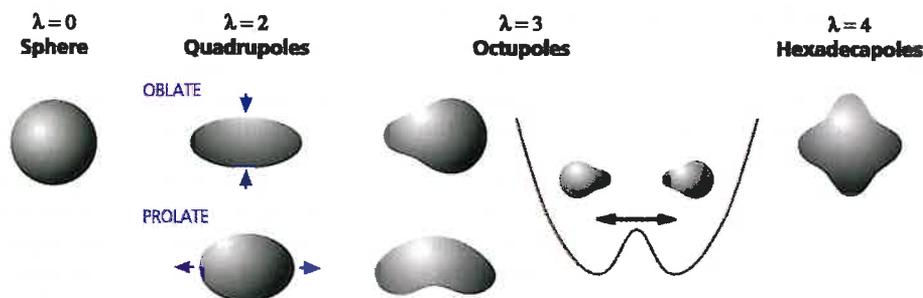


Fig. 1: Currently observed nuclear shapes. The different shapes can be parametrized by spherical harmonic functions, where λ characterises the different orders of the corresponding distributions.

ferred to a (heavy ion, xn) reaction, the former reaction being favoured by the large intrinsic quadrupole moment of $^{238}_{92}\text{U}$ and offering a good possibility to study high spin effects. The rotational band of $^{238}_{92}\text{U}$ was observed up to spin $32\hbar$ in accordance with a single particle picture and collective approach. The transition energies in the ground state band show a regular increase with increasing spin up to the higher spin. The measured transition probabilities correspond to an axially deformed nucleus rotating about an axis perpendicular to its symmetry axis and having a constant electric quadrupole moment.

Very heavy nuclei

The structure of the heaviest elements still remains a challenge to experimental and theoretical studies. The theoretical predictions of sizeable deformations can only be confronted in a few experiments. The formation mechanism and the shape of the fission barriers are not completely understood. It is important to study the underlying shell structure of nuclear shapes for the search of even heavier nuclei. Recently the coupling of recoil separators with efficient γ -arrays (FMA (Fragment Mass Analyser) + GAMMASPHERE at Argonne and RITU (Recoil Ion Transport Unit) + JUROSPHERE at Jyväskylä) has enabled the study of decay schemes with production cross sections below $1\mu\text{b}$ in the study of $^{254}_{102}\text{No}$ and $^{252}_{102}\text{No}$ [ref. 5]. The measured rotational bands extend up to spin 16^+ in $^{254}_{102}\text{No}$ and to 18^+ for $^{252}_{102}\text{No}$. The first sets of gamma spectroscopic data on transfermium nuclei have proven that, in accordance with theoretical predictions, $^{254}_{102}\text{No}$ and $^{252}_{102}\text{No}$ are deformed nuclei with an axis ratio of about 1:1.3. By comparing the population of the ground state bands in $^{254}_{102}\text{No}$ and $^{252}_{102}\text{No}$, the influence of the neutron shell closure can be studied. The study of nuclear structure of nuclei with $Z > 100$ is in full development.

Shape transitions and shape coexistence

In an isotopic chain, shape transitions of the ground states can occur with the variation of neutron numbers. They can be identified either from the large differences in the energies of the first excited states (for instance the energy of the 2^+ state suddenly drops from 1223 keV in $^{98}_{40}\text{Zr}$ to 270 keV in $^{100}_{40}\text{Zr}$), or from the variation of the measured mean square radii (such as in Hg, Au or Pt isotopes).

Ambiguous results can be clarified by observing the shape evolution as a function of the neutron number along a com-

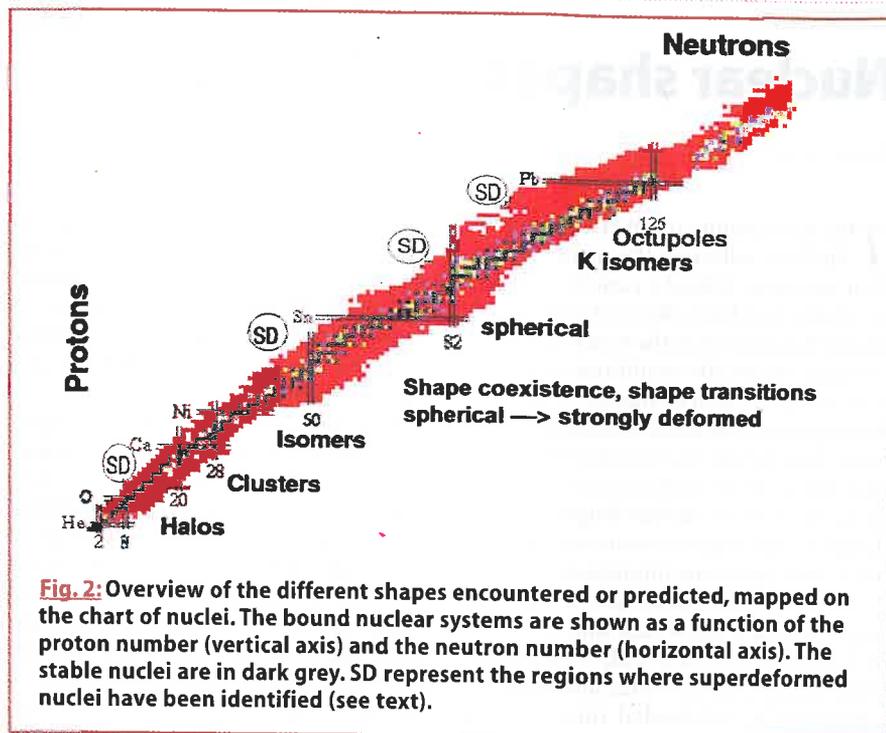


Fig. 2: Overview of the different shapes encountered or predicted, mapped on the chart of nuclei. The bound nuclear systems are shown as a function of the proton number (vertical axis) and the neutron number (horizontal axis). The stable nuclei are in dark grey. SD represent the regions where superdeformed nuclei have been identified (see text).

plete chain of isotopes. For example a fission-fission reaction has been used to study neutron-rich palladium nuclei (which cannot be reached in any other manner until the advent of new radioactive beams), thereby completing the systematics of nuclear structure studies from $^{106}_{46}\text{Pd}$ to $^{118}_{46}\text{Pd}$ [ref. 6].

Shape coexistence phenomenon (the existence of two stable shapes at the same excitation energy) can inform us upon the interplay between single particle and collective degrees of freedom. The nuclei in the mass region around $A \sim 70-80$, especially those close to the $N=Z$ line, are predicted to exhibit a wide variety of shapes including large prolate and oblate deformations, triaxial and spherical shapes. Several 0^+ states are expected at low excitation energy. They can be isomeric states (states with strongly inhibited electromagnetic decay modes) and decay to the ground state by means of electric monopole transitions. Evidence for such $E0$ transitions, which are directly linked to a change in the mean square radius of the nucleus, has been found in $^{74}_{34}\text{Se}$, $^{74}_{34}\text{Se}$, and recently in $^{76}_{36}\text{Kr}$. The shape of the yrast band¹ appears to change from prolate for $^{76,74}_{36}\text{Kr}$ to oblate for $^{80}_{36}\text{Kr}$. Coulomb excitation experiments might give a full characterisation of the low lying collective states in the intermediate nucleus $^{78}_{36}\text{Kr}$.

Another example is given by the neutron deficient lead isotopes just below the doubly-magic ^{208}Pb which reveal many different aspects of shape coexistence at

both low and high spins. Recent evidence for such a coexistence has come from the observation of excited 0^+ states and rotational bands in $^{184-190}_{82}\text{Pb}$. These experiments were made in Canberra [ref. 7] and in Finland [ref. 8]. The existence of two excited low-lying 0^+ states have been confirmed in $^{208}_{82}\text{Pb}$ that has been interpreted as evidence for a triple shape coexistence. The microscopic structure of the coexisting states in the lead isotopes and the development of shape coexistence have yet to be studied thoroughly by the complete repertoire of available spectroscopy.

K Isomers

The study of isomeric states provides direct information on microscopic nuclear structure effects. In deformed axially symmetric nuclei, isomers occur when there is a secondary minimum for a certain value of K , the projection of the total nuclear spin along the symmetry axis of the nucleus (fig 3). Trapped in this pocket, it is difficult for them to change their spin orientation relative to an axis of symmetry. These isomers are known as K traps. High K isomers are known in the $A \sim 180$ mass region for neutron deficient isotopes of W, Hf and Os which have a prolate shape. The occurrence of K isomers in neutron rich nuclei have been predicted and tested in many cases [ref. 9]. Recent experiments carried out at GSI (Darmstadt) [ref. 10] using projectile fragmentation of $^{208}_{82}\text{Pb}$ at relativistic energy (here $1\text{GeV}/A$) has led to the population of excited states in $^{190}_{76}\text{W}$.

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Box 1: Magic numbers

In atoms, the electrons fill quantum electron shells at atomic numbers of 2, 10, 18, 36, and 54. These elements are chemically inert as the energies of orbits are grouped in shells with large gaps between them. By analogy, in nuclei, the shell model was developed to explain the extra stability of some nuclei. According to quantum mechanics, the neutrons and protons fill their quantum states independently, so that both full neutron and full proton shells can occur as magic nuclei. The nuclei have then a spherical shape and this happens for the magic numbers 2, 8, 20, 28, 50, 82 and 126. Between the major shell gaps smaller subshell gaps cause some extra stabilisation and semi-magic behaviour is found.

the liquid drop energy leading to the stabilisation of a superdeformed (SD) shape (corresponding to an axis ratio of 2:1). While the liquid drop model leads to a minimum in the potential corresponding to a spherical shape, the addition of the quantal shell corrections change the fission barrier shape and give rise to a deformed ground state and a second minimum at a greater elongation. This was the first observation of a deformed nuclear shape beyond the oblate or relatively modest prolate deformations around the sphere. Afterwards more than 35 fission isomers have been identified in the actinide region, with $Z=90-97$, $N=141-151$. Due to competition with fission these superdeformed states are only populated at low angular momentum and their decay towards the normally deformed well are known in only two cases.

It was later predicted that superdeformed shapes can occur at high angular

The decay of an isomeric state populates the levels of the rotational band built on the ground state, which have been newly identified. This explains the low hindrance factor observed for the decay of this isomer as having a $K^\pi=10^-$ two quasi neutron configuration. This result helps to understand the structure of recently discovered superheavy elements with analogous proton numbers ($Z=114$ and 118).

Octupole deformations

Experimental evidences have also been shown for nuclei having an instability toward octupole deformations (pear-shaped nuclei). In this case, the nucleus has no longer the reflection symmetry, and one can observe rotational bands displaying a sequence of states with parities alternatively positive and negative linked by strong E1 transitions [ref. 11]. This phenomenon has been encountered in the Ra-Th region and also in lanthanide nuclei with $N\sim 88$. The borders of the octupole deformation region are however not well established. The behaviour as a function of spin of the positive and negative parity energy levels has to be studied. The theoretical treatment includes the axially symmetric deformation components as well as the non axial modes. These octupole correlations will play an important role for superdeformed and hyperdeformed structures (see next paragraph). Similarly, octupole-vibrational states are suggested to explain states of rather low excitation energies in the mass region around $A=190$. This remains to be verified.

Superdeformed nuclei

In 1962, the discovery of an actinide ($^{242}_{95}\text{Am}$) isomer with an abnormally short period (few ms) was explained by Strutinsky in terms of shell corrections added to

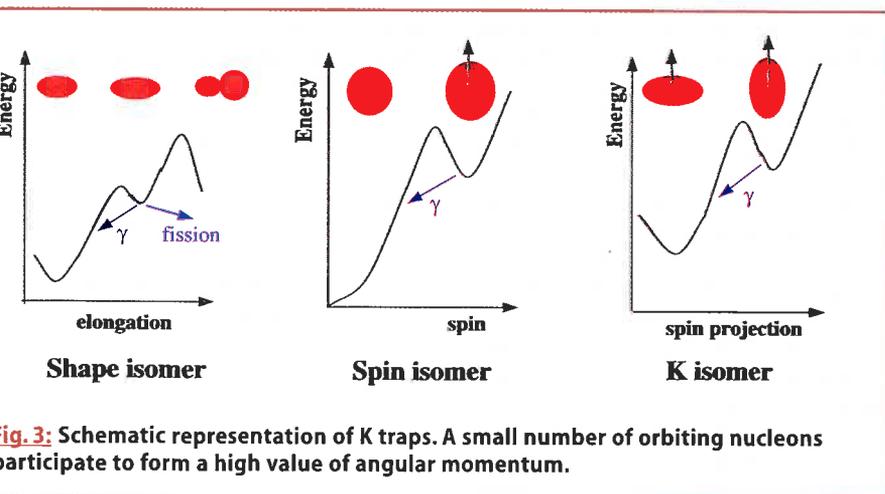


Fig. 3: Schematic representation of K traps. A small number of orbiting nucleons participate to form a high value of angular momentum.

momentum in lighter nuclei. The success of these models was illustrated by the discovery in 1986 of the first superdeformed band in ^{152}Dy . The characteristic picket fence gamma-ray pattern of a rotational band was observed for spins as high as $60\hbar$ and the measurement of the quadrupole moment indicates a deformation with an axis ratio of 2:1. Since then, using fusion evaporation reactions with stable beams, superdeformed nuclei have been discovered in distinct regions of the periodic table with masses around 60, 90, 130, 150, 190 and 240 and with axis ratios from 1.3 to 2.

Although strong progress has been made in research on superdeformation many questions remain open [ref. 12]. The major challenge is to determine the excitation energy and spins of superdeformed levels. In the different mass regions, the linking transitions between SD and normal deformed states have only been established for some nuclei such as, for example, ^{60}Zn , ^{149}Gd , ^{194}Hg and ^{194}Pb . Therefore, almost all superdeformed bands discovered so far are "floating bands" as the transitions connecting a SD band with low lying states are not known. This is probably due to the strong fragmentation of the decay into many paths, thus requiring high-fold coincidences for their observation. The new generation of γ -arrays associated with auxiliary detectors such as electron conversion spectrometers will help to find these links as E0 transitions may compete with γ -ray transitions. If the deformation of the states is known, the E0 decay strength may give information on the mixing of the wave functions.

The extreme regularity of SD bands has allowed the study of deviations from expected behaviour in a very accurate way. Hence, the phenomenon of "identical bands" (neighbouring nuclei rotating with exactly the same rotational frequency, within about two parts in a thousand) was first noted in SD bands, but has now been found to be a common feature of rotational bands in normally deformed nuclei. This phenomenon is not yet quantitatively understood and deserves other studies. Another surprising phenomenon is the observation of the oscillations of the moments of inertia, has been tentatively explained by the onset of new types of symmetry involving the C4 point group symmetry [ref. 13].

Perspectives

The borders of the SD regions have yet to be established. Since all identified superdeformed bands are populated via fu-

Box 2: Isomers

Isomeric states, states with strongly inhibited electromagnetic decay modes, occur when there is a secondary energy minimum for some values of shape elongation, spin or spin projection on the symmetry axis. This leads to the three main configurations schematically presented in fig 3. Shape isomers can decay by γ -ray emission or by fission if the fission barrier is low enough (fission isomers). The facility for spin isomers trapped in the energy pocket to decay by γ -ray towards lower energy states depends on the selection rules. For K isomers, the orientation of the nuclear spin vector has also to be taken into account.

sion-evaporation reactions, only neutron deficient nuclei are reached. Thus the discovery of superdeformed bands in neutron rich regions is still a challenge. It is also expected that octupole correlations will play an important role in the structure of superdeformed states. Moreover, actinide nuclei open a unique opportunity to investigate also the structure of SD nuclei at low angular momentum. Tentative experiments to populate these states by transfer reactions have as yet proved unfruitful. The continuous improvement of detector systems should, it is hoped, allow one to reach this objective.

A third well with hyperdeformed shape (axis ratio 3:1) has been identified in thorium isotopes from resonant states in the (d,p) reaction [ref. 14]. Nevertheless no hyperdeformed band has been measured yet in γ spectroscopy, although several theoretical calculations predict that states with very elongated shapes become yrast for spins $I \sim 70\hbar$ in some nuclei, such as ^{146}Gd or ^{168}Hf [ref. 15]. At this very high spin value the stabilisation of secondary minima in the potential well may compete with the vanishing of the fission barrier making observation of such a very deformed state very difficult. This will be one of the main challenges in the next coming years.

The various examples given show the variety of possibilities offered by the choice of beam (stable or radioactive) and the dependence of the outcome on the excitation energy attained, on channel-entrance effects (direct or inverse kinematics) and on the different types of reactions studied (fusion-evaporation, transfer, fission and coulomb excitation). More and more sophisticated gamma arrays and auxiliary instruments (neutron, charged

particle and fission fragment detectors) have to be used to observe and chart the many facets of nuclear shapes. The conjunction of all the usable means will allow the thorough study of this field of nuclear structure to be extended for nuclei further and further from stability.

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Extra-solar planets

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There are hundreds of billions of galaxies in the observable Universe, with each galaxy such as our own containing some 10^{11} stars. Surrounded by this seemingly limitless ocean of stars, mankind has long speculated about planetary systems other than our own, and the development of life elsewhere in the Universe. Only recently has evidence become available to begin to distinguish the extremes of thinking typified by opinions ranging from 'There are infinite worlds both like and unlike this world of ours' (Epicurus, 341–270 BC) to 'There cannot be more worlds than one' (Aristotle, 384–322 BC). Shining only by reflected starlight, extra-solar planets comparable to bodies in our own Solar System should be billions of times fainter than their host stars and, depending on their distances from us, separated from their accompanying star by, at most, a few seconds of arc. This combination makes direct detection extraordinarily demanding. Alternative high-precision detection methods, based on the dynamical perturbation of the star by the orbiting planet, on planetary transits, and on gravitational lensing, have therefore been developed.

Although planets around other 'normal' stars were expected to be common, the astronomical world was nevertheless taken by surprise when the first such discovery was announced by Mayor & Queloz in 1995. High-precision radial velocity (Doppler) measurements revealed a planet of about 0.5 Jupiter masses around a star similar to our own at a distance of about 15 pc. But, contrary to expectations, the planet was at a distance from its parent star of only about 0.05 AU, completing an orbit every 4 days. How such a 'giant' planet could have been formed in, or could have migrated to, such a location, sparked controversy,

intensified efforts to detect other systems, and is stimulating much new theoretical and modelling effort in explaining their formation and evolution. Today (December 2000), about 50 extra-solar planets are known, and their numbers are increasing steadily.

Stars, Brown Dwarfs and Planets

Stars form from gravitational instabilities in interstellar clouds of gas and dust grains, leading to collapse and fragmentation. In particular, a density perturbation (e.g. due to a shock wave) may cause the gravitational binding energy of a cloud to exceed its thermal energy. In that case it begins to contract, and a star is born. The resulting stars shine by thermonuclear fusion, with stable hydrogen burning occurring for masses above about $0.08 M_{\odot}$ (about $80 M_J$), when the central temperature triggers nucleosynthesis. Brown dwarfs are objects which occupy the mass range of about 12 – $80 M_J$. They have also formed 1 by gravitational instability in a gas, but are not massive enough to ignite stable hydrogen burning. Below about $12 M_J$, objects should derive no luminosity

from thermonuclear fusion at any stage in their life. Such objects are broadly classified as planets if they formed through the agglomeration of residual protoplanetary disk material, rather than direct gravitational collapse and fragmentation.

A number of theories of the origin of our own Solar System have been advanced, starting with the ideas of Laplace more than 200 years ago. In the most widely considered 'solar nebula theory' planet formation in our Solar System (and, by inference, planetary formation in general) follows on from the process of star formation. Basically, the dust grains first settle into a dense layer in the mid-plane of the disk. They then begin to stick together as they collide and form macroscopic objects with sizes of order 0.01 – 10 m. These all orbit the protostar in the same direction and in the same plane, analogous to the few hundred metre thick rings around Saturn. Over the next 10^4 – 10^5 years, further collisions lead to the formation of 'planetesimals', objects up to a km or so in size, driven by gravitational interactions. In the presence of an adequate mass of planetesimals, rapid runaway growth occurs as a result of dynamical friction and three-body effects. When the gravitational pull of the largest planetesimals is sufficient, they grow rapidly to the size of small planets by mutual collisions and mergers, with the terrestrial planets growing over time scales of 10^7 – 10^8 years. Mergers proceed by pairwise accretion until the spacing of planetary orbits becomes large enough that the configuration is stable for the lifetime of the system.

In our Solar System, formation theories can be confronted with numerous observational constraints: orbital motions, stability, and spacings of the nine planets; planetary masses, rotations,

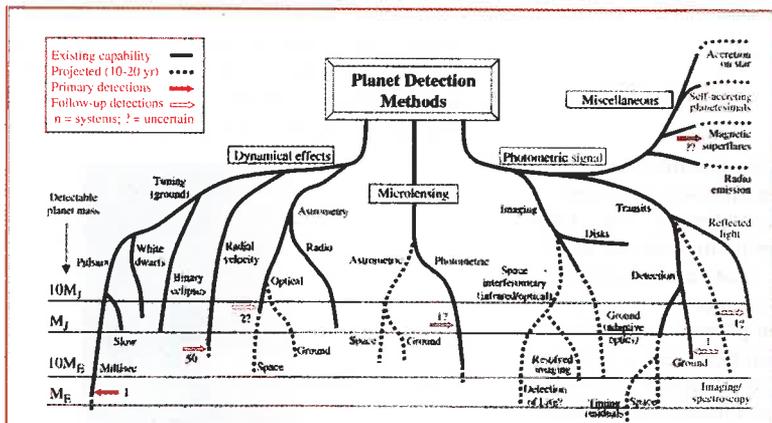


Fig. 1: Detection methods for extra-solar planets. The lower extent of the lines indicates, roughly, the detectable masses that are in principle within reach of present measurements (solid lines), and those that might be expected within the next 10–20 years (dashed). The (logarithmic) mass scale is shown at left. The miscellaneous signatures to the upper right are less well quantified in mass terms. Solid arrows indicate (original) detections according to approximate mass, while open arrows indicate further measurements of previously-detected systems. '?' indicates uncertain or unconfirmed detections. The figure takes no account of the numbers of planets that may be detectable by each method.

features

and the existence of planetary satellites and rings; angular momentum distribution; bulk and isotopic composition; radio-isotope ages; cratering records; and the occurrence of comets, asteroids and meteorites including the presence of the Oort Cloud and the Edgeworth-Kuiper Belt. The present paradigm of planet formation offers many attractive features, but various problems remain, and it seems wisest to view it as a plausible framework with which future observations are to be confronted.

Detection Methods

Figure 1 summarises the detection possibilities referred to in this section, and Figure 2 illustrates the respective parameter regions probed by some of these methods.

Imaging

Imaging of an extra-solar planet general-

ly refers to the detection of an unresolved point source image of the object seen by the reflected light from the parent star (resolved imaging of an extra-solar planetary surface will require ground- or space-based interferometric arrays of 10–100 km baseline). The ratio of the planet to stellar brightness is given by:

$$\frac{L_p}{L_*} = p(\lambda, \alpha) \left(\frac{R_p}{a} \right)^2$$

where $p(\lambda, \alpha)$ is a wavelength and phase-dependent ‘albedo’, and α is the angle between the star and observer as seen from the planet. L_p/L_* is very small, of order 10^{-9} for a Jupiter-type object. Viewed with a ground-based telescope, with a star-planet separation of 1 arcsec (Jupiter viewed from 5 pc) the planet signal is immersed in the photon noise of the telescope’s diffraction profile ($\lambda/D \approx 0.02$ arcsec at 500 nm for a 5-m telescope) and more problematically within the ‘seeing’ profile (of order 1 arcsec) arising from turbulent atmospheric refraction. Under these conditions elementary signal-to-noise calculations imply that obtaining a direct image of the planet is not feasible.

Imaging efforts are directed at ways of reducing the angular size of the stellar image, suppressing scattered light, minimising the effects of atmospheric turbulence, and enhancing the contrast

between the planet and the star by observing at longer wavelengths. Many ambitious ground- and space-based efforts related to extra-solar planetary imaging are on-going, but none of these imaging techniques has been successfully applied to extra-solar planetary detection so far. But they represent important long-term efforts since they provide the basis for attempts to measure the spectral features of planets, and therefore the possibility of detecting signatures of life in their atmospheres.

Dynamical Perturbation of the Star

The circular motion of a planet and star around their common barycentre causes the star to undergo a reflex motion, with orbital radius $a_* = a \cdot (M_p/M_*)$ and period P . This results in the periodic perturbation of three observables, all of which have been detected (albeit in different systems): in radial velocity, in angular (or astrometric) position, and in time of arrival of some periodic reference signal.

Radial velocity

The velocity amplitude K of a star of mass M_* due to a companion with mass $M_p \sin i$ with orbital period P and eccentricity e is:

$$K = \left(\frac{2\pi G}{P} \right)^{1/3} \frac{M_p \sin i}{(M_p + M_*)^{2/3}} \frac{1}{(1 - e^2)^{1/2}}$$

The effect is about $K = 12.5 \text{ m s}^{-1}$ with a period of 11.9 yr in the case of Jupiter orbiting the Sun, and about 0.1 m s^{-1} for the Earth. The $\sin i$ dependence means that the radial velocity measurements can de-

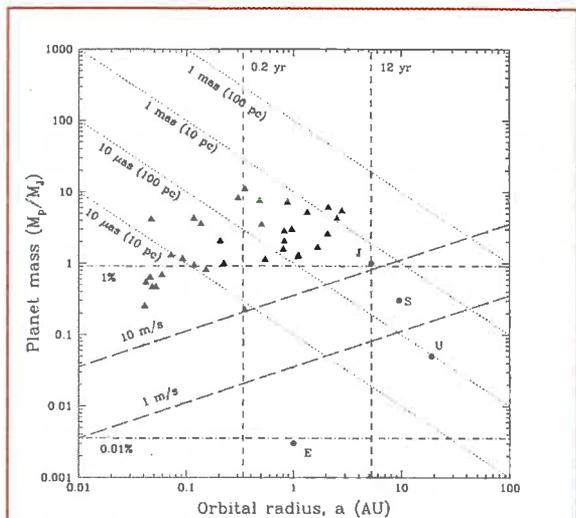


Fig. 2: Detection domains for methods exploiting planet orbital motion, as a function of planet mass and orbital radius, assuming $M_* = M_\odot$. Lines from top left to bottom right show the locus of astrometric signatures of 1 mas and 10 μarcsec at distances of 10 and 100 pc (equation 3). Very short and very long period planets cannot be detected by planned astrometric space missions: vertical lines show limits corresponding to orbital periods of 0.2 and 12 years. Lines from top right to bottom left show radial velocities corresponding to $K = 10$ and $K = 1 \text{ m s}^{-1}$ (equation 2). Horizontal lines indicate photometric detection thresholds for planetary transits, of 1% and 0.01%, corresponding roughly to Jupiter and Earth radius planets respectively (neglecting the effects of orbital inclination, which will diminish the probability of observing a transit as a increases). The positions of Earth (E), Jupiter (J), Saturn (S) and Uranus (U) are shown, as are the lower limits on the masses of first 34 known planetary systems (triangles).

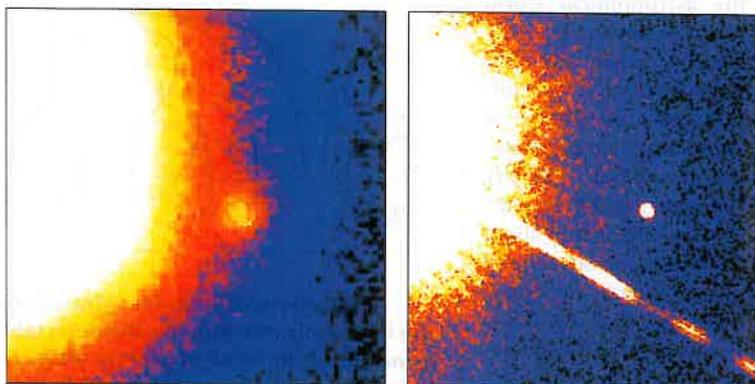


Fig. 3: Image of the brown dwarf Gliese 229 b, obtained with an adaptive optics system at the Palomar Observatory 60-inch telescope (left) and with the Hubble Space Telescope (right). The brown dwarf is 7 arcsec to the lower right of the companion star, Gliese 229. The star/brown dwarf brightness ratio is ~ 5000 , and the distance between the two objects corresponds roughly to the Sun-Pluto separation. A Jupiter mass planet at a distance of 10 pc would be 14 times closer to its parent star, and roughly 200 000 times dimmer than Gliese 229 b (courtesy of Tadashi Nakajima).

termine only $M_p \sin i$ rather than M_p , and hence provide only a lower limit to the mass of a specific planet.

All of the known extra-solar planets around ordinary stars have been discovered, starting with the first in 1995, using radial velocity techniques. A very significant effort is now directed at radial velocity detection by many groups and at many telescopes around the world, and some 50 extra-solar planets are presently known. Current measurements reach accuracies of around 3 m s^{-1} . Because the stars are only faint sources of light, large telescopes, long integration times, and very precise instrumental calibrations are required.

Astrometric position

The path of a star orbiting the star-planet barycentre appears projected on the plane of the sky as an ellipse with angular semi-major axis α given by:

$$\alpha = \frac{M_p}{M_*} \cdot \frac{a}{d}$$

where α is in arcsec when a is in AU and d is in pc. Astrometric techniques aim to measure this transverse component of the photocentric displacement. Jupiter orbiting the Sun viewed from a distance of 5 pc would result in an amplitude of 1 milliarcsec, while the effect of the Earth at 5 pc is a one-year period with $0.6 \mu\text{arcsec}$ amplitude.

Measurement of sub-milliarcsec displacements in the optical is impossible so far because of atmospheric effects, although measurements at the tens of microarcsec or better are projected using interferometric techniques planned for the world's largest ground-based telescopes, such as the Keck Interferometer, and from the European Southern Observatory's VLTI.

Astrometric measurements can be made more accurately from above the Earth's atmosphere, from where ESA's Hipparcos satellite provided ~ 1 milliarcsec accuracy for about $\sim 120\,000$ stars. Future ambitious space experiments at the microarcsec-arcsec level include NASA's SIM space interferometer mission (launch 2009), and GAIA, ESA's stereoscopic mission to map the 3-d positions and space motions of more than a billion stars in our Galaxy, to be launched around 2010. In the process, GAIA should detect many thousands of extra-solar planets out to 100--200 pc, due to the wobble of their photo-

centre caused by orbiting planets.

Timing and the pulsar planets

Although all orbital systems are affected by changes in light travel time across the orbit, in general there is no timing reference on which to base such measurements. A notable exception are radio pulsars, rapidly spinning highly-magnetised neutron stars. Accurate timing of the pulse arrival can in principle reveal objects as small as an Earth mass in orbit around them. This technique led to the first planetary system detected around the 6.2-ms pulsar PSR 1257+12, with at least two plausible companions having masses of 2.8 and 3.4 Earth masses, and almost circular orbits with $P = 98.22$ and 66.54 days respectively. A couple of other much higher mass companions around other pulsars have been discovered in the last few years, but planetary systems around these old neutron stars seem to rare.

Periodic Photometry:

Transits and Reflections

Detection of extra-solar planets, by observing their eclipse of the host star, was first considered almost 50 years ago. The method is conceptually simple: star light is attenuated by the transit of the orbiting planet across its disk, with the effect repeating at the orbital period of the planet. The method is presently considered as one of the most promising means of detecting planets with mass-

es significantly below that of Jupiter, with the detection of Earth-class (and hence habitable) planets within its capabilities. Extrapolation of the method down to masses of planetary satellite may even be feasible.

Detection probabilities depend on the transit geometry and on the luminosity drop produced by an object on the line of sight to the star, which approximates to:

$$\frac{\Delta L}{L_*} \approx \left(\frac{R_p}{R_*}\right)^2$$

under the assumption of a uniform surface brightness of the star. Values of $\Delta L/L_*$ for the Earth and Jupiter transiting the Sun are 8.4×10^{-5} and 1.1×10^{-2} respectively. The duration of the transit is about 25 hr for a Jupiter-type planet and 13 hr for an

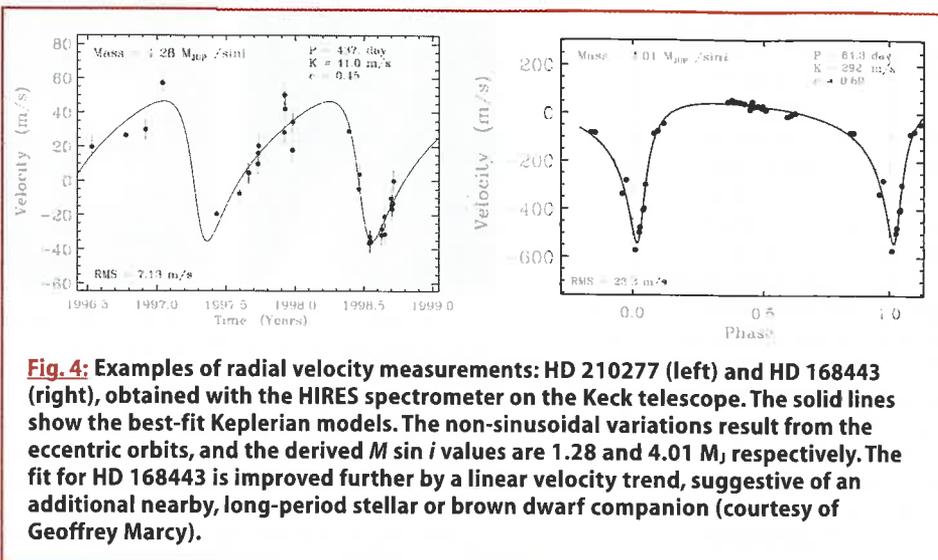


Fig. 4: Examples of radial velocity measurements: HD 210277 (left) and HD 168443 (right), obtained with the HIRES spectrometer on the Keck telescope. The solid lines show the best-fit Keplerian models. The non-sinusoidal variations result from the eccentric orbits, and the derived $M \sin i$ values are 1.28 and 4.01 M_J , respectively. The fit for HD 168443 is improved further by a linear velocity trend, suggestive of an additional nearby, long-period stellar or brown dwarf companion (courtesy of Geoffrey Marcy).

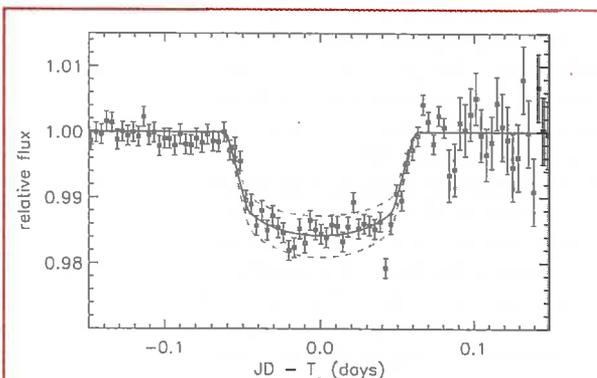


Fig. 5: The first detected transit of an extra-solar planet, HD 209458. The figure shows the measured relative intensity versus time. Measurement noise increases to the right due to increasing atmospheric air mass. From the detailed shape of the transit, some of the physical characteristics of the planet can be inferred (courtesy of David Charbonneau).

features

Earth-type system. If the radius of the star is known, then R_p is also determined. The greatest disadvantage of the method is that it requires configurations in which the viewing direction (to the Earth) happens to lie in the orbital plane of the planet.

Ground-based photometry beyond 0.1% accuracy is complicated by variable atmospheric extinction and scintillation, and extension of the transit method to space experiments, where very long uninterrupted observations can be made above the Earth's atmosphere, therefore holds particular promise. Small 'precursor' space experiments are underway, while an ESA mission, Eddington, devoted to both planetary detection and asteroseismology studies, has recently been approved.

An important result in extra-solar planetary studies has been the detection of the first transit event, for the system HD 209458 (Figure 5). The precise shape of the light curve yields estimates of the mass and radius of the orbiting planet. The estimated density of $\rho \sim 380 \text{ kg m}^{-3}$ is consistent with a hydrogen gas giant, and yields a surface gravity of $g \sim 9.7 \text{ m s}^{-2}$. Other experiments to survey large numbers of stars from ground, from the Hubble Space Telescope, and to detect reflected light from orbiting planets, are also in progress.

Gravitational Microlensing

Gravitational lensing is the focusing and amplification of light rays from a distant source by an intervening object, first considered by Einstein in 1936. Precise alignment between the observer, some intervening object, and the more distant planetary system, can lead to significant brightening of the background object due to this lensing effect, with a duration depending on the relative velocity of the lens and source. The phenomenon offers a powerful but experimentally challenging route to the detection and characterisation of planetary systems. However, the chance of substantial microlensing magnification is extremely small, being $\sim 10^{-6}$ for background stars in the Galactic bulge. Since 1993 several hundred photometric microlensing events have now been observed. Events with durations ranging from hours to months are detected and reported while still in progress, allowing concerted follow-up observations. Detailed light-curve structure probes the lens kinematics, the frequency and nature of binary systems, stellar atmospheres, and the presence of planetary systems. Unconfirmed planetary candidates have been identified in these data.

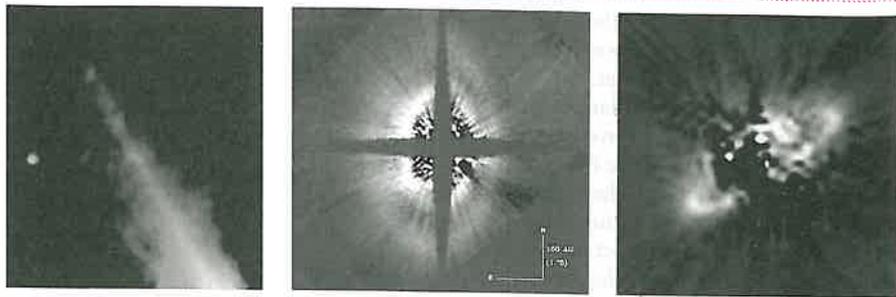


Fig. 6: Images of disks from the NASA/ESA Hubble Space Telescope. Left: part of the β Pic disk imaged by the WFC2 instrument. Clumps of dust might represent elliptical rings viewed edge-on, possibly created by the gravitational force of a stellar encounter $\sim 10^5$ years ago (courtesy of Paul Kalas). Centre: the circumstellar disk of HD 141569 imaged in reflected light at $1.1 \mu\text{m}$ with the NICMOS instrument. The central star and the dark vertical and horizontal bands are regions obscured by a coronagraphic mask (courtesy of Alycia Weinberger). Outwards from the centre, a bright inner region is separated from a fainter outer region by a dark band, superficially resembling the Cassini division (the largest gap) in Saturn's rings. The disk extends to about 400 AU, about 13 times the diameter of Neptune's orbit, with the gap at 250 AU. An unseen planet may have carved out the gap, in which case its mass can be estimated at $\sim 1.3 M_J$, and its orbital period as 2600 years. If it takes ~ 300 orbital periods to clear such material then the gap could be opened in $\sim 8 \times 10^5$ years, consistent with the age of the star. Right: the circumstellar disk around HR 4796A, also observed by coronagraphic imaging by NICMOS. The ring is almost completely visible, although the clumpy structure arises from the coronagraphic system and is not real (courtesy of Glenn Schneider, Brad Smith, and the NICMOS IDT/EONS team). The colour of the material (from infrared measurements at 1.1 and $1.6 \mu\text{m}$) implies particles with a size of a few μm , larger than typical interstellar grains. The implied confinement of material also argues for dynamical constraints on the particles by one or more as yet unseen bodies.

Miscellaneous Signatures and Planetary Disks

Other possible signatures of planetary presence include searching for evidence of giant impacts during the late stages of planetary formation, 'super-flares' caused by magnetic reconnection between fields of the primary star and a close-in Jovian planet, coherent cyclotron radio emission driven by the stellar wind/magnetospheric interaction, or signatures of a planet's final accretion onto the central star.

It is now relatively easy to observe the precursors of planetary systems, protoplanetary disks. Not only are they extremely large – a typical disk extends to of order 1000 AU from the star – but the surface area of the small particles which make up the disk is many orders of magnitude larger than that of a planet. Disks appear to be long-lived, $\sim 10^6 - 3 \times 10^7$ years, are common throughout our Galaxy, and appear quite similar to the picture of our primitive solar nebula. A number of disk systems have been imaged using the Hubble Space Telescope (Figure 6).

Properties and Formation Theories

The extra-solar planets discovered so far are all more massive than Saturn, and most either orbit very close to their stars

or travel on much more eccentric paths than any of the major planets in our Solar System. While Doppler surveys are most sensitive to small orbits, what had not been generally anticipated was the small orbital radii and large eccentricities of many of the first systems discovered. This trend has continued: 14 of the 50 known planets reside in orbits with $a < 0.1$ AU, and 24 have $a < 0.3$ AU. Close-in planets are generally in rather circular orbits, while the 26 planets beyond 0.3 AU are all in non-circular orbits with $e \geq 0.1$, with 22 having $e \geq 0.2$.

A robust formation mechanism must explain the mass distribution, the large eccentricities, and the large number of orbits with $a < 0.2$ AU, where both high temperature and relatively small amount of protostellar matter available for their agglomeration would inhibit formation *in situ*. The existence of the close-in planets has focussed attention on some earlier predictions that Jupiter-mass gas giants could be formed further from the star, followed by non-destructive migration inwards, driven by tidal interactions with the protoplanetary disk. Increasingly realistic simulations of evolving planetary systems have been made possible through improved physical models and developments

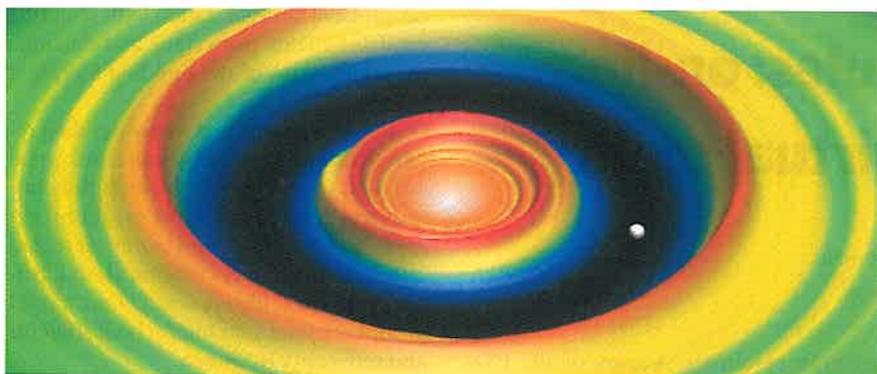


Fig. 7: Simulation of the formation of a planetary system. The surface density of disk material has been reduced by four orders of magnitude near the planet of mass $M_p/M_* = 10^{-3}$, and waves are clearly seen propagating both inward and outward away from it (courtesy of Douglas Lin).

in computer speed and computational algorithms. Figure 7 shows results of simulations of disk-planet interactions and tidal interactions with the central star.

Apart from the pulsar example, only two multiple extra-solar planetary systems are presently known. Their relative orbital inclinations are still unknown. This information is required for stability analyses, and for further investigation of the formation theories. As the temporal baseline of the radial velocity measurements increases, it is likely that many other multiple systems will be discovered, and it is not yet known what fraction of planetary systems will turn out to be multiple.

Predicted spectral properties of extra-

solar planets were made in advance of their discovery, giving brightness versus mass and age, and including sensitivity to parameters such as deuterium and helium abundance, rotation rate, and presence of a rock-ice core. Models have been updated subsequently, including effects of the outer radiative zones caused by the strong external heating which inhibits atmospheric convection. Hydrostatic evolution calculations and atmospheric models, including radiative effects, are being used to determine structures, radii, equilibrium temperatures, luminosities, colours, and spectra of objects with temperatures from 1300 K down to 100 K. These will help to classify and characterise the planets as more information about them becomes available.

The Future

The search for other planets is motivated by efforts to understand their formation mechanism, and to gain an improved understanding of the origins of our own Solar System. Search accuracies will progressively improve to the point that the detection of telluric planets in the 'habitable zone' will become feasible. Improvements in spectroscopic measurements, whether from Earth or space, and in atmospheric modelling, will lead to searches for planets which are progressively habitable, inhabited by micro-organisms, and ultimately by intelligent life. Search strategies will be assisted by improved understanding of the conditions required for development of life on Earth. This will be a cross-disciplinary effort, with the participation of astronomers, chemists and biologists. The last few years has seen a number of exo-biology initiatives, and numerous conferences on the search for life, beginning finally to quantify a philosophical

debate that has been ongoing for centuries.

Based on present knowledge, about 5% of solar-type stars may harbour massive planets, and an even higher percentage may have planets of lower mass or with larger orbital radii. If these numbers can be extrapolated, the number of planets in our Galaxy alone would be of order 1 billion. Global astrometric and photometric measurements from space should lead to the detection and characterisation of many thousands of significantly lower mass planets by the year 2020. Together, such data sets will provide a vast statistical description of planetary masses, orbits, and eccentricities, allowing important constraints to be placed on the complex processes believed to be involved in planetary formation. Improved knowledge of individual systems, in particular from transit measurements, combined with improved atmospheric modelling and theories of habitability, will narrow down the range of identified planets on which life may have developed. Nearby, Earth-mass planets should exist, and would be the natural targets for infrared space interferometers which, by 2020, may succeed in imaging and providing evidence for life on them.

We now know that other worlds – large ones at least – are common. Developments have been so rapid over the last few years that many significant developments, and many new surprises, can be predicted with confidence.

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Bibliographical Details

Michael Perryman holds a degree in theoretical physics and a PhD in radio astronomy from Cambridge University. He has been employed in the Space Science Department of the European Space Agency since 1980, and is professor of astrophysics at Leiden University. For his involvement in the Hipparcos space astrometry mission, he was awarded the Prix Janssen of the Société Astronomique de France in 1996, and the Academic Medal of the Royal Netherlands Academy of Arts and Sciences in 1999.

1 AU = 1 astronomical unit (mean Sun-Earth distance) $\approx 1.5 \times 10^{11}$ m. Solar mass = 1.99×10^{30} kg. Jupiter mass = 1.90×10^{27} kg. Earth mass = 5.98×10^{24} kg. For Jupiter, $a = 5.2$ AU and $P = 11.9$ yr. Stellar distances are conveniently given in parsec (pc), defined as the distance at which 1 AU subtends an angle of 1 second of arc (or arcsec); 1 pc $\approx 3.1 \times 10^{16}$ m ≈ 3.26 light-years. For reference, distances to the nearest stars are of order 1 pc; there are about 2000 known stars within a radius of 25 pc of our Sun, and the distance to the Galactic centre is about 8.5 kpc. Parameters used are mass M , radius R , and luminosity L , with subscripts $*$ and p referring to star and planet respectively. Systems are characterised by their orbital period P , semi-major axis a , eccentricity e , orbital inclination with respect to the plane of the sky i ($i = 0^\circ$ face-on, $i = 90^\circ$ edge-on), and distance from the Solar System d .

Visualising molecules: on-line simulations and virtual reality

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Science education, in particular physics education, is being changed by the use of new technology. One of the most promising means of teaching and learning science is the Internet. A lot of material has appeared on the Web. Its impact in education has in most cases still to be evaluated.

Relatively small and less developed countries like Portugal offer interesting ground for observing the dissemination of computers in science education. The Portuguese Physical, Chemical and Mathematical Societies set up, in 1991, a common action – “Softsciences - for creating, producing and distributing software for learning Science and Mathematics, especially at the middle and high schools levels. “Softsciences” had the intention of making somewhat “softer” the learning of the so-called “hard” sciences, but without compromising rigour. The Ministry for Education and the Ministry for Science and Technology have supported this project.

In 1997 all software programs were brought together in a CD-ROM, under the suggestive title “Omniscience”. A multimedia program was included (“Multimedia Periodic Table”) as well as copies of Web pages with abundant teaching and

learning resources. A copy of the CD-ROM was given to all (around 1500) Portuguese middle and high schools. “Omniscience” has a home page with the address: <http://nautilus.fis.uc.pt/~softc/omni98>, through which new materials have been offered (in Portuguese).

Our work in the group “Computers in Science Education” at the Centre for Computational Physics of the University of Coimbra, which gained experience with “Omniscience”, is now centred on on-line materials. The Web gives much more accessibility and universality compared with off-line programs (see, for example, Web Multimedia Periodic Table in <http://nautilus.fis.uc.pt/st2.5/>). On-line simulations in “Java” are a convenient format for representing many physical phenomena in a pedagogic way. They may be used interactively, without the need for downloading and installing.

Another method for visualizing and manipulating scientific concepts goes under the name of virtual reality, a technique where virtual scenarios are felt as real by users. This novel technique, which is becoming cheaper, needs further testing and evaluation.

We describe here two recent experiments which are being carried out by us and which use on-line simulations and virtual reality in the teaching and learning of the structure of matter.

“Molecularium”: On-line simulations in Physics and Chemistry

In the project “Molecularium” we aim to produce a set of computational simulations for the Internet dealing with various physical-chemical processes (<http://nautilus.fis.uc.pt/molecularium>). Based on recent Internet technologies, our aim is the teaching and the learning about the microscopic world. One of the main problems in science education is experienced by students when faced with abstractions. Computer visualization tools are particularly effective to overcome this problem. For example, when learning the atomic and molecular structure of matter, the

progressive familiarization with scientific models benefits from static and dynamic representations of the building blocks of matter.

The simulations that we are building relate to thermodynamical concepts (pressure and temperature), phases (solids, liquids and gases) and phase transitions, energy and entropy, and some assorted chemical phenomena (chemical equilibrium, salt dissolution, etc.). Our target groups are final year high school students and university freshmen.

One simple example of the “Molecularium” aims to help students to understand how food (containing water) is heated in a microwave oven (<http://nautilus.fis.uc.pt/molecularium/mw>). Rotating a button, radiation is transferred to the molecules (Fig. 1) which start to undergo faster rotation. Their vibrational and translational motion is also increased and the thermometer rises, indicating an increase in temperature. Of course, one of the drawbacks of this simulation is the lack of quantal features, such as the quantum nature of molecular rotation.

Another example is the solid-vapor transition in iodine (<http://nautilus.fis.uc.pt/molecularium/sv>). It helps students to understand the influence of the division of the solid phase in the microscopic rate of the transition (Fig. 2). They could graph why iodine sublimation gets faster when the substance is pulverized.

“Virtual Water”: Virtual reality for understanding of water

Some of the animations in the “Molecularium” are in 3D (Fig 1). Virtual reality (KALAWSAKY, 1993) extends the traditional 3D graphics world to include stereoscopic, acoustic, haptic (i.e., related to touch) and other feedbacks to create an al-

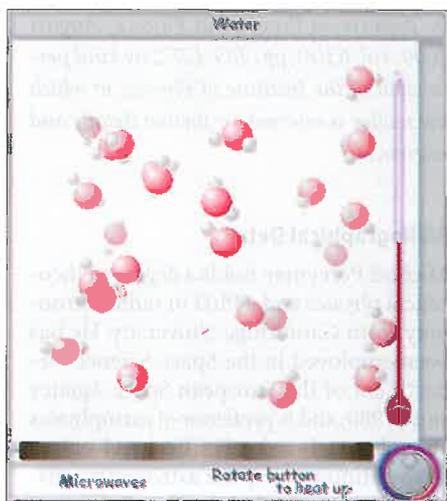


Fig. 1: Water molecules inside a microwave oven. This picture was created in “Java”. Translations, rotations and vibrations take place at the same time.

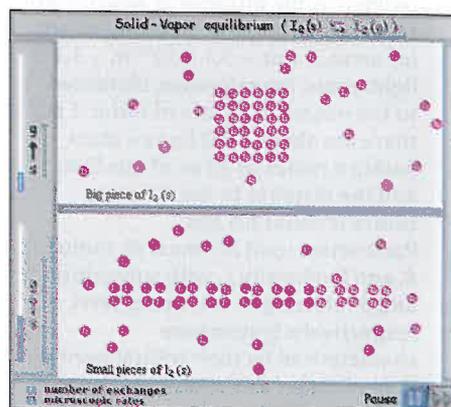


Fig. 2: Solid-vapor equilibrium for different divisions of the solid. For simplicity, the iodine molecules are represented as single spheres which are vibrating in the solid phase.

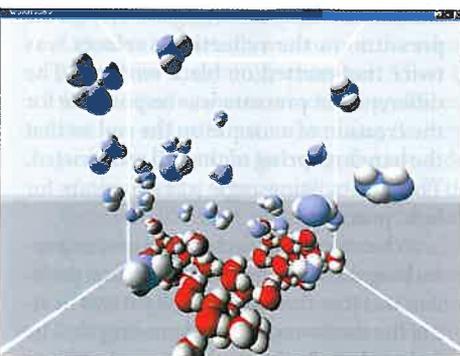


Fig. 3: Snapshot of a virtual reality simulation of water showing the vapour - ice transition. The blue objects make up the gas phase while the red ones are the solid phase (the color is for pedagogical convenience and may be switched off). These pictures were created with "Visual C++" on "WorldToolkit".

most complete sense of immersion. A stereo image gives a stronger sense of depth. The hardware for virtual reality consists of real-time graphics generators, stereo displays or views, tracking sensors, sound machines, and haptic devices. Tracking sensors – which determine the position and orientation of the viewer's head, hands, body parts or other inputs – allow the calculation of stereo images, the manipulation of models and the navigation in virtual environments. Sound "machines" provide a sense of location and orientation of certain objects and activities in the environment. Haptic devices vibrate and touch the user's body enhancing the interaction.

Water is an abundant substance but also one with unusual properties. For example, it has a maximum density at 4°C in the liquid state and, below 50°C, the isothermal compressibility grows with cooling (cold water is more "squeezeable" than warm water). Moreover, the solid floats on the liquid unlike in other substances.

We are using virtual reality as a tool to introduce students to the molecular bonding and structure of water. Using head-mounted colour displays and haptic interfaces, students navigate through an environment created with specialized software ("World Tool Kit"). The environment, under the title "Virtual Water" (<http://nautilus.fis.uc.pt/rv>), is designed to illustrate scientific concepts such as molecular orbitals and densities, molecular geometry, and the phases and phase transitions of water itself (Fig. 3).

Our molecular dynamics simulations use the equations of Newtonian Mechanics integrated with Verlet's algorithm. We

assume classical dynamics because more realistic simulations (incorporating quantum effects) are also much more computationally demanding (SPRIK and PARRINELLO, 2000). We also assume that the force between any pair of molecules depends only on the distance between them, using the Lennard-Jones potential. Some programming tricks were used to obtain a compromise between realistic behaviour and pedagogical utility.

Water molecules in the liquid phase tend to cluster. Computational and laboratory work has focused on the detailed characterization of the water dimer, trimer, tetramer and large clusters. Some of these isomers are transient structures. The cyclic hexamer (Fig. 4), one of the newest morphologies found in simulations of liquid water, is shown in our virtual environment.

Students exposed to our computer environment were very enthusiastic. One of them wearing a glove said: "I never thought of touching molecules!". Although a quantitative evaluation of the educational impact of our materials is still under way, the virtual environment seems to be a valuable tool. All textbooks and almost all available computer simulations that discuss these concepts stick to 2D representations, so that the change to a 3D world is quite a dramatic step. The "touch and feel" dimension is an additional stimulating feature.

Problems we faced in implementing our system were the price of hardware / software and the implementation of good graphics and haptics interfaces. A problem in generalizing the use of programs like ours is the "technophobia" of some teachers, which contrasts to the extraordinary computer abilities of some of their students.

Enter the Internet

Internet is a road to the future. Though the bandwidth in communication channels is not yet satisfactory, the Internet is becoming gradually the preferred vehicle for all those materials. Teaching and learning processes in multimedia formats on the Web have the obvious advantage of making educational content freely available. Molecular simulations in the Web, in a simple and modular format ("Java"), such as those we have described, seem particularly well suited to this new pedagogical genre.

On the other hand, virtual reality offers additional features such as stereo viewing and haptic interaction. The very idea of navigation inside the microscopic world preceded modern computers (see "Mr. Tompkins" book by George Gamow, from

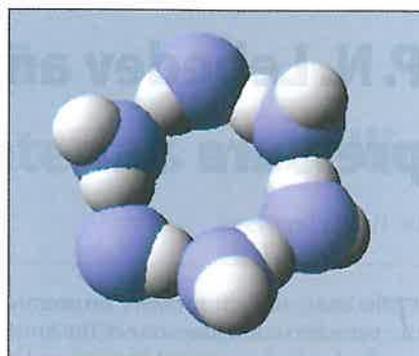


Fig. 4: The cyclic water hexamer, which may be regarded as the smallest piece of ice.

which a new edition has appeared (GAMOW and STANNARD, 1999). Our "Virtual Water" project turns this idea "real". We are thinking about a Web version, running either Java or VRML (the Internet 3D language).

Both projects point ways to the future of technology in science education. Computational tools may indeed facilitate the understanding of some scientific concepts. But the complexity of the challenges faced by scientific education does not find a panacea in the new technologies. Many changes are needed, computer technologies being only one of the ways to achieve an improvement.

Acknowledgments

We are grateful to Dr. Victor Gil and Dr. José Carlos Teixeira for their precious help in these projects.

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gered the modelling of systems in which there are large concentration gradients and where there may be electronic excitation.

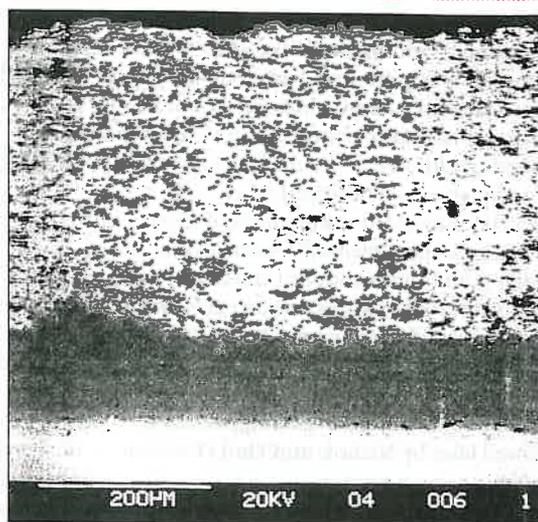
If large national laboratories were crucial to the early stages of materials modelling, the field has developed into an international activity, with a major academic component and a new software industry. There are enormous changes happening in the science, in the computer hardware and software, and in the industries which it might serve. Information technology is changing, and its impact on the ways people work is dramatic. Such changes, coupled with the restructuring of many familiar industries, often at the expense of their R&D functions, raise questions about the future. We have all seen many changes in the last two decades: changes in computing, notably the rise of the PC; the evolution of software industries; the loss of research from large national laboratories, government or industrial; the reorganisation of industry and the growing international components both in modelling and in the industries to which it relates. It seemed time to assess ways forward. These developments and questions prompted the UK Materials Foresight Panel to seek a review of the issues and the state of UK predictive materials modelling. What did UK scientists think of their roles, their international standing, and of their futures? What should be done? More specifically, to introduce reality into the picture, what might be done without spending any significant money?

There is more to materials modelling than condensed matter physics. There is a drive from technology, which emphasises materials performance and fitness for purpose: photographic materials must function; adhesive joints must adhere. Whole life behaviour is a concern, whether the life of a silicon oxide film under electrical stress or a turbine blade at high temperatures. Customers must accept cost and appearance. There are economic, safety and environmental constraints: polythene bags and aluminium beverage cans may be among the most successful innovations of the twentieth century, but they can create perverse disposal problems. Conventional solid state physicists can concentrate on a far narrower range of systems and situations than those for materials modelling. Baked beans, foam rubber, nuclear fuels and weld materials are all legitimate areas for the materials modeller. The properties can be thermal, mechanical, electrical, magnetic, active optical (like photochromics), catalysts or gas sensors.

The length scales range from the atomic to the macroscopic (engineering) dimensions, with a key mesoscopic regime for which microstructure matters. Timescales can range from femtoseconds to the geological.

It is only natural that the aims of materials modelling differ from those of condensed matter physics. The general thrust is clearly somehow to aid the improvement of materials for identifiable needs. Whether this means new materials, new processes, new inspection methods, or some other development, depends on the context, the constraints and the drivers. The style and level of modelling depends strongly on the problem. The science varies from simple scoping calculations, through systematic use of interatomic potentials and thermodynamic databases to the state-of-the-art electronic structure calculations (often, usually wrongly, called "a priori" or "first principles"). But modelling doesn't depend only on the science: there are constraints from the time and funds available, and from the view as to what is a solution. This is an important difference. Looking at previous reviews of materials modelling, there is an implicit assumption that computer hardware or software is the most serious limitation. This view is changing. The hardest parts now seem to concern brainware and experience. Can you frame the problem in a way which can be modelled at an *appropriate* level of detail? Can you understand the modelling output well enough to give adequate answers? Have you enough *confidence* in those answers to take an unpopular decision: could you tell an enthusiastic senior manager "You can't do things this way," for example? Robust reliability is the key to acceptance of modelling.

The response to the UK review carried some surprises. The first surprise was the level of interest. More than half of those sent email questionnaires actually replied. Another substantial group, largely different, came to a meeting in London - it was actually overbooked. One very good feature of Foresight studies is that you meet new, even when you think you know most of the community. The second surprise was the range of subject. We tend to think that our own personal part of the modelling scene is its core, and there isn't much



Microstructures of ceramic thermal barrier layers formed by plasma spray deposition, in which small ceramic particles pass through a plasma, where they melt, and then "splat" onto a surface. The model (by I S Doltsinis, J H Harding, M Marchese 1998 Arch Comp Meth in Eng 5 59) modelled all the stages of these processes, including the thermal and mechanical properties of the product film; they also developed genetic algorithm tools to optimise operating conditions for chosen properties.

else that we don't know about. As one who has been involved in many fields through working in a large technology-based organisation, I was delighted to realise how much more there was which was unfamiliar to me. The third surprise was that, instead of the hyperconfident tone of some scientific papers, there were serious questions about realism and accuracy. Almost everyone knew that conventional materials modelling (finite element, finite difference, computational fluid dynamics) was allowing manufacturers to avoid building prototypes. The computer has replaced a lot of building of large-scale, real physical models. Yet hardly anyone said "We will design a new material from scratch, such that you can cut out all those tests and experiments." They did not say "We'll design you new aerospace materials by computer, such that we would be happy to fly in a plane built with it." The reality is that present modelling can do an enormous amount to improve materials, or to eliminate tempting but deceptive ideas. Yet its accuracy, even in the hands of the best teams with state-of-the-art codes, is not yet of a quality to eliminate large-scale experimental work. Partly this is because of working approximations; partly because industrial needs are much more complicated than the simpler systems which are

the usual targets of scientific modelling.

One final surprise was in the nature of the comments. There was not much talk along the lines "Give us bigger computers and we'll sort you out." True, bigger and faster were highly desirable. There was strong support for keeping up with the leaders around the world. But there was far more emphasis on how a human brain can take a technological question and transform it into a scientific question which might (with luck) be answered on a sensible timescale at sensible cost. There was also sympathetic recollection of the saying (originally due to J Willard Gibbs) "Thermodynamics owes more to the steam engine than the steam engine owes to thermodynamics". In other words, novel applied science pushes the scientist towards new basic scientific ideas.

The survey led to a number of recommendations, described below. Even though the emphasis was on the UK, the strongly international character of both science and industry give modelling a broader dimension. There are plenty of opportunities for Europe, although even a European view may be too narrow.

Expansion of materials modelling courses, especially so as to include those scientists with industrial experience. Education is not just for new graduates. Since industry is highly international, the UK should encourage students from all national backgrounds, without restrictive grant rules. Software use (how to run this or that large code) is only a small part of what should be taught. Much more important are "defining the problem" issues, the "brainware" aspects, so that students can address the unanticipated problems in the industries of today and tomorrow. Trained students would be valuable in many roles in industry: student numbers should not be restricted by estimates of numbers anticipated for those doing solely materials modelling.

Experience and learning from the past The losses of know-how and of knowledge are serious, given industrial reorganisation, the closures of large laboratories, the reductions or elimination of their libraries, and the associated losses of unpublished reports. Web searches do not access some important knowledge readily, especially internal reports (and changes of data storage formats may destroy databases which are not transferred; some, especially in declining industries, may be irreplaceable). Effective artificial intelligence approaches need encouragement. There has been a general feeling in some UK circles that networking replaces large labora-

tories, and that someone else will do the work and pay the bill. This is not credible. National laboratories should be supported as a national resource for some of these needs, especially when the time scales are longer than those for major reorganisations of industry.

Software industries (which did not exist in the early days of modelling) have a crucial role in transforming early versions of science-based codes from industry or academia into products for non-specialist users. This process is just as hard as turning a prototype of scientific equipment into a laboratory tool. Yet funding the development of software (or hardware) is very difficult in the UK. This must be resolved for the scientific software industries to flourish, ideally allowing development in whichever sector (industry, academia, national laboratory) is best equipped.

Software needs seemed more subtle, since much of the field is less mature. Credibility of results is a very significant issue, often not appreciated sufficiently by scientists. The practical man in industry knows how much to trust Finite Element predictions, but is (rightly) far less sure about electronic structure or mesostructure, where the working assumptions are less instinctive. Even minor academic squabbles about details can damage credibility. Benchmarking may help in some cases; in other areas, easily-accessed, objective advice is needed.

International competition drives *enhancement of hardware*. It is important that public-funded, state-of-the-art, equipment is available to industry users (as well as to academics) under reasonable conditions.

Management Few managers in industry recognise the opportunities created by predictive modelling. Active groups in industry are often too small and too transient to be effective. Achievements of modelling are easily underestimated, especially its role of filtering out flawed proposals. There are good case studies (like those listed in my first paragraph), and these should be publicised. Management courses could help to create informed customers for modelling.

Timescales Ways must be found to support activities with longer timescales (say 5 years). Such longer perspectives are most easily met in national laboratory or university settings. Universities have particular problems if graduate students write software, since it is hard for them to document it properly on the standard UK timescales.

Materials modelling is itself a wealth-

What is Foresight?

Foresight is about being ready for the future. No-one can predict the future. What we can do is look ahead and think about what might happen so that we can begin to prepare for it today.

Led by Government, the UK Foresight programme brings together business, the public sector, the science base and others to identify the threats and opportunities that we are likely to face over the next 10-20 years. In doing so, Foresight aims to improve wealth creation, enhance quality of life and bring about a culture change in the way business and the science base relate to each other and to the future.

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generating industry. It is relatively new, firmly based in physics and in information technologies. Moreover, it is international, and can gain enormously from collaborations within a framework which generates trust.

My wrist watch contains many new materials new since I was an undergraduate. Even if few, if any, were computer-designed, computer methods would have been conspicuous in their development. The next time you use a mobile phone, drink from an aluminium beverage can, or even eat a new-style ice cream, you'll be dealing with materials which are either new or significantly improved since you were born. And predictive materials modelling made its contribution.

The group which carried out the study for the Office of Science and Technology of the Department of Trade and Industry, was chaired by Marshall Stoneham (Massey Professor and Director of the Centre for Materials Research, University College London, and previously Chief Scientist, AEA Technology), Andy Howe (Principal Scientist, Corus) and Tim Chart (Chart Associates), with the support of John Patterson (BNFL) from the Materials Foresight Panel. We had input from all sectors of the UK community, plus international input, including that from the US Westmoreland Report and from European materials scientists. Our full report will be available on the DTI Foresight Website.

The views in this article are those of Marshall Stoneham.

First data on Higgs candidates reported at CERN

submitted by Sau Lan Wu, CERN

Our present understanding of nature is based on the extremely successful Standard Model. In this Model, there are twelve fermions of spin 1/2, conveniently classified into three families (sometimes called generations, see Box 1).

Protons and neutrons, for example, are each made of three quarks (up or down) of the first family.

Fermions interact with each other by swapping gauge bosons of spin 1. In the Standard Model, there are four gauge bosons: the photon, the W, the Z and the gluon, responsible for electromagnetic, weak and strong interactions. All these twelve fermions and four gauge bosons have been observed in the laboratory.

One of the most intriguing aspects of nature is there are masses; for example, the quarks all have non-zero masses while the photon is massless. Without these masses, the physical world as we know it, including ourselves, cannot exist. In the Standard Model, this problem of the mass is neatly solved by introducing one single particle – conventionally called the Higgs boson.

The Higgs boson is responsible for giving masses to all the particles in the Standard Model, with the exceptions of the photon and the gluon, which remain massless. The mass of a particle is determined by the strength of the coupling of that particle to the Higgs boson: the stronger the coupling, the larger the mass. Because of this important role, the Higgs boson is sometimes called the God particle: God could not have created our universe without this Higgs boson.

This Higgs boson has a number of additional distinctive features, including the following two:

- It is the only elementary particle of spin zero; and
- It is the only elementary particle that has not previously been seen in the laboratory.

This second feature may be about to change: Recent experiments using the electron-positron collider LEP at CERN have obtained first data on Higgs candidates. If confirmed, this will mean one of the most significant triumphs of the Standard Model, having all its particles observed in the laboratory.

How does one produce a Higgs boson at LEP? Similar to the production of a photon by shaking an electron, one simple way to produce a Higgs boson is to shake a suitably chosen particle. Since, as already mentioned above, the mass of a particle is proportional to its coupling to the Higgs boson, this production process of a Higgs boson is more likely to happen if we shake a heavier particle. Since the available energy at LEP is not high enough to produce a pair of top quarks – the heaviest particle in the Standard Model – the experimen-

Box 1:

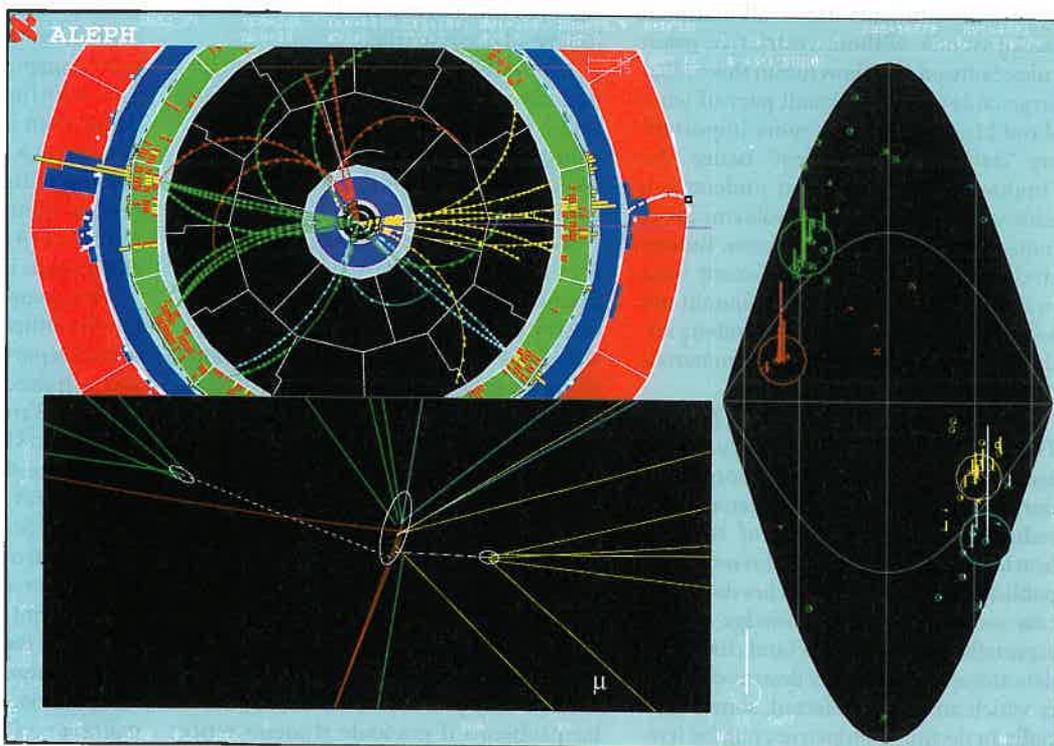
up quark	charm quark	top quark
down quark	strange quark	bottom quark
electron neutrino	muon neutrino	tau neutrino
electron	muon	tau

talists have to be satisfied with shaking the next heaviest particle, the Z, which is one of the gauge bosons for weak interactions. Thus the desired process is

$$e^+ + e^- \rightarrow Z^* \rightarrow Z + H$$

i.e., the annihilation of the electron and the positron into a virtual Z, designated by Z*, which then becomes a Z by shaking off a Higgs boson H. The resulting Z and H are then identified in the detectors from their decay products.

The LEP Collider was originally designed for a maximum centre-of-mass energy of 200 GeV. Last year (1999), this maximum design energy was reached and



The upper left figure is the event display for run 54698, event 4881, a 2b four-jet candidate with reconstructed Higgs mass of 114.3 GeV/c². Each of the two b-jets has a clear secondary vertex, as shown in the lower left figure. The figure on the right shows the four clusters of the four jets.

exceeded, making it necessary for CERN to renegotiate the agreement with the French government. This year, the centre-of-mass energy is further increased up to 208 GeV. Since the mass of Z is 91.2 GeV/c², this is enough energy in principle to produce a Higgs boson of mass up to 116.8 GeV/c². The CERN accelerator physicists are to be congratulated for their success in reaching significantly beyond the design energy.

The dominant decay mode of the Z is a quark-antiquark pair. For a Higgs boson in this mass range, its dominant decay mode is a bottom quark and a bottom anti-quark. Since both quark and anti-quark appear in the detector as a jet of particles moving in roughly the same direction, the most important events to search for is the annihilation of an electron and a positron into four jets.

The search for such Higgs events is very complicated. The observation of four-jet Higgs candidates at a Higgs mass around 114 GeV/c² was first reported on September 5 by the ALEPH Collaboration, one of four experiments using LEP, the others being DELPHI, L3 and OPAL. The ALEPH analysis includes the following major components, among others: identification of bottom jets, neural network techniques, and the use of likelihood ratio. One of these ALEPH Higgs candidates is shown in the figure. In this case, the mass of the Higgs boson is 114.3 GeV/c², very close to the 116.8 GeV/c² discussed above. It would not have been possible to get these events if the original design maximum energy had not been exceeded. More precisely, this ALEPH result is that an excess of four-jet Higgs candidates is seen in the experimental data, giving a three to four standard deviation incompatibility with the absence of a Higgs boson. Even though this four-jet mode of ZH is about 65% of all decay modes and is hence the most important one, it would be nice to see similar Higgs candidates where the Z decays into a lepton pair or a neutrino pair. For that purpose the running of LEP has been extended by one month. During that time a new Higgs candidate with a mass of 114.4 GeV/c² has been observed by the L3 experiment in the channel where the Z decays into a pair of neutrinos. The combination of the four experiments presented at CERN on November 3 agreed with the presence of an 115 GeV/c² Higgs at 2.9 standard deviations which is not enough to claim discovery (5 standard deviations). But on November 8th, the decision of stopping LEP has been taken (see Europhysicsnews 31/6).

How to explain the relevance of R&D to European Union policies

Sean McCarthy

European R&D programmes are an important source of funding for European researchers. The criteria that are used to assess proposals include the scientific excellence of the proposal; the economic and social relevance of the proposal; the structure of the consortium; the project management approach; and the relevance of the proposal to European Union policies.

This article describes how to explain the relevance of your proposal to European Union policies.

The Role of European Union Policies

The activities of the European Union can be summarised in Figure 1

The Treaty defines the areas where the member states co-operate e.g. environmental protection, transport, social issues, development of the regions etc. Article 164 of the Amsterdam treaty states that the member states will undertake R&D to support EU policies and to support the competitiveness of EU industry. Policies are detailed plans on how the treaty will be implemented. The policies include, for example, regional policy, social policy, transport policy, environmental policy etc.

Policy can be implemented in two ways:

- Through legislation, where member states are obliged to implement the policy
- Through funding programmes where or-

ganisations and individuals are provided with finance to support the EU policies.

Most researchers who submit proposals to the EU spend considerable time studying the funding documentation. This diagram shows that it is also essential to understand the areas of policy that the funding supports. Every single line of the EU R&D work programmes can be traced to a policy document of the European Union.

The background to policy

To really understand EU policy it is necessary to understand the political priorities in Brussels i.e. 'How do they think in Brussels?'

Figure 2 is a graphical display of how the politicians and the bueracrats in 'Brussels' think.

- The first level is the level of citizen. "We want a Europe built for the citizens by the citizens" Mr. Prodi, Lisbon, June 2000
- The next level they think at is the region. In 'Brussels' they do not think about Germany, France, Portugal etc. They divide Germany into 13 regions, Portugal into 5 regions, Greece into 3 regions, etc. They define a region as the geographical area where initiatives can be implemented, where resources can be shared and where co-operation can take place at a personal level. There is even an EU institution called the 'Committee of the Regions'. If your project has a geographical dimension

it is best to base your research at regional level rather than national level.

- The next level they think at is Europe. They are not interested in Peugeot, Renault, Mercedes, and BMW - they are interested in the European automobile industry. They are not interested in researchers who undertake research on Alzimers Disease in

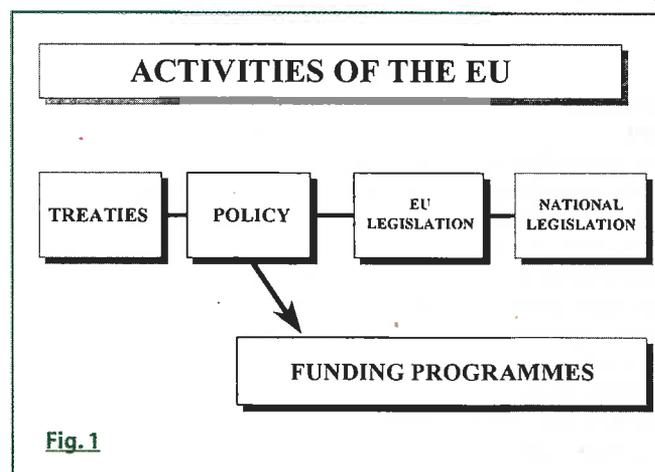


Fig. 1

Sweden, Germany, and Italy. They are interested in European Research on Alzheimers. One of the main differences between national and EU R&D funding for industry is that national R&D is focussed on individual companies whereas EU funding is based on the EU industrial sectors.

The final level they think at is the international level and the role of the EU on the international stage. In practice international usually means the USA and Japan. If you examine the recently published document 'Towards a European Research Area' the first chapter and practically all of the annexes compare EU research activities with those of USA and Japan. In the recently published Futures Report (<http://futures.jrc.es>) technology maps are presented for all of the main technology areas. The colour coding of the technology maps compare EU technology levels with USA and Japan.

The Key Point!

EU policies and EU funding are designed to fill 'Gaps' and all the 'Gaps' are relative to the 'EU Average' (figure 2). If you research can help fill any of these 'Gaps' then your proposal will be very welcome in Brussels. There is a golden rule in EU funding. You never go to Brussels looking for money for your R&D? You only go to Brussels to help them to fill a 'Gap' that THEY have identified.

The following is an overview of the 'Gaps' shown in Figure 2

GAP 1: The Social Relevance of your proposal

First you must identify a group of EU citizens where some aspect of their lives is below the European average (e.g. the elderly, the disabled, the long term unemployed; cancer patients, AIDS patients). If the EU has a policy to fill this 'gap' then you have identified an ideal area for your research proposal.

GAP 2: The Structural Funds and Sustainable Development

The best example here is case of Ireland. In the early 1990's, Ireland's gross domestic product (GDP) was less than 75% of the EU average GDP. Ireland received 8 billion euros of structural funds to fill the 'GDP Gap'. Over the past eight years Irelands economy has grown significantly and today Ireland's GDP is 95% of the EU average GDP. In April 2000 the Irish Government applied for further structural funds. As there was only a small 'Gap' they received only a fraction of the previous

structural funds. In other words "no gap, no funding".

GAP 3: The Economic Relevance

This is the most important 'gap' for researchers. If you can identify a sector where Europe is behind the USA or Japan and if your research will help the sector to catch up (or better still to help the EU sector to be the world leader) then your proposal will be very welcome in Brussels.

Priorities of EU R&D Programmes

If we now translate the above thinking into the priorities of the EU R&D programmes we identify the following:

- The aim of the Quality of Life programme is to improve the quality of life of citizens where some aspect of their lives is below the European average.
- The aim of the Growth Area is to improve the competitiveness of EU industry (with relevance to the US and Japan)
- The aim of the Energy, Environment and Sustainable Development programme is to improve job creation and sustainable development (at a regional level.)
- The aim of the International Co-operation (INCO) programme is to increase the globalisation of knowledge (i.e. develop researchers who can operate at an international level.)
- The final (and most important aim) of EUR&D programmes is to establish the EU as a focal point for scientific and technological excellence. This is the most important point in your proposals i.e. what aspect of your proposal will establish the EU as an international leader.

Sources of information

When you are writing an EU proposal it is essential to be able to access the policy documents and the background documents which established your area as an EU priority. This section identifies the sources of information which can be used to identify the relevant EU polices. All of these Web-sites can be found on: www.hyperion.ie/usefulwebsites.htm

- Towards a European Research Area. (<http://europa.eu.int/comm/area.htm>)
- The Future Report (<http://futures.jrc.es>) This report identifies the technologies that

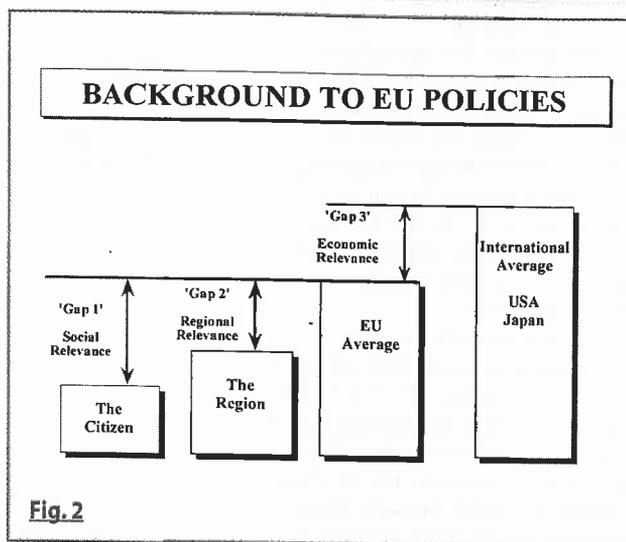


Fig. 2

the EU will need over the period 2000-2010. It consists technology maps for each technology (e.g. energy, materials, IT etc.) and it clearly identifies the 'Gaps' between EU and US technologies.

- Europa – the official EU web-site <http://europa.eu.int> The main policy areas can be found under the Commission's web-page. For example to find the policies on Transport , select the commission web page and then the transport policy web page.
- EU Search Engines <http://europa.eu.int/gen-info/> In this web-site there are a range of search engines. The most important is ECLAS. ECLAS contains 200,000 EU documents which have been used in the preparation of EU policies. (This is one of the best sources of information.)
- OECD website (www.oecd.org) The Organisation for Economic Co-operation and Development was established to provide policy makers with information for national and EU policies. It is a very good site to source international data for your proposal.

Conclusion

Over the past two years Hyperion has trained over 3600 researchers on EU policy and the role of research in the policy making process. The researchers have found the understanding of EU policy and the relevance of their work to EU policy both interesting and rewarding – they are winning more EU R&D contracts.

Author

Sean McCarthy (sean.mccarthy@hyperion.ie) is Managing Director of Hyperion Ltd. Hyperion specialises in the development of training course for research managers. Full details of their training courses can be found on www.hyperion.ie.

The Physics on Stage Festival

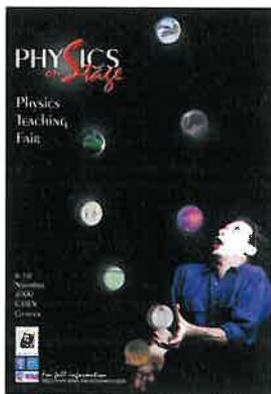
Clovis de Matos, Helen Wilson, Barbara Warmbein

A screeching noise emanates from one of the 22 fair stands: the Irish delegates are demonstrating with a violin bow, a metal plate and some sand, how sound waves propagate through the metal plate. New patterns form in the sand depending on where the bow is struck. A few metres away, in CERN's main auditorium, 400 physics teachers and physics popularisation experts are throwing small wooden blocks in the air to find out on which axis they rotate in a stable manner. Two young Germans - one dressed up as a talk show host, the other as a confused scientist - have captured their audience with their performance. A few doors down the hall, a workshop group of some 30 delegates sits in deep discussion over how physics should best be taught in secondary schools to motivate the youth of today to become the scientists and engineers of the future.

Physics on Stage took place at CERN in Geneva between the 6th and 10th November 2000 - and it was a great success.

Physics on Stage was initiated and carried out by the international organisations CERN, ESA, and ESO. It was a unique initiative that had a significant impact on the public understanding of physics and on the teaching of physics. The European Commission supported this project as part of the 5th Framework Programme.

The climax of the Physics on Stage programme was the recent 5-day festival, which brought together over 400 experts on physics teaching and popularisation; including high school physics teachers, university lecturers and researchers, curriculum developers and scientific and educational journalists. At this unique event, delegates from 22 European countries presented their ideas and techniques for making physics a fascinating subject for schoolchildren and the public alike. The range of ideas was as wide as can be - experiments with electricity,



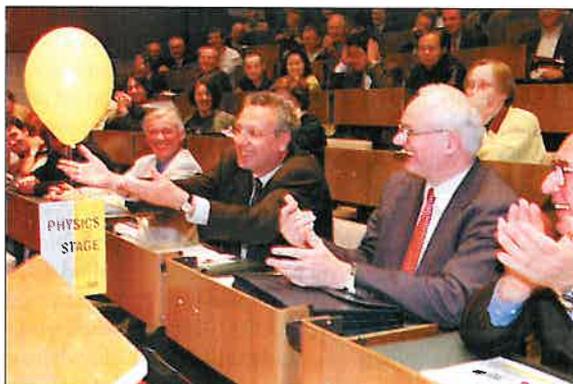
light, sound, speed, chaos theory, toys, free fall and the big bang - and the ways these ideas were presented were highly creative and original.

The festival in Geneva was the culminating event of a year of wide-ranging activities in each of the participating countries. The national programmes, drawn up by the National Steering Committees, played a crucial role in the physics on stage programme.

Thanks to the enthusiasm and engagement of all delegates, the main objectives of the Physics on Stage programme have been successfully reached:

- A debate on physics teaching amongst educators, the media and politicians has been catalysed.
- The most effective and innovative methods for teaching physics have been identified, incorporating demonstrations, lectures, innovative teaching materials, hands-on-activities, theatre, video, web applications and more.

A colourful highlight of the Physics on Stage festival was the physics teaching fair, where all countries had the opportunity to present their methods, ideas, experiments, books, and brochures. It was the living soul of the week, buzzing with life, sound, conversations and surprises at every turn. It was so much of a real fair that there were even gingerbread hearts (of course reading " $E=mc^2$ ") and heart-shaped helium balloons proclaiming "Physics is at the heart of everything"



High-flying spirits / grasping the spirit of POS: Dr Philippe Busquin, 9th Nov 2000

Other important components of the festival were the plenary presentations, which were of outstanding quality, and the special performances, which brought theatre and physics to the stage hand in hand and more than once made the audience roar with laughter or go silent with astonishment.

The Visit of the Directors General of ESA, ESO and CERN and the active involvement of the European Commissioner for Research, Dr Philippe Busquin, during the Festival were an important source of motivation and inspiration for the educational community as well as for the organisational team. The European Commission and the European Science Organisations demonstrated strong political support to the Physics on Stage Festival and its outcome.

Throughout the festival, participants met in small groups to discuss various themes close to the heart of physics education. These workshops, with titles such as "Mapping the Crisis", "Women in Physics" and "Curriculum Developments", provided a forum for the delegates to suggest actions that could be taken to improve the current status of physics literacy in Europe.

From a total of 74 recommendations the present crisis in the teaching of physics has been clearly identified. This crisis will have a major impact on the cultural identity of Europe. A frightening trend is underway regarding the lack of interest in physics amongst the general public (particularly young people) and the diminishing number of physics teachers in Europe. Altogether, these points indicate that if no action is taken, now, Europe will enter a dark age of knowledge.

The European science organisations discussed with the educational community what role they could play in the future of physics education.

To close the conference a voting session took place amongst all the participants, to establish priorities in the list of recommendations. The results of this vote will soon be published in the proceedings of the Festival. This vote represents a good statistical assessment of the will of the European physical teaching community.

It was a wonderful week: many contacts have been established across European frontiers and the Physics On Stage participants are looking forward to putting some of the new ideas into practice.

For more information, visit the following web sites:

<http://www.estec.esa.nl/outreach/pos>
or <http://www.cern.ch/pos>

The word from Brussels

Tom Elseworth

As I am writing this the French Presidency is drawing to a close and the Swedish are about to take over. Big things perhaps? Framework Programme 6 taking shape in a timely fashion (unlike its five older siblings)? It seems not, the new Swedish Presidency web site is in its infancy but so far it says only this on research: "Research is increasingly crucial to development, renewal and employment. Negotiations on the EU's Sixth Framework Programme for Research and Technical Development will commence during Sweden's presidency. Efforts to strengthen European research and further develop cooperation in this field will be carried forward in accordance with the guidelines formulated by the European Council in Lisbon.

Hardly earth shattering. The word on the streets in Brussels is that no real step forward is expected on the content. At best there will be discussion of broad issues and outline structures. The horrible prospect of a funding black hole looms closer it seems. On the other hand it is said also that commissioner Busquin is determined to make his mark with FRAMEWORK PROGRAMME 6 given that the vagaries of Belgian politics are unlikely to allow him a second bite at the cherry. The drive seems to be in the direction of fewer but big (integrated) projects. The cynics think this is largely driven by the need to reduce the number of projects so that the limited manpower of DG Research is better able to cope with them. Some say that it is a renewed attempt to re-launch the JRC concept (that will please lots of Governments I am sure!). It is also known that our Commissioner favours more basic research and is a great fan (as am I) of the Improving Human Potential programme element of the current Framework Programme. The latter may be extended in Framework Programme 6 to include mechanisms that can find ways to block the brain drain.

Talking of management, the news from the frontline may be both good and bad for Europe's scientists. First the good news; a commission news release of 1st December holds out the promise of quicker decision making on funding proposals. The idea is that the Director-General (Achilleas Mitsos) will be able to inform pro-

posers of his decision without waiting for a formal Commission decision. It will be sufficient for Commissioner Busquin to have tabled the matter once.

The bad news at least in the short term, is the much heralded re-organisation (not for the first time, the word over a *bière blanche* is that it is due to be implemented next week!). Can the already stretched management resources of the DG keep their collective eye on the ball and on their own backs, at the same time? In a news release at the end of November the Director-General is quoted, "on the very first day of my arrival I received a mandate from the Commissioner to change the organisation of the Research DG. We must create a number of political directorates to advance the ERA (European Research Area) objective A majority of officials will continue to be dealing with the Framework Programme (which) will serve directly the objectives of the ERA". There will be a reduction in the number of directorates (by three to six) but "...no one will lose their jobs ... like any organisation we need to find the right balance between experienced people and new blood". DG Mitsos concedes that with a Framework Programme 6 proposal needed by March 2001, "the timetable ... is demanding". What does all this mean in reality? Time will tell, but the demands of continuity in research funding are perhaps unlikely to allow of a great discontinuity in style and content between FRAMEWORK PROGRAMME 6 and the present programmes.

The Research Council met in mid November. People we know who know about these things, regarded it as a rather lack lustre affair. However, of some importance to physics was the establishment of an approved negotiating mandate for the Commission as a basis for preparation of an "ITER legal entity" to construct and operate an International Thermonuclear Experimental Reactor. It may prove to be a lion without teeth, as the mandate is not backed by any commitment to funding (the Council concluded that this must wait until the content of FRAMEWORK PROGRAMME 6 is known - I would think that it is certainly likely to be at least until then!). There was also some green coloured resistance that has resulted in the

Commission having to conduct yet another review of fusion in the context of EU research.

DG Energy and Transport (TRAN) has also pushed the boat out in favour of nuclear energy - fission in this case - in a green paper on energy supply security. The document talks about the medium-term contribution from nuclear power as a key element in tackling climate change and maintaining European energy autonomy. In our humble opinion these are objectives worthy of devoted support and the taking and giving of hard blows. The first of these is not too far off, recent discussion at the EP gave evidence of substantial opposition from Greens and a broad swathe of left leaning members.

Practical Information

IGLO is an informal grouping of the liaison offices based in Brussels. Their role is generally, to facilitate national access to EU research funding. There are members from Finland, France, Germany, Hungary, Israel, Italy, The Netherlands, Portugal, Slovenia, Spain, Sweden, Switzerland and the UK. Their web site (<http://www.euratin.net>) provides hot links to the site of your own representative, as well as such services as helping to find research partners. Use them, tell them what you think, tell them what you need.

ELECTRA is an Excel 97 application to help Framework Programme project coordinators capture the project information required for the Contract Preparation Forms (CPF) stage of establishing a new project. I have used it, it works well and is certainly helpful to all concerned. The most recent version is dated September 2000 (see <http://www.cordis.lis/fp5/electra.htm>). What a pity that it does not interface with ProTool, the software used for preparation of the original proposal!

ProTool (see <http://www.cordis.lis/fp5/protool/home.html>) is a specially written and substantial bit of software that gives very considerable help to proposal co-ordinators. It is far more than just an easy way of completing those awful forms, for instance it includes validation routines that print out very useful listings of all the possible shortcomings in the set of forms you have prepared. This was well nigh impossible if the job was done by hand and called for a massive investment of time to spot the mistakes. But it has its quirks (e.g. when using cut and paste for text prepared elsewhere considerable care is required), it is far from a complete answer to the problem and is not totally user friendly. Nevertheless it is far more so than the hard copy

forms it replaces! The system also allows electronic submission (although many Commission officials discourage this privately and I must say I agree with them).

Calls for Proposals

Quality of Life and Management of Living Resources; opens 15/11/2000, closes 28/02/01 and 15/03/01

Environment Sustainable Development; opens 15/11/2000, closes 15/02/01

Improving Human Research Potential and the Socio-economic knowledge base, Enhancing access to research infrastructures, opens 15/11/2000, closes 15/02/01

Energy, Medium to Long term Target Actions and Priorities of Strategic importance, opens 24/10/2000, closes 09/02/01
Energy, short term Target Actions and Priorities of strategic importance, opens 24/10/2000, closes 15/03/01

Energy, new Open Call to replace previous Open Call 1999/c 77/15

Nuclear Energy, Fission, Shared-Cost Actions, Concerted Actions and Thematic

Networks, opens 17/10/2000, closes 22/01/2001

Nuclear Energy, RTD Activities of a Generic Nature, Support for Research Infrastructures, Training, Accompanying Measures, opens 17/10/2000. Continuous submission scheme with evaluation cut off dates

User-Friendly Information Society 5th Call for Proposals, opens 14/10/2000, closes 15/01/01

For the entire above see the Framework Programme 5 web site at <http://www.cordis.lis/fp5>

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 Rela-

tions and Public Affairs.

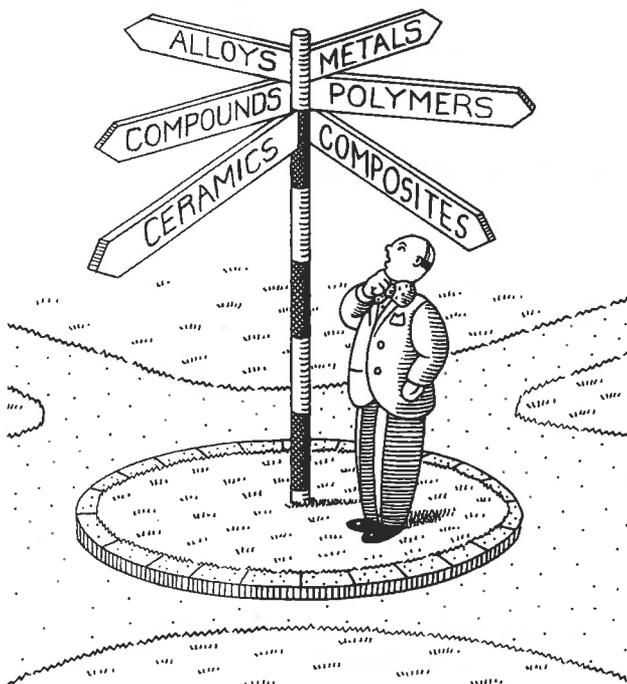
Tom Elsworth, one of the partners in Communiqué PR, has prepared this article (it reflects his own opinions on matters in Brussels). Tom has experience working in the external relations of major science based organisation extending over 25 years and in locations including London, Brussels and Washington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

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noticeboard

Candidates to the Executive Committee

Elections to the Executive Committee will be organized at the EPS Council meeting in March. Candidates are requested from national physical societies that are members of the EPS and from IOMs. Nominations must be accompanied by a CV, an election statement as well as a statement that the person accepts the nomination. Nominations must be received no later than 15 February 2001, and should be sent to D. Lee, EPS, BP 2136, 68060 Mulhouse Cedex, France.

Council 2001

Please note that the EPS Council will take place on March 30 and 31 in Mulhouse. More information will be sent to Council participants shortly.

EPS Prizes

Nominations are now sought for the following prizes.

EPS Quantum Electronics and Optics Prize, 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 nominations procedure which must be followed will be given at the EPS web page www.eps.org. Deadline for receipt of applications at the EPS office is March 9, 2001 for both prizes.

The Awards will be announced at the CLEO/Europe - EQEC Focus meeting, associated with Laser 2001 - World of Photonics, in Munich, June 18-22, 2001. Belgium, e-mail: Marcel.Ausloos@ulg.ac.be

The Hannes Alfvén Prize 2001

The Hannes Alfvén Prize 2001 goes to Prof. Shafranov from the Kurchatov Institute in Moscow for his outstanding contributions to the theory of magnetostatic equilibrium and stability (Kruskal-Shafranov limit) in high temperature plasmas.

Editors for the European Journal of Physics

The European Journal Physics is a joint venture between the EPS and the Institute of Physics. The journal deals with education and scholarly studies in physics at the university level, and publishes original articles on the fundamentals of physics and physics education. The journal needs 5 new editors in 2001. If you are interested, please send your name and contact co-ordinates to D. Lee, EPS, BP 2136, 68060 Mulhouse Cedex, France.

Errata

Please note that Andrey Bychkov was the author for the interview of Z. I. Alferov in EPN 31/5, pp 28-29.

Secretary General's Report

Education Division

A. Kleyn, the chairman of the new Physics Education Division called a meeting of the provisional Board in November. The two day meeting worked on the action plans of the Pre-university Section (G. Tibell, Chair) and the University Section (U. Titulaar, Chair).

European Innovation Area

Under the French Presidency of the European Union, a 2 day work shop was organized in Lyon on a European Innovation Area, as an addendum to P. Busquin's European Research Area. Each of the 3 public roundtables voted on a series of predetermined questions to send 15 recommendations to the EU. The round table on financing, capital and innovation for example recommended to: Support the early stages of innovative businesses; Mobilise private financing for innovation; Co-ordination the national and European support mechanisms for innovative companies; Promote the development of European venture capital; and Decentralise European support to innovation in SMEs. More information is available at <http://www.presidence-europe.fr/pfue/static/acces6.htm>.

Position Paper on Fusion Energy

The Executive Committee approved a position paper on the "Importance of European Fusion Energy Research", prepared by the EPS Plasma Physics Division. The following is from F. Wagner, the Chairman, on the feedback on the political developments around fusion in the last weeks and the possible role of the position paper. "The discussion within the German Bundestag on fusion went fine in the sense that there was not a negative decision - this would have been what we were most afraid of. The discussion will continue with us as proponents in the technical and science committee. The meeting of the Council of Ministers was successful in the sense that ITER will continue and that the commission has been charged to study specific legality aspects around ITER siting and co-operation. The position paper was sent to all involved (or committed) people. I assume that it helped."

David Lee is the Secretary General of the EPS
email d.lee@univ-mulhouse.fr

Publish in Europe

D. Jérôme

Given that European laboratories produce one third of the world's production of research in physics, the time is ripe to take a closer look at the channels used by the researchers to publish their results. It is evident that Europeans are largely responsible for the incredible growth of the journal published by the American Physical Society (APS). At present, more than 70% of the articles submitted to Physical Review and Physical Review Letters come from non-American physicists, with Europe contributing to half of these (see APS News August/September 2000, and the article by J. Langer in Physics Today, August 2000). Over the past decade, contributions by American authors to PR and PRL have remained stable, leading to the present situation where European actually publish more articles in these journals than Americans. Is this a healthy situation? If this trend continues, we may be heading towards a Single Journal. Are we aware and do we really want this? Journals differentiate themselves from pre-print servers through their review process, which is the principle

task of the editorial board all high quality journals. Although all editorial boards are multinational and represent multiple view points to remain impartial, there is still a need for more than just one journal. So where is Europe in all of this? To avoid the proliferation of multiple national journals, European physicists have taken concerted action to join forces in publishing world class journals. The EPS and 17 national physical societies collaborate to produce Europhysics Letters. The EPS and 8 national Societies are members of the Scientific Advisory Committee of the European Physical Journal. Created 3 years ago in a merger among the publications of 2 national physical societies and of Springer Verlag, this journal is growing on a regular basis. The Institute of Physics and the German Physical Society launched the New Journal of Physics, an innovative on-line journal also gaining in importance. Even though there are numerous Europeans who wish to see an even greater concentration among European publications, each of the actors must accept their part of the fragmented situation in Europe. The learned societies and publishers need to see that we are in the age of "merge or perish!" The evolution of the publication scene in Europe must inevitably pass through the realisation by physicists of the serious nature of the present situation, and the need to submit more of their research papers to European publications. Is it really too much to ask European physicists to submit, for example 50% of their research to European publications?

A life's work in exile

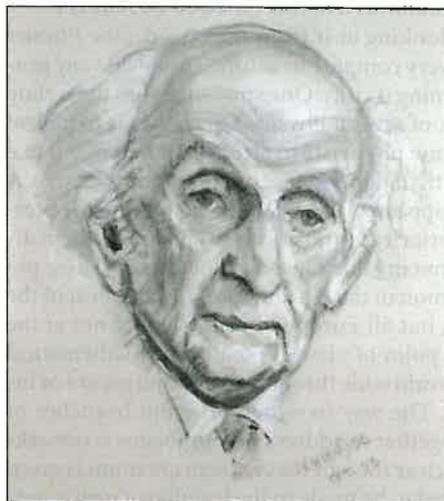
*Cornelius Lanczos : collected published papers with commentaries.
North Carolina State University, 1999 ISBN 0-929493-01-X*

Cornelius Lanczos died in 1974 during a visit to the Roland Eotvos Physical Society in Budapest, the city that he had left in 1922. Like so many other brilliant scientists of his generation, he was driven abroad by the political turmoil of his homeland. He was not such a restless migrant as Leo Szilard, but societal forces were to send him further afield twice more. His first sojourn in Germany culminated with his inevitable departure in the early thirties, this time to the United States. During the McCarthy period he responded to an invitation to join the Dublin Institute for Advanced Studies, where he settled happily for the last two decades of his life. There he is remembered, as is his colleague Schrödinger, for his fondness for philosophical discussions, a tendency generally welcomed in Ireland.

Even in those later years he remained active and versatile, with interests extending from fundamental physics (particularly relativity) through applied mathematics to the new subject of computation and the numerical algorithms that it required. Some of his time in the U.S. had been spent in industry, and it may be that this practical side of his work will enjoy the most enduring recognition.

Now W.R. Davis and an extensive team of co-editors have done him the honour of publishing a six-volume, 3,200-page collection of his works. Not only is it comprehensive to the point of including magazine articles (often a very revealing form of communication), but it also supplies full translations into English, aligned on the opposite page. All of this is complemented by introductions and commentaries, prefaces and biographical notes, lists and photographs. Excerpts from correspondence with his colleague Einstein are included. Not many leading physicists had their professional reputations so skilfully embalmed.

It is refreshing to see science historians look away from the dazzling accomplishments of Einstein to spend time and effort on



Portrait of Cornelius Lanczos
Courtesy of the Royal Irish Academy

one of his contemporaries. A secondary figure perhaps – but significant and exemplary in every sense.

Normally such a mammoth compilation could be recommended only to libraries as a reference work. In this case the editors have crowned their assiduous efforts by negotiating sufficient support to achieve a very economical price. This puts all of the life and times of Lanczos, save perhaps the more personal details, within the reach of anyone whose research has been touched by his work, or wishes to follow the peregrinations of that remarkable Hungarian diaspora.

Denis Weaire

To order, contact Wesley O. Doggett, Professor Emeritus, North Carolina State University, doggett@ncsu.edu, or refer to the web page, <http://www.physics.ncsu.edu/lanczos>, for an order form. The price is US\$ 150 for the complete set.

Relations between physicists and mathematicians

Jean-Pierre Bourguignon

Where do we stand?

Throughout history, one finds numerous situations where Physics and Mathematics have cross-fertilized one another. To list them is banal but not tedious because of their diversity. In the second half of this century, the scientific life has become more and more specialised. This fact could have put this tradition in jeopardy. An analysis of the development of these two sciences in the last 25 years shows it is not the case. In fact the level of relations between the two disciplines may now reach an all time peak in diversity, in intensity and in fruitfulness.

How do the two communities live this renewed closeness?

At least to someone looking at it from the outside, the Physics community reveals a very complex structure. This makes any general statement concerning it risky. One sometimes has the feeling that one should speak of several Physics. One only has to look at the passion put by some physicists to stress their belonging to a sub-discipline rather than fighting for the community at large. A similar phenomenon appeared also in Mathematics with the pressure to give a higher priority for positions to applied mathematicians. In some departments this caused serious fights. These periods of tension, common in the 70s and the 80s, have most of the time been overcome, but all European countries are not at the same stage from this point of view. Presently, the mathematical community is living world wide through an exciting period of internal restructuring. The way in which different branches of Mathematics come together to address new problems is remarkably fruitful. It is not clear though that enough attention is given to the changes that need to be made to the training of new generations. An open approach and some new ideas are required. Are we really working hard enough at that?

Areas of interaction between Mathematics and Physics have proliferated, from very theoretical to plain experimental. It is satisfying to see that in the area of Quantum Mechanics (in its diverse disguises, including Quantum Field Theory), mathematicians have gone beyond providing the general framework based on the analysis of Hilbert spaces. They are finally convinced of exploring its revolutionary conceptual content in more depth. This forces them to think over some of their classical paradigms. As a result, this should enable them to broaden the scope of Mathematics, in Algebra (with more consideration given to non-commutativity, and to representations of groups or of more general structures), in Geometry (the possible structures of space or space-times, the systematic study of moduli spaces of geometric structures), in Analysis (spectral problems in non compact spaces, Field Theory, hyperbolic equations, ...), and in Probability Theory (tunnel effects, Monte-Carlo methods). There are many other areas of Physics living such an experience: domains where a stochastic approach prevails; domains where non-linear models (often based on massive numerical simulations) have become

unavoidable (including the twilight, and still very fragmented, zone covered by the expression "chaos theory", in which only few general results are firmly established); domains stemming from ingenious experiments (as the ones connected to super-focalisation of acoustic waves, just to name an example).

This happens right at the moment where mathematicians substantially open their discipline to more intensive interactions with other natural sciences, such as Chemistry and even more Biology. At the same time, mathematical developments triggered by a closer relation to human and social sciences, in particular economy, have brought in Mathematics paradigms other than the more classical mentioned before. This new avenue has very quickly acquired its nobility, and should be pursued to ensure a healthy balance for the future development of Mathematics.

The need for an open approach is made even more compelling by the emergence of computer science as an autonomous discipline, still keeping privileged relations with Mathematics, and the call for mathematicians from many new economic sectors, in particular in connection with high technology.

In this context, it is no longer possible to consider the training of scientists in the same way. It does not make any difference that they work in the academic world or in companies or services. There is a need for a broader approach, without giving up a thorough learning of some precise and structured knowledge, still a must!

Working at putting together informal structures easing these interactions is now for me a priority, if one is to take full advantage of these new directions. I am therefore pleased to see that a number of new institutes have appeared in Europe with this explicit task in their mission. The Institut des Hautes Etudes Scientifiques, of which I am presently in charge, belongs to this group. There, exchanges between physicists and mathematicians are still as rich as in its early days. This justifies the claim that the fundamental ambition of its founder, Léon Motchane, has been fulfilled. Soon, some biologists will join them, and such an evolution is in line with the development I just made.

In my eyes though, ahead of us lies a major challenge, namely counteracting the declining enrolment in scientific sections of higher learning institutions. This affects in particular students who want to study sciences in depth. We must deal with this threat, for the benefit of sciences of course, but also for that of the whole society. Indeed, it now stands out that several major economic sectors will require manpower with a high scientific qualification. Since, at the same time, universities and research institutions, all over Europe, will have to replace their personnel at a pace that was never experienced before, we will have to face this unprecedented hiring wave. This can of course be an extraordinary opportunity to start a number of things anew, provided the question is not approached in a too narrow way, e.g. just as an accounting problem. This should be a new frontier for the whole society.

In my opinion, this problem requires a global approach, to be properly addressed, This will mean making adjustments to the school system at all levels, including the primary one. The diversity of education systems within Europe has to be taken into consideration (and preserved), but I cannot understand why, to tackle such a question, one would have to oppose experimental observation and formal reasoning. We should view this struggle as a call for initiative and adventure. For me, there is no alternative but working together. Any other more confrontational attitude could prove terribly damaging for all the scientific community.

From this point of view, the goal proposed by Commissioner Philippe Busquin, i.e. making emerge a European Research Area,

that was endorsed by Heads of States in Lisbon in March 2000, can prove a very effective tool. There is a proviso though. To go for it, one should not take too technocratic approaches which in all countries are characterised by their short-sightedness and their massive underestimation of personnel problems. To deal with such problems requires long term planning and careful implementation, features that strict market approaches miss almost all the time, but that call for a close association of teachers and scientists. European learned societies seem to me very natural partners for that purpose. Up to now they have always been considered as minor partners by the European Commission. Let us hope that the personality of Mr. Philippe Busquin, and a broad mobilisation, will impose a new approach where they will have their say at all levels.

Jean-Pierre Bourguignon is Directeur de recherche, Centre National de la Recherche Scientifique, Director of the Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette, France, and the Past president of the European Mathematical Society

Mission accomplished?

On January 1, 2000 The European Physical Journal launched its new section EPJ E on SOFT MATTER motivated by the conviction of a large number of European scientists that a journal covering all aspects of "Soft Matter" is needed. The study of soft condensed matter has stimulated fruitful interactions between physicists, chemists, and engineers, and is now reaching out to biologists. Most importantly, complex fluids have many applications in everyday life and fundamental research in "Soft Condensed Matter" is often closely linked to industrial research.

A broad interdisciplinary community involving all these areas of science has emerged over the last 30 years, and with it our knowledge of Soft Condensed Matter has grown considerably with the active investigation of polymers, supramolecular assemblies of designed organic molecules, liquid crystals, colloids, lyotropic systems, emulsions, biopolymers, biomembranes, etc.

The central goal of EPJ E SOFT MATTER is to provide a meeting place for the various communities involved in "Soft Condensed Matter" science; a "melting pot" for ideas coming from physics, chemistry, materials science and, not to forget, also from biology. EPJ E SOFT MATTER wants to become a forum for the publication and discussion of complementary contributions from all the community involved in studying soft condensed matter and complex molecular assemblies. It should form a bridge for the understanding of structure formation and properties on the one side and the synthesis and design of new materials and functional systems on the other side.

Beyond mere scientific soundness, papers should only be accepted that represent a significant step forward and are not just a minor improvement or advance on earlier work. The scope of a paper, as outlined in its introduction, must make it understandable to the general reader in soft condensed matter. Interdisciplinary papers are encouraged.

The journal provides also adequate scope for presentation and discussion of controversial ideas (perspectives, commentaries, etc.). It intends to explain and open up to all communities involved in "Soft Matter" science fundamental current problems of common interest which are intensively debated or not yet suffi-

ciently well-known.

In order to strengthen the links between the various communities, certain issues of EPJ E SOFT MATTER are dedicated to specific topics of general interest in Soft Condensed Matter: among the first of these issues are "Polyelectrolytes" and "Molecular Functional Materials".

It is already clear from the work published during the last year that EPJE is proving a success, with a large number of high quality submissions already in the pipeline. The limited number of pages available turns out to be an advantage as it requires a strict and thorough selection of the papers accepted for publication. Commentaries on "Glass transition in thin polymer films" and on "Polymer crystallization" have also drawn attention on the journal.

Finally, the Editors-in-Chief are keen to stimulate discussion amongst our community even further. It is therefore very desirable if potentially exciting - or controversial - manuscripts are identified to the Editor-in-Chief, so that the possibility of additional commentaries or editorial comments can be considered; where related papers are under consideration they can be published together to encourage debate.

The large number of submissions and the highly appreciated possibility of debate within a journal demonstrate that the scope of EPJ E SOFT MATTER is actually addressing the needs of the community. So, while EPJ E SOFT MATTER has not yet fully accomplished its mission, we feel that it is on the right track.

The Editors in Chief

Schrödinger lecture

The Annual Schrödinger Lecture of Trinity College Dublin was recently presented by Professor Helmut Rauch of the Atominstut der Österreichischen Universitäten. The lecture was entitled Neutrons as Schrödinger Waves and Cats.

In the area used for the reception that followed there stood a large wooden crate, recently delivered. On that evening there appeared upon it the following notice, together with a switch.

Schrödinger Box, Type 73927/A Irish Model

Instructions were included:

- (1) Open lid
- (2) Place Celtic Tiger¹ in box HANDLE WITH CARE
- (3) Press QFE Switch (Quantum Feline Exterminator)
- (4) Open lid STAND WELL BACK
- (5) Observe
- (6) Tell a friend (preferably Bob or Alice)
- (7) Retire to pub to discuss
- (8) Any paradoxes must be reported to the College Safety Officer

[1 Editor: "Celtic Tiger" is the current name given to the Irish economy]

The source of these notices is unknown but a former President of the EPS is under suspicion.



2000

The EPS European Physicists Biographies Project

EDITOR: DR. SVETLANA ERLYKIN

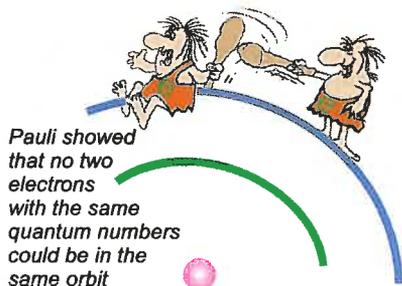
Graphics: Pauline A. Russell
Svetlana Erykin

The venture is aimed at increasing the interest in physics of 12-17 year old students by way of a brief description of the personal as well as the scientific aspects of those famous physicists, whose names are mentioned in school text books



Laplace developed game theory

Kamerlingh Onnes studied liquified gas at very low temperatures



Pauli showed that no two electrons with the same quantum numbers could be in the same orbit



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address: Department of Physics,
University of Durham, Durham DH1 3LE, UK



Ampere, Andrie Mariek, French
Angstrom, Anders J., Swedish
Arago, Dominique F., French
Archimedes, Greek/Sicilian
Aristotle, Greek
Avogadro, Amadeo, Italian
Bachmetjew, Porphiry, Bulgarian
Bacon, Roger, British
Becquerel, Antoine H.E.C., French
Bernoulli, Daniel, Swiss
Bohr, Niels, Danish
Boltzmann, Ludwig Edward, Austrian
Born, Max, German
Boscovich, Rudjer, Croatian
Boyle, Robert, British/Irish
Bragg, William Lawrence, British
Bragg, William Henry, British
Brahe, Tycho, Danish
De Broglie, Louis Viktor, French
Bruno, Giordano, Italian
Carnot, Sadi, French
Cassini, Giovanni Domenico, Italian/French
Cavendish, Henry, British
Cherenkov, Pavel A., Russian
Copernicus, Nicolaus, Polish
Coulomb, Charles Augustin, French
Curie, Sklodowska, Marie, Polish/French
Curie, Pierre, French
Dalton, John, British
Dirac, Paul, British
Doppler Christian, Austrian
Einstein, Albert, German
Eotvos, Roland, Hungarian
Faraday, Michael, British
Fermi, Enrico, Italian
Fitzgerald, George Francis, Irish

Fresnel, Augustin Jean, French
Gabor, Dennis, Hungarian
Galileo, Galilei, Italian
Galvani, Luigi, Italian
Gamow, George, Russian/American
Goepfert Mayer, M., German/American
Green, George, British
Hahn, Otto, German
Halley, Edmond, British
Hamilton, William Rowan, Irish
Heisenberg, Werner Karl, German
Helmholtz, Hermann L.E., German
Herschel, William, German/British
Hertz, Heinrich R., German
Hooke, Robert, British
Hulubei, Haria, Romanian
Huygens, Christiaan, Dutch
Joule, James, British
Kamerlingh Onnes, H., Dutch
Kapitza, Peter L., Russian
Kastler, Alfred, French
Kelvin, Lord, British/Irish
Kepler, Johannes, German
Kirchhoff, Gustav R., German
Lagrange, Comte Joseph L., French/Italian
Landau, Lev Davidovich, Russian
Laplace, Marquis P.S., French
Lavoisier, Antoine L., French
Leonardo da Vinci, Italian
Lomonosov, Mikhail V. Russian
Lorentz, Hendrik, Dutch
Marci, Large Jan M., Czech
Marconi, Guglielmo, Italian
Maxwell, James Clerk, British
Meitner, Lise, German
Mendeleev, Dmitri I., Russian

Milankovic, Milutin, Serbian
Mohorovicic, Andrija, Croatian
Nadjakoff, Georges, Hungarian
Neumann, John, Hungarian
Newton, Isaac, British
Occhialini, Giuseppe, Italian
Oersted, Hans Christian, Danish
Ohm, Georg Simon, German
Pacal, Blaise, French
Pauli, Wolfgang, Austrian
Planck, Max Karl, German
Popov, Aleksandr S., Russian
Ptolemy, Claudius, Greek/Egyptian
Pupin, Michael Idvorsky, Serbian/American
Roemer, Ole Christensen, Danish
Roentgen, Wilhelm Conrad, German
Rutherford, Ernest, New Zealand/British
Segre, Emilio Gino, Italian
Schrodinger, Erwin, Austrian
Siegbahan, Karl Manne, Swedish
Simonavicius, Kazimieras, Lithuanian
Stevin, Simon, Dutch
Swan, Joseph Wilson, British
Szilard, Leo, Hungarian
Tamm Igor E., Russian
Tesla, Nikolas, Serbian/American
Thomson, George Paget, British
Thomson, Joseph John, British
Torricelli, Evangelista, Italian
Tsiolkovsky, Konstantin E., Russian
Volta, Count A.G.A., Italian
Van der Waals, Johannes D., Dutch
Von Laue, Max, German
Wilson, Charles Thomson R., British
Young, Thomas, British
Zeeman, Pieter, Dutch



Leo Szilard

1898-1964

On his plaque is written: *Leo Szilard, brilliant physicist, was born here on 11 February 1898. He was one of the founders of the first atomic reactor, and worked tirelessly to prevent the proliferation of nuclear weapons and to promote the peaceful use of nuclear energy.*

In 1942 Leo Szilard and Enrico Fermi set up the first nuclear chain reaction. What does it mean: 'chain reaction'? It is when the break up of a uranium nucleus, triggered by neutron bombardment, releases other neutrons that can trigger more 'fissions' and so on. The energy release in chain reactions is enormous. The chain reaction can be made to proceed slowly and in a controlled manner in a nuclear reactor, or explosively in a bomb.

Leo Szilard was born in Budapest. His father was an architect. His mother devoted herself to her three children and worried about their education. She hired a private tutor to come to the villa daily. At six, Leo could read German, when nine he began to speak French. At the age of ten Leo entered an eight-year high school. He was excellent in mathematics and physics. At the age of 12 he read university textbooks on electricity and tried to repeat all the experiments described in them, including wireless telegraph for communication between remote parts of their house.

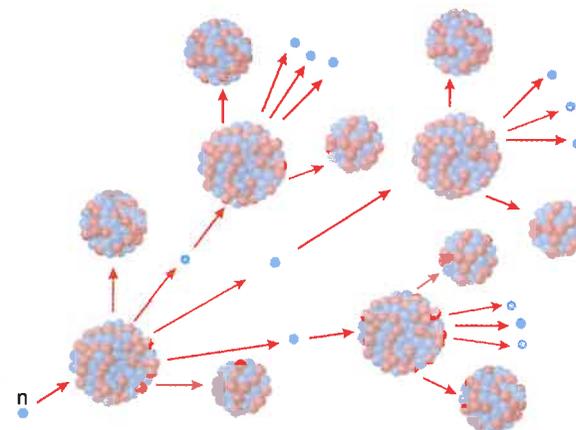
From an early age Leo considered his role as to think and to instruct while others toiled or played with his designs. The only sport Leo seemed to enjoy was ice-skating.

The girls found him handsome and lively but also shy and inhibited, sensing that his mind and his energy were focused elsewhere.

According to his biographies 'humor afforded Leo an escape from emotional pressures and he embraced and nurtured an ironic wit for the rest of his life'.



He enjoyed ice skating



Together with Fermi he set up the first controlled nuclear chain reaction

When Leo was 16 World War I erupted. He studied army engineering in Kufstein (Austria). Sensing the approaching collapse he declared himself ill, traveled back to Budapest and continued to study at the Institute of Technology. Soon the political situation forced him to leave Hungary and he never returned.

In 1920 he found himself in Berlin, the capital of modern physics at that time. After graduating from Berlin University he was 'assistant in theoretical physics' and then, in 1925, he became Privatdozent.

In 1933, the rise of Hitler convinced Szilard, who was Jewish, that he should leave Germany. He fled first to Vienna and then to England. During this period Szilard began to think about the possibility of a nuclear chain reaction. Towards the end of 1938, Leo decided to move to USA. There he participated in the Manhattan Project on the atomic bomb and together with Fermi he witnessed the first controlled nuclear reaction.

Finally he recognized the horrible human tragedy that would result from the use of the atomic bomb. Later Szilard spend a major portion of his time working for the control of the demon he had helped to release: atomic energy.

In the late 1940s, Szilard turned to biology. He developed the chemostat, an instrument that aids in the study of bacteria and viruses by making it possible to regulate various growth factors.

In 1951 Szilard married Gertruda Weiss, whom he had met in 1933 in Vienna, where she was a medical student. The couple had no children. Leo Szilard died of a heart attack in his sleep in 1964.

S.E.

EUROPHYSICS NEWS RECRUITMENT

Contact Susan Mackie • EDP Sciences • 250, rue Saint Jacques • F-75005 Paris • France
Phone +33 (0)1 55 42 50 51 • fax +33 (0)1 46 33 21 06 • e-mail mackie@edpsciences.org



EC-Human Potential Programme
Transnational Access to Major Research Infrastructures
EU Contract No HPRI-CT-1999-00058

European Research with Synchrotron Radiation CALL FOR PROPOSALS

MAX-lab provides researchers from the European Union and Associated States access to the facility through the Access to Research Infrastructure action of the Improving Human Potential Programme.

Researchers using synchrotron radiation are invited to submit proposals for experiments to be carried out during the time period **July 2001 to June 2002**.

Applications must reach MAX-lab at the address given below no later than

February 23, 2001

Application forms and instructions can be obtained by contacting the laboratory at the address given below or they can be downloaded from our web-site <http://www.maxlab.lu.se>

Proposals are selected on the basis of scientific merit by an independent peer review panel. Successful applicants will be allocated facility access free of charge, including logistical, technical and scientific support.

Travel and subsistence expenses for eligible users will be reimbursed. Information on the eligibility of research teams is found on http://www.cordis.lu/improving/src/ari_eligi.htm

General description of the laboratory

The laboratory operates two storage rings for electrons, MAX I (550 MeV) and MAX II (1.5 GeV), which provide synchrotron radiation from the infrared spectral region to the x-ray (1Å) region. Research is carried out in physics, chemistry, biology, materials science and technology. Beamlines and experimental stations are available for experiments utilising various electron and photon spectroscopies, x-ray diffraction and lithography. More detailed information about the laboratory and the available experimental facilities are found at our web-site <http://www.maxlab.lu.se>

Address:

MAX-lab, Lund University, P.O. Box 118, SE-221 00 Lund, SWEDEN.
Fax +46-46 222 4710

Contact person:

Prof. Ralf Nyholm, tel. +46-46 222 4452,
e-mail ralf.nyholm@maxlab.lu.se

EU-Contract Manager:

Prof. Nils Mårtensson, tel. +46-46 222 9695,
e-mail: nils.martensson@maxlab.lu.se

POSTDOCTORAL OR RESEARCH ASSOCIATE POSITION

THEORETICAL CONDENSED MATTER PHYSICS

The laboratory for theoretical solid state physics of the University of Namur, Belgium, invites applications from PhD's in theoretical condensed matter physics for a Research Associateship sponsored by the prestigious Francqui Foundation of Belgium.

The applicant will work, in collaboration with Profs A. Lucas, J.-P. Vigneron and Ph. Lambin, on topics in Reduced Dimensionality Systems such as fullerenes and nanotubes; optical or acoustic band gap materials; theory of local probe microscopy and spectroscopy (STM, STS, SNOM, EELS).

The position is for one year, renewable (max. 2 years). Approximate monthly salary depends on experience, starting from about 55 kBEF net (1 Euro = 40 BEF). The position comes with a functioning budget of about the same net monthly amount to include relocation, lodging, travel, computing, etc...

Please send a CV, a statement of research interests and a list of three referees to:

Prof. A. Lucas
Physics Dpt
FUNDP
61 rue de Bruxelles
B-5000 Namur
Belgium.
amand.lucas@fundp.ac.be



UNIVERSITY OF GENEVA

The Faculty of Sciences has an opening for a position as

**Full Professor or Associate Professor
in**

**THEORETICAL CONDENSED MATTER PHYSICS
(Professeur ordinaire ou adjoint)**

Responsibility: This is a full time appointment comprising at least 6 hours of teaching per week and research activities in the area of condensed matter physics. The successful candidate is expected to conduct a vigorous research programme in the field of theoretical condensed matter physics with emphasis on strongly interacting electron systems.

Degree requirements: Ph.D. or equivalent

Beginning: October 1, 2001, or as agreed

Applications, including curriculum vitae, list of publications, list of references and a short research plan are to be sent to the Dean of the Faculty of Sciences, 30 quai Ernest-Ansermet, CH-1211 Geneva 4 (Switzerland), where further information on this position can be obtained.

Closing date for applications: March 15, 2001.

NB.: In an effort to involve both men and women in teaching and research, the University encourages applications from women.



UNIVERSITY OF GENEVA

The Faculty of Sciences opens a position of

**MAITRE D'ENSEIGNEMENT
ET DE RECHERCHE**

Responsibility : This is a full time appointment, comprising 6 hours of teaching per week and research in the area of theoretical physics and mesoscopic physics.

Titre exigé : Ph.D. or equivalent. Teaching and research experience.

Beginning : 1st October 2001

Applications, including curriculum vitae, list of publications and a list of references are to be sent by the 30rd April 2001 to **Director, Department of Theoretical Physics, University of Geneva, 24, quai Ernest Ansermet, 1211 Geneva 4, Switzerland**, where further information on this position can be obtained.

NB : In an effort to involve both men and women in teaching and research, the University encourages applications from women.

**The Niels Bohr Institute for Astronomy,
Physics and Geophysics
University of Copenhagen
Faculty Renewal Program**

Associate Professor in Experimental Atom Physics

As part of its program of faculty renewal, the Niels Bohr Institute for Astronomy, Physics and Geophysics (NBIfAFG) announces the availability of a position as **associate professor in experimental atom physics**. The position will be open from August 1, 2001. The NBIfAFG constitutes the physics department of the University of Copenhagen with a faculty of 70. The Institute has experimental activities within atom physics and optical physics, directed at studies of very cold atomic systems and quantum optics. The Institute has extensive experimental equipment for laser cooling of atoms. The activities include international co-operation programmes, such as EEC networks. Consecutively with this, theoretical studies are carried out at the Institute and NORDITA, specifically aimed at the physical properties of the Bose-Einstein condensates. Furthermore the Institute has an active group within nano physics.

Applicants must have an independent research profile, which can support and complement the Institute's current activities in the above-mentioned experimental area, especially in relation to the studies of very cold atom physics. The position involves participation in all facets of university teaching, and the successful candidate must be able to teach undergraduate physics courses in Danish within two years of appointment.

In accordance with the Ministerial Circular on Job Structure, appointment to the position of associate professor requires documented scientific production at an international level. In the event that the applicant lacks sufficient teaching experience through an appointment as assistant professor or acquired corresponding teaching experience, the appointment will be probationary for a period of up to 1 1/2 years.

Terms of appointment and salary are set by agreement between the Ministry of Finance and AC (The Danish Confederation of Professional Associations on Academics in the State). In addition to salary based on seniority, the successful applicant will receive an annual pensionable supplement of DKK 65,951.63.

Applicants will be considered for appointment without regard to race, sex, national origin, or religion.

The deadline for applications is noon March 9, 2001. This announcement is an extract of the full legal announcement. The latter must be followed and can be found on the Institute homepage: <http://ntserv.fys.ku.dk/afg/> or obtained from the Personnel Office (Phone +45 3532 2645)

The key to better engineering lies in the knowledge of imperfections in materials

The Faculty of Applied Sciences, one of TU Delft's seven faculties, is comprised of the departments of Biotechnology, Materials Science & Technology, Chemical Technology and Applied Physics. The Faculty is currently seeking:

Professor (full time)

Phenomena at Surfaces and Interfaces in Materials

You will head a group engaged in advanced and fundamental research on the formation and manipulation of structures and microstructures in materials, i.e. at boundaries, interfaces and surfaces. This focus of research combines well with the growing importance of materials technology at a nanoscale. You will have the opportunity to select specific materials science research subjects. You will supervise M.Sc. and Ph.D. students, and postdocs, and contribute to the educational programme and the management of the faculty.

Our preferred candidate is an scientific researcher with a Ph.D. in Materials Science, Physics or Chemistry, with a true interest in the combination of fundamental and applied research, and with an established international reputation in the field.

You are an inspiring teacher with an interest in educational tools making use of modern media. You possess good managerial skills.

The Phenomena at Surfaces and Interfaces in Materials Group is part of the Materials Science & Technology Department. The Department focuses its research on the evolution of the microstructure and its relation to materials properties, primarily of metals and polymers, with some additional activities on inorganic materials.

TU Delft offers: The conditions of employment and salary conform to the provisions of the collective bargaining agreement for Dutch universities.

Your application: Please send your application letter (indicating TNW 0072), together with a curriculum vitae and a list of publications, to the Personnel Department of the Faculty of Applied Sciences, Lorentzweg 1, 2628 CJ Delft, or by e-mail : g.boukhcibi@tnw.tudelft.nl

For information:

Information about the position can be obtained by contacting Prof.dr.ir. S. van der Zwaag, e-mail: S.vanderZwaag@tnw.tudelft.nl , tel. direct: +31 (0)15 2782248, private: +31 (0)172 477189, secretary: +31 (0)15 2783976.

For general information, contact Mr M. van Veen, Personnel Department, e-mail: M.J.M.vanVeen@tnw.tudelft.nl, tel. +31 (0)15 2784405 or 2787004.

Additional information: see www.tn.tudelft.nl under "Jobs"

The Niels Bohr Institute for Astronomy, Physics and Geophysics University of Copenhagen Faculty Renewal Program Associate Professor in Theoretical Subatomic Physics

As part of its program of faculty renewal, the Niels Bohr Institute for Astronomy, Physics, and Geophysics (NBIfAFG) announces the availability of a position as **associate professor in theoretical particle physics or theoretical nuclear physics**. The position will be open from January 1, 2002. The NBIfAFG, which constitutes the physics department of the University of Copenhagen, with a faculty of 70, has a strong position in theoretical particle physics and nuclear physics with connections to astrophysics and to the physics of complex systems. An extensive guest program, run in close co-operation with NORDITA, supports these theoretical activities. The Institute has experimental programs, which include relativistic heavy-ion physics and participation in the ATLAS-project at CERN.

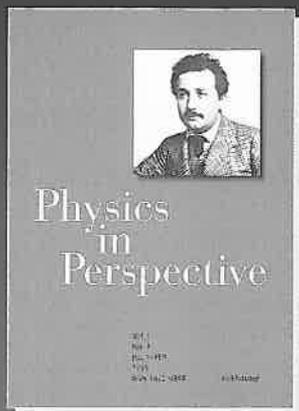
Applicants must have an independent research profile, which can support and complement the Institute's current activities in the above-mentioned theoretical areas. This position involves participation in all facets of university teaching, and the successful candidate must be able to teach undergraduate physics courses in Danish within two years of appointment.

In accordance with the Ministerial Circular on Job Structure, appointment to the position of associate professor requires documented scientific production at an international level. In the event that the applicant lacks sufficient teaching experience through an appointment as assistant professor or acquired corresponding teaching experience, the appointment will be probationary for a period of up to 1 1/2 years.

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Applicants will be considered for appointment without regard to race, sex, national origin, or religion.

*The deadline for applications is **noon April 30, 2001**. This announcement is an extract of the full legal announcement. The latter must be followed and can be found on the Institute homepage: <http://ntserv.fys.ku.dk/afg/> or obtained from the Personnel Office (Phone +45 3532 2645)*



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Physics in Perspective (PIP) was created to convey to a broad spectrum of readers a deeper understanding and appreciation of the way physics is conducted, of its content and application, and of the profound influence that physics has had in changing our conception of the natural world and in shaping our modern scientific and technological culture. The journal strives to deepen the reader's physics "literacy" and thereby bridge the gulf between the physicist and the non-physicist by encouraging the publication of historical and philosophical studies. Moreover, there will be biographical accounts, review articles and close-ups on specialized topics. They will have one common quality: the power to make the results of historical and philosophical studies in connection to physics vibrant and exciting to physicists, teachers, students and the public at large.

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The Institute of Physics' landmark event for physicists world-wide

March 18-22, 2001

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The Institute of Physics' Annual Congress is for physicists everywhere. An extensive programme of scientific conferences combined with exhibitions, meetings on science policy, activities for physics students and a lively social programme makes this the best opportunity for physicists to meet their colleagues and to discuss their subject. A single fee covers most conferences (£10/day Institute student members, £45/day Institute members, £95/day non-members). Many events are free of charge. See the first flyer insert with this issue of *Physics World* or contact the Conferences Department at the Institute of Physics address below.

Conferences

Future of technological plasmas; Polymers in drug delivery; High speed imaging and image processing; The physics of materials in sport; Managing risk in high-tech markets; The physical environment and health; Optical techniques for sensing; Innovative approaches in undergraduate teaching and learning

Exhibition

The UK's largest exhibition of physics related equipment and service will run alongside Congress. Focusing on optics and vacuum technologies plus a programme of key workshops.

Plenary lectures

By Andrew Rickman, Chief Executive of Bookham Technology; Lord Sainsbury, Minister for Science; and Sir Martin Rees, the Astronomer Royal

Policy seminar

Benchmarking, quality assurance, the UK's national qualifications framework and other issues of topical concern for university physics departments.

Activities for physics students and recent graduates

Poster and lecture competitions, social events and more.

Public and schools' programme

Interactive physics for all; a cybercafé; and a Family Fun Physics Day. Throughout the week an extensive programme of talks and demonstrations covering chocolate, lasers, juggling and other fascinating applications of physics. INSET training days for teachers of physics at Key Stage 4, both specialist and non-specialist. Interactive, hands-on science for pupils aged 10-12 with lectures and activities for older pupils.

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