9th EPS GENERAL CONFERENCE

Florence, 14-17 September 1993

Shifting the Emphasis

The EPS-9 opening ceremony was the occasion to celebrate the Society's 25th Anniversary and it was in this spirit that P. Blasi, the Rector of the University of Florence, welcomed the participants. G. Salvini, President of the *Accademia Nazionale dei Lincei*, then took up the theme of the unity of physics. The aim of physics is unity in all aspects. A strong EPS is needed for this so one must thank the Society's founders (G. Bernardini — the first President — speaking later gave a sprightly and vigorous account of how he remembered the early years, especially colleagues). The basic point is that people must work together and, recalling discussions about the SSC collider in the USA, not simply strive to agree on major programmes and facilities. C. Rizzuto, Director of the *Consortio Interuniversitario Nazionale per la Fisica della Materia* (INFM) who represented Italy's Minister for Research and the Universities, desribed from his viewpoint as chairman of the CODEST physics panel how these interactions are promoted by the European Community's Human Capital and Mobility programme.

Short but warm statements by N. Cabibbo, President of the *Ente per la Nuovo Tecnologie, l'Energia el'Ambiente* (ENEA) and by L. Maiani, President of the *Istituto Nazionale di Fisica Nucleare* (INFN), congratulating EPS on its 25th Anniversary, were followed by G. Chiarotti, Chairman of the Physics Committee of the *Consiglio Nazionale delle Ricerche* (CNR), reminding the audience that physics figures strongly in CNR activities (20% of the CNR budget with nuclear physics handled by the INFN). However, his organization often faces what he called "hints" — hints that science should move more towards applications; hints that it should be useful to the community at large. Such hints are important and must be acted on. However, science can only develop if it nourishes its own criteria, both scientific and cultural (freedom of choice, freedom of individuals). But in doing this one must nonetheless recognize that it is still necessary to find motives for developing specific branches of science, specifically at the EC level which is gaining importance but where science seems to be ignored.

The outlook for physics was taken up by A. Zichichi, the EPS President in 1978-80, who argued that in spite of all its successes physics is under "heavy attack" and is not doing enough to defend itself, preferring instead to take for granted the resources it enjoys. The community must react by sending out clear messages stressing that it has control of what it is doing; that it works in a structured way to tackle fundamental problems. Physics will thereby demonstrate that it does not take for granted the world around us, notable its pollution where an "environmental holocaust" is conceivable. He urged physicists to speak up out about environmental issues: the community should propose projects and seek the public's "direct support". The EPS can meanwhile play a major rôle in this "cultural clarification". Indeed, N. Kroó, the EPS President, in closing the ceremony by outlining the new challenges, spoke of how EPS will be governed by society instead of by research. But the spirit of Florence must be kept alive in addressing new goals, such as strengthening Divisional activities and helping parts of Europe reestablish themselves.

Left, upper: sitting in the front row at the EPS-9 opening ceremony were (from left to right) A. Zichichi, G. Salvini, G. Chiarotti, and C. Rizzuto.
Left, lower: L. Maiani, the President of INFN.
Right, upper: G. Bernardini (on the left) with R.A. Ricci, who chaired the conference.
Right, lower: the Cecil Powell Memorial Medal was presented to W. Buckel by C.A.P. Foxell (on the left) President of The Institute of Physics.

EPS-9 SCIENTIFIC PROGRAMME

Physics at Frontiers

While it is true that the EPS-9 scientific programme maybe did not bring to light radically new physical concepts, such remarks do not do justice to the breadth and scope of today's physics revealed in what **E. Brézin** (ENS, Paris), the Chaiman of the Programme Committee, called a beautiful demonstration of the health of the field. The 17 plenary talks and the 16 parallel sessions made outstanding efforts to render a world composed of frontiers — frontiers in space, time, energy, temperature, and velocity — as accessible as possible. There was discussion of nuclear models, atoms in high-intensity fields, atomic-level probes, light forming patterns, carbon in softer forms and novel structures, chemical reactions at femtosecond scales, and the Universe's unknown matter. Moreover, the sophistication of modern techniques such as parallel supercomputers, thin-film storage media, advanced detectors, and ultra-high power lasers was not overlooked, for experimental capabilities are probably advancing more rapidly today than theoretical understanding.

WORKING AT THE ATOMIC LEVEL

The programme began with the continuing developments that are opening up the nanometre world with **H. Rohrer** (IBM, Zurich) highlighting the new frontiers offered by working with individual objects down to the atomic scale. They derive from the radically different nature of the physical processes determining nanoscale properties (*e.g.*, chemical bonding rather than bulk effects control mechanical properties, relaxation times reduced by 1000 times); from the 1000-times larger electric fields that can be supported; and from the dominance of non-classical features (*e.g.*, quantum and single electron effects). Using local probes (Fig. 1) one can handle today only a few aspects (structure, electrical properties, growth and diffusion) of simple model systems in surface science and electrochemistry. The challenge is to go far beyond this to the surface science of real systems involving simultaneous experiments on individual objects that are inhomogeneous at the atomic scale. Later will come tools, processes, sensors, and devices, ending up

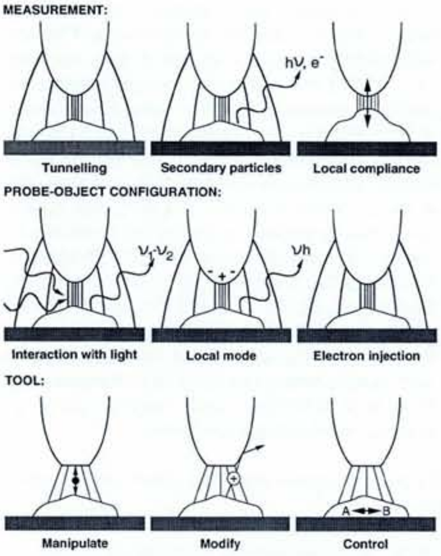


Fig. 1 — Atom probes: some principles and applications.

one day with so-called smart probes involving self-assembly.

Subtle Interplays Decisive

One can also "juggle with single atoms" and according to **C. Cohen-Tannoudji** (ENS, Paris) the great surprise in pushing back the frontiers of techniques to cool atoms to very low temperatures (and velocities in free space) has been the great variety of possible cooling mechanisms, especially those involving interplays between well-known effects involving beautiful applications of the basic laws of conservation. The importance of this work relates not only to the enormous potential for application owing to long interference times, long de Broglie wavelengths and new states of matter but also to the widespread interest from theorists working on quantum dissociation processes, anomalous random walks, quantum Monte-Carlo simulations, and similar topics.

Professor Cohen-Tannoudji illustrated his main point by recalling the history of the laser cooling of atoms. It was known early on that an atomic beam could be slowed down by the radiative pressure of a laser beam and that cooling was needed to reduce the velocity dispersion. Cooling based on the Doppler effect was developed, leading to the clouds of cold atoms (optical molasses) announced by Bell Labs in 1985. Owing to competition between Doppler cooling and heating due to the random nature of spontaneous emission, workers argued that there was a minimum temperature (the Doppler limit). Surprisingly, measured temperatures were much lower. Laser cooling was thought to be involved and new cooling mechanisms were proposed. The first were based on the multilevel structure of the ground state of alkali atoms combined with laser polarization gradients which cannot be avoided in experiments performed in three-dimensions. The outcome was a 1991 report by the ENS group that an optical light-shift method based on adjusting the laser intensity and detuning gave temperatures of 2.5 μK (corresponding to 12.5 mm/s), close to the predicted value of < 2 μK or $\approx 1\%$ of the Doppler temperature. This particular method, others have been developed, is called Sisyphus cooling since the atom is always climbing a potential hill.

Quantum limits intervene so one cannot cool atoms indefinitely. Calculations by the ENS group reported in 1991 showed an unusual situation whereby the (quantized) energy levels at the quantum limit for a laser-cooled neutral atom were well resolved, with about 50% of the cold atoms localized in the vibrational ground state (*i.e.*, in the two lowest bands). The first observation of these quantized levels in a neutral atom in an optical field followed shortly using the absorption (or amplification) of a weak laser beam to probe a 1-d optical molasses of Cs atoms. Confirmation came in 1992 with a fluorescence study of a Rb molasses. By early 1993, groups at the ENS and in Germany reported the first observation of quantized atomic motion and confinement in an optical molasses, where the cold atoms are bound to a regular array of wells in the optical potential formed by standing waves (an optical lattice or crystal; Fig. 2). The next step will be to see what happens on increasing the atom density so that statistical effects come into play upon multiple occupancy of sites (hence the interest for theorists in other fields).

Regarding applications of cold atoms, a first step has been made towards an interferometer of the Fabry-Pérot type for atomic de Broglie waves because the ENS group has demonstrated multiple bouncing of a cloud of Cs atoms on a reflective surface of useful size (previous work only demonstrated two bounces). While the interferometer is far off, the mirror configuration may serve as a trap for atoms analogous to other neutral particle storage devices (hydrogen maser, neutron bottle). Regarding atomic frequency standards, the Cs atomic fountain clock's precision has been improved using velocity selection [see *EN* **24** (1993) 204] and a next step plans to use microgravity conditions to extend the lifetime of the cold atoms.

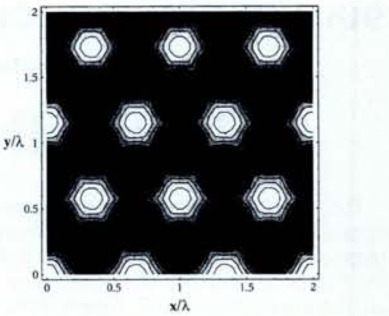


Fig. 2 — Optical lattice: calculated spatial dependence of the optical potential for a 2-d molasses geometry produced using three coplanar laser beams of equal intensity. Minima (dark regions) of the potentials wells are located on a hexagonal lattice. [Grynberg C. et al., Phys. Rev. Lett. ***70** (1993) 2249.]*

From the left, Ph. Choquard, Y. Imry and H. Rohrer.

A. Aspect (on the left) and C. Cohen-Tannoudji.

THE ONE-ELECTRON LIMIT

Physics at the microscale enters the commercial world of electronics as it moves towards the 100 nm transistor. The wave nature of the electron is fundamental in these so-called mesoscopic systems where the electron phase coherence is preserved at a scale much larger than atomic dimensions. **Y. Imry** (Rehovot) pointed out that many non-trivial phenomena emerge including dephasing and quantization of conduction, perhaps the most remarkable being the observation in 1992 of steps in current-voltage curves that are a direct manifestation of pairing in the superconducting ground-state (Fig. 3). But developing the basic understanding of mesoscopic effects has not been plain sailing. For instance, many doubted that persistent currents arose in small conducting rings threaded by magnetic flux until a group at the Bell Labs measured in 1990 the current in an array of 10^7 copper rings of 0.5 μm diameter. However, the current was 100 times greater than predicted and among the many attempts to resolve this discrepancy, an approach based on the effect of local charge neutrality appears promising.

It has been learnt that there is a tremendous difference between elastic and inelastic scattering (the former gives well-defined phase shifts with complicated interferences, the latter phase uncertainty with no interference), that one must distinguish self-averaging from sample-specific effects, and that there are some remarkable universalities owing to universal correlations in spectra of complex objects (in other words, once a system is complex is enough it satisfies some universalities). Here the scattering matrix

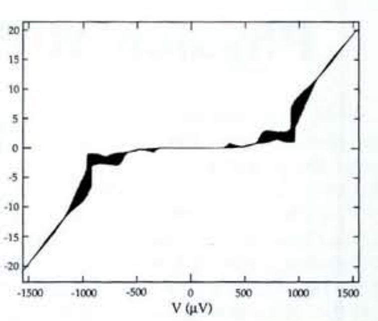


Fig. 3 — A plateau on a current-voltage curve for an Al-Al_2O_3-Al single-electron tunnelling transistor in the superconducting state results from the tunnelling of a Cooper-pair. [Tuominen M.T. et al., Phys. Rev. Lett. ***69** (1992) 1997.]*

describes transport, Hamiltonians the thermodynamics, and the relaxation matrix the spectrum of relaxations. Many unnecessary papers were inspired by the transition from pure quantum behaviour to classical behaviour (how the inelastic scattering of electrons washes out). The dephasing part of electron-electron interactions is now understood: a phase uncertainty destroys interference when one of two parallel partial waves flips the environment to an orthogonal state.

In general, mesoscopics has shown that one can work at a one-electron level even though there are 10^7 electrons in the system: whether or not this level of sensitivity is useful remains doubtful.

F.T. Arrechi (on the left).

From the left, M. Key, Mrs. Bradley and P.L. Knight.

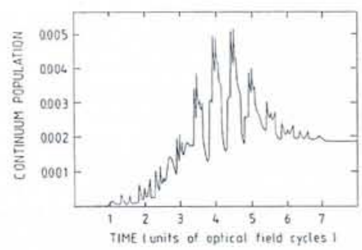


Fig. 5 — Suppression of superintense-field ionization of atoms. The figure shows the calculated ionization yield for an 8-cycle pulse may only reach 0.18% if the laser is tuned appropriately. This value is 12 times less than calculated yield for a laser tuned to give conventional wave packets where there is substantial overlap of superperimposed excited Rydberg states with the nucleus to allow enhanced ionization. The stabilization arises because the laser pulse forms spatially extended superimposed states where the electron's wave function has a vanishing amplitude at the ion core at the end of the pulse. At this time, and at the periodic recurrences of the vanishing amplitude, ionization is largely precluded. [Burnett K. et al., Phys. Rev. Lett. ***66** (1991) 301.]*

LASERS EXTEND LIMITS

Optical Patterns as Metaphores

Interest in pattern formation in nonlinear optics comes from its use as a metaphore for similar phenomena in other areas of physics (chemical waves, fluid dynamics, quantum mechanics, *etc.*). By providing real-time control of pixels of information it is also the basis for advanced optical and parallel computing systems. As in fluid dynamics and chemical diffusion, optical patterns arise from the interplay between gradient and non-linear terms but it was only in 1991 that clear evidence was reported for spatial instabilities in the structure of electromagnetic fields transverse to the direction of propagation. **F.T. Arrechi** (INO, Florence) described two experimental approaches based on plane-wave perturbation using a phase medium placed in front of a mirror illuminated by a laser and eigenfunctions (or modes) produced in thin-cavity superimposition. Using the first, good agreement between theory and experiment has been found for the transition from hexagon- to roll-like patterns (Fig. 4). A theory based upon a simple system of two coupled partial differential equations (a diffusive one for the refractive index and a diffractive one for the optical field) accurately describes the effect of varying the laser intensity on the stability of the patterns (in a parallel computing scheme, each pattern would constitute an element).

For the second approach, a ring-cavity oscillator has been constructed with a signal beam passing through a laser-pumped photorefractive crystal. Analysis of the wave front shows that patterns compete in a regular way on changing the size of the cavity pupil. Symmetry arguments suggest there is some universality in the interplay between the various modes that may apply in other fields. Different observation techniques (*e.g.*, phase detection) are needed to monitor more complex patterns such as vortices which transform into dislocations. But what is theoretically very interesting is that one is dealing with phase transitions that depend upon an extensive parameter rather than an intensive one, where the transition is from strong to weak confinement as the parameter is varied.

Electrons in Super-Intense Fields

Referring to high-intensity lasers as being in the petawatt class highlights the new limits being explored in fundamental electron physics using roughly 1 J/1 μm in diameter laser pulses of picosecond duration that can now be delivered by table-top systems. **P.L. Knight** (Imperial College, London) described the components and principles needed to do achieve this performance, taking as an example the system built in his lab. As it is difficult to amplify high-frequency pulses without damaging optical elements, the trick is to use chirped pulse amplification. Multiphoton processes are prominent among the physical phenomena being explored. They were predicted in 1931 and induced (as opposed to spontaneous) emission in hydrogen was first observed, by accident, in 1950 in RbF. They remained "something of a novelty" until the late-1960's when lasers meant one could do things that were done with RF fields, only more precisely. Since then there has been continuous interest in the behaviour of atoms under strong irradiation. Work was spurred by the availability of very short pulses where the laser-atom interaction is comparable to electron binding energies.

Ionization over a large range of laser intensities is proportional to the intensity, but not

Fig. 4 — A transition from rolls, hexagons to hexagons + rolls in an optical diffractive system on varying the input intensity. [Pamploni E. et al., Europhys. Lett. ***28** (1993) 647].*

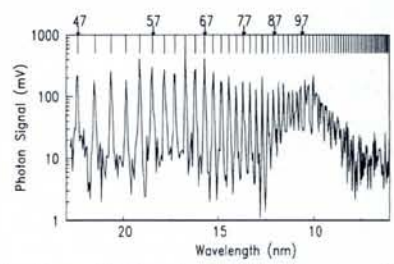
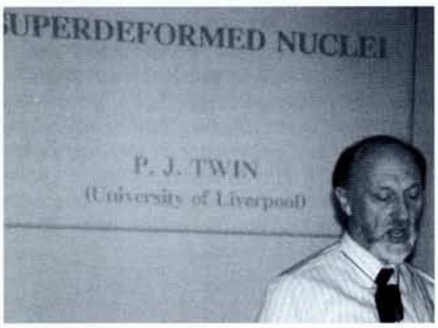


Fig. 6 — High-order harmonic generation in rare gases: the spectrum is for Ne gas jet at 40 Torr struck by a 1 ps, 1053 nm laser pulse with an intensity of 1.5 x 10^{15} W/cm^2. [L'Huillier A. & Balcou Ph., Phys. Rev. Lett. ***70** (1993) 774.]*

indefinitely. High-intensity, short-pulse ionization will at some point differ markedly from ionization with longer pulses because the larger laser bandwidth may coherently excite several atomic states. Different types of stabilization against photoionization have been proposed but experimental confirmation of the predicted effects for neutral atoms is difficult because it is very hard to fulfill the condition that the photon energy is comparable to the binding energy of the atomic state. This is not the case for excited states where predictions (Fig. 5) start to be confirmed.

Another effect, first observed in 1987, is the disappearance of the lowest energy photoelectron peaks in the multiphoton ionization of rare gases. Some argued that this effect results from the pondermotive potential (the amount by which the energy of a free electron is raised in a light field). Very recent work has shown for the first time that the full pondermotive shift for both neutral atoms and Cl^- ions is indeed equal to the threshold shift (working with negative ions offers major simplifications for these types of experiments). This research ushers in the world of "wiggle dominated" atomic physics.

A second type of phenomenon concerns high-order optical harmonic generation (OHG) with single-shot laser pulses. As in above-threshold ionization, the bound electron absorbs many more photons from a stronger laser field than the minimum number for weak-field ionization, but instead of ionizing the electron emits a shorter wavelength photon and makes an optical transition back to the lower bound state. Harmonics well above the 100th have been observed (Fig. 6) in various rare gases using a range of laser wavelengths. Experiments at Saclay have recently confirmed a simple formula showing that the harmonics cut off when the system reaches the maximum energy it can absorb. Coherent light emission by OHG processes will undoubtedly lead to the the development of bright, short-pulse sources of coherent radiation in the soft x-rays so one can contemplate doing work on non-linear optics in this wavelength range.



THE LIMITS OF NUCLEAR MODELS

Before describing how the spectroscopy of superdeformed nuclei is being used to probe the limits on nuclear models using data provided by advanced detector arrays, **P.J. Twinn** (Liverpool) reviewed the history of superdeformation (SD). It started with the astonishing discovery in 1986 of γ-ray spectra comprising lines of constant spacing (a "picket fence") for the SD band in ^{152}Dy resulting from a heavy-ion fusion-evaporation reaction. Analogous to the fission ionmers observed in 1962, three regions of superdeformation have been found so far.

Detectors are evolving from the original TESSA 3 array of Ge detectors with a full peak efficiency of 0.5% at γ-ray coincidence used for the discovery. Mapping the life histories of the nuclei after neutron boil-off shows that only a few cascades involve SD bands (0.5% in ^{152}Dy). So while high-spin spectroscopy allows fine details of the underlaying shell structure to be examined for the first time, the fact that weak cascades of γ-rays must be identified within an enormous electromagnetic flux means that little is known about the mechanisms for the population and depopulation of SD bands. The situation is now starting to change. The French-UK EUROGAM I partially spherical array of 45 large co-axial Ge detectors giving a full-energy peak efficiency of 4.5% which operated for the first time in October 1992 at Daresbury has increased the observational limits by about 5% in spin (to 67 h - Fig. 7). A further increase is expected when the spherical array is completed with 24 highly efficient clover detectors (EUROGAM II: 7.5% peak efficiency) and operated in Strasbourg in early-1994. Meanwhile, Italy stared operating GASP (40 Ge detectors; 3% efficient) in June 1992 and the USA's Gammasphere array competitive with EUROGAM II should start operating in 1995. Finally, a next-generation array called EUROBALL III with about 260 individual detectors (12% peak efficiency)

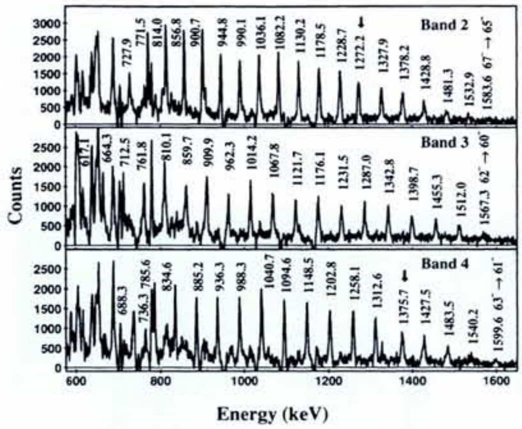


*Fig. 8 — Triple-coincidence spectra from EUROGAM I of 3 bands in ^{150}Gd: transitions (marked with arrows) from 55⁻ to 53⁻ states in bands 2 and 4 are highly perturbed (shifted in energy) due to band interaction. [Beausang C.W. et al., Phys. Rev. Lett. **71** (1993) 1801.]*

is being studied for completion in 1996 by a collaboration from 7 European countries.

First results from EUROGAM illustrate that clear signals are emerging from the background noise, confirming that a variety of new experiments can be envisaged for the first time. One issue is the single-particle picture. Is it correct and can one identify orbits? The study of nuclei in the mass 150 region with its long regular sequences of γ-ray emission is particularly interesting. The variation in moment-of-inertia that can be traced back to the occupation of different intruder orbitals with high principle quantum numbers N is beginning to provide a new conceptual framework. For example, the structure of excited SD bands usually involves the occupation of differing numbers of intruder orbitals through particle-hole excitations. Bands within the same nucleus may therefore have different intruder configurations, one result being that the energies of several γ-rays from SD bands are shifted owing to the interaction between bands at nearly degenerate levels (Fig. 8).

Time was too short to go into all the details of phenomena which are just beginning to be opened up, such as identical SD bands with the same microscopic configurations, and the reason why proton pairing correlations do not show up in these nuclei (pairing is known to be significantly stronger in odd-mass nuclei). Pseudo-spin is under under study, along with higher symmetries (first evidence in ^{149}Dd from EUROGAM I; thought to be due to tunnelling between two orientations of the SD shape), de-excitation out of SD bands (the decay from SD to normal bands is observed to be much faster than expected so it maybe involves tunnelling). New, accurate date on excited SD bands shows that the decay-out spin is the important quantity so static neutron pairing correlation is starting to play a rôle, thus opening up the question of correlation. Finally, studies of the feeding of SD bands in ^{152}Dy using different heavy-ion reactions is being used to probe high-spin reaction dynamics. There is evidence that the SD nucleus remembers how it was formed, suggesting that the hot compound nucleus model that lies at the heart the heavy-ion fusion-evaporation route to producing SD states is not the whole story and that there exists another reaction mode. If all this is not enough to wet one's appetite, there may exist collective ("banana") modes of motion and hyperdeformed "peanut-shaped" nuclei.

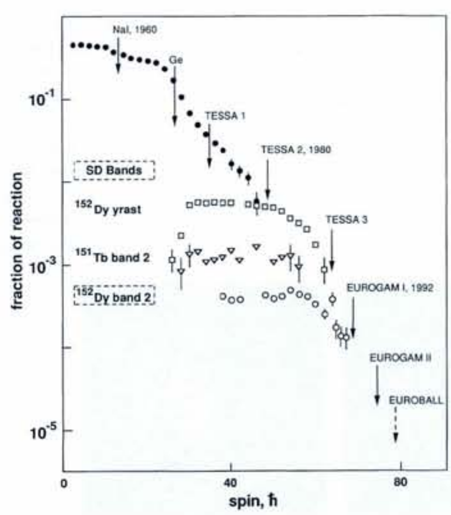
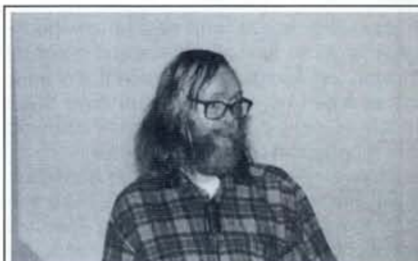


Fig. 7 — The observational limits of γ-rays for various detector arrays.



J.R. Ellis

TOWARDS THE BEGINNING

Cosmology: A Health Warning

Turning to enormous distance scales, **M.J. Rees** (Cambridge) described recent progress in cosmography showing that the structure of the Universe within about 3 x 10^8 light-years of us is not fractal in nature but has major aggregates (Fig. 9) with the largest structures having scales up to a few percent of the Hubble radius R_H. Such results imply that simple homogeneous models of the Universe are adequate; they are made possible by technical progress (notably in detectors based on CCDs) that allows modern astronomers to probe 90% of the Universe's life by observing amongst other objects, quasars out to a record redshift of 4.89.

But did the Universe's structure as we know it emerge from the Big Bang? Estimates of the relative abundances of ^{7}Li, ^{3}He and ^{4}He for primordial nucleosynthesis and the COBE satellite's beautiful cosmic background spectrum showing near-perfect ($\leq 10^{-4}$ deviation) black-body radiation provide strong support. However, some results could refute the "standard" hot Big Bang fireball, notably the discovery of objects with less than 23% ^{4}He and the fact that the mm-wave background is weaker than the black-body extrapolation. Nonetheless, the consensus is that Big Bang model is "often in error but never in doubt".

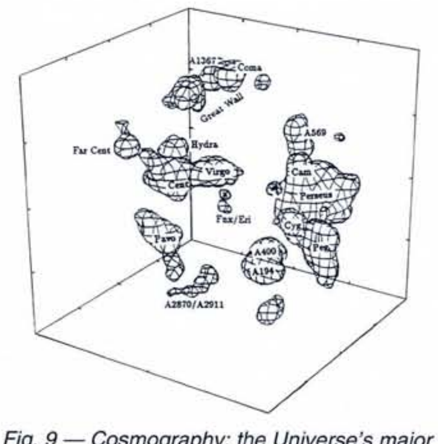


Fig. 9 — Cosmography: the Universe's major aggregates within ≈ 3 x 10^8^ light years. Plotted are the largest regions with normalised density differences greater than unity. They have scales <1% of the Hubble radius.

The general trend is to place several problems relating to the early Universe in sharper focus. For instance, it seems dark matter exists, but how much is there and where is it? These are major questions for the 1990's. Another trend is to refine simulations. It is thought that density differences in the Universe result from quenching out by gravity instabilities: as the Universe expands, progressively large mass-scales condense (smaller structures merge) so that the largest bound systems will have formed from peaks in the initial fluctuation spectrum. Simulations predict different distributions of dark matter depending on the type of dark matter (Fig. 10), but they need to be refined as introducing dynamic and other non-linear effects is difficult. There is also a new line of attacking the galaxy formation problem which involves angular fluctuations, hence the importance of new measurements of the cosmic background.

Constraints on the primordial fluctuation amplitudes on various scales are another major issue. Various objects give estimates (Fig. 11) which can be fitted by a "first guess" model to within a factor of 2. But a better fit requires a tilted spectrum and/or 30% of dark matter as neutrinos with a mass of about 10 eV. What is needed is to extend the data to large and small scales to address questions such as the nature of dark matter and the reason why the Universe set off with metric fluctuations of about 10^{-5} on all scales (*i.e.*, homogeneously). And where did the fluctuations come from? Generally speaking, in working out how the Universe evolved it is useful to think in terms of a very early stage ($< 10^{-3}$ s) of cosmic history involving uncertain and speculative physics. Then comes the standard, hot big bang fireball (10^{-3}-10^{13} s), involving well-known, basic microphysics. This is followed by the post-recombination stage leading to galaxies, clusters, *etc.* which is complex owing to non-linearities. In view of this sequence, Professor Rees ended with a "health warning" to those who mix up what is well known with what is not in attempting to popularise cosmology.

The Frontier is Dark

J.R. Ellis (CERN), although handicapped by a broken arm, gave a very thorough overview of the issues involved in understanding known and unknown forms of matter. Regarding Big Bang nucleosynthesis, he repeated that except for the ^{4}He deficit, there is good qualitative agreement between observation and theory for the abundance of light elements in the Universe, but that there are too few bayrons to give a critical nucleus. The idea of an inflationary cosmology which accounts for the homogeneity of the Universe agrees with the COBE satellite data so one seems to be going in the right direction. Hearkening Professor Rees's remarks about the importance of understanding dark matter (DM), he showed that a "running" model based on 70% hot DM and 30% cold DM fits all the available data for the composition of the galactic halo. As there is only one sure candidate for HDM (namely massive neutrinos) but several for CDM it is probably more important to search for massive neutrinos in the laboratory (CERN is preparing two experiments — NOMAD and CHORUS — and is exploring the possibility of directing a neutron beam from the proposed LHC machine to a detector located underground at the Gran Sasso to look for neutrino oscillations). Of the CDM candidates, one is mainly interested in looking for the neutralino — a supersymmetric particle — and WIMPS, the main strategies being annihilation on the galactic halo (no longer interesting), capture by elastic scattering in the Sun or Earth to give high-energy neutrinos that are detected underground (not sensitive enough), inelastic scattering, and elastic scattering on heavy nuclei in the laboratory for which shell-model calculations have been carried out. The interaction with F nuclei remains very promising and a Ge experiment is being prepared in the USA.

Regarding trends in particle physics, **C. Rubbia** (CERN) essentially gave a report (summarized on page 224) of the status as revealed by last summer's conferences, notably July's *Europhysics International High Energy Conference* in Marseilles.

No Low-Energy Neutrino Deficit – Probably

Four major experiments (3 radiochemical, 1 direct) which have been running for three years currently address the solar neutrino problem — one of the great unresolved questions for physics. **E. Fiorini** (Milan) summarised the latest situation. We should be patient before concluding too much, but in general it seems that for the relatively easily detected high-energy neutrinos corresponding to minority reactions in the Sun, some 30-50% of the flux predicted by the Standard Solar Model is lacking. One should also be cautious and say that the GALLEX detector at Gran Sasso and more recently SAGE in Russia (in a 1992 run) have observed a "significant signal" which can be accounted for by the low-energy neutrinos from the dominant p-p reaction (this reaction has the advantage that it is relatively insensitive to the Sun's central temperature). Some might stick their necks out and say there is no significant deficit because it seems that if there is one it can be accounted for by small adjustments to the model (although many argue what should be changed in the model — and by how much).

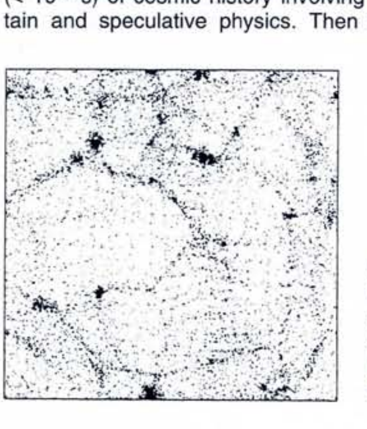


Fig. 10 — The evolution of a co-moving cube of dark matter: this supercomputer simulation for light (≈ 20 eV) neutrinos shows that free-streaming of the neutrinos homogenizes scales of ≤ 10^{15} times the solar mass. Galaxies could form by condensing into the wells of dark matter shown in the figure.

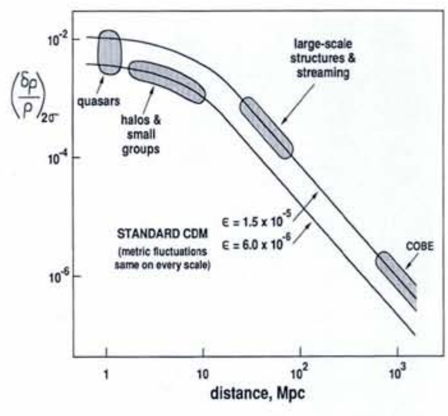


Fig. 11 — Constraints on the primordial density fluctuation amplitudes on various scales: the lines are calculated for a first-guess model with metric fluctuations of 1.5 x 10^{-5} and 6 x 10^{-6}.

Regarding the various experiments, Homestake (mainly B and Be reactions) finds 2.25 ± 0.24 SNU compared with the theoretical 6.4-8.0 SNU and Kamiokande (with a 5.3 keV threshold, so mainly B) gives = 0.50 ± $0.04_{stat} \pm 0.06_{syst}$ for the ratio of the experimental to theoretical neutrino flux. Working at lower energies with Ga detectors, the predicted flux is 125-132 SNU. GALLEX, after some difficulties in cleaning its gallium chloride solution, gives $87 \pm 14_{syst} \pm 7_{stat}$ SNU for the complete set of two years of data, while SAGE, which uses Ga metal from which extraction of the reaction products is more difficult, gives $85 \pm ^{22}_{32} \pm 20$ SNU. Calibration of both SAGE and GALLEX using isotope sources is pending.

While a truly monochromatic neutrino detector is a "dream", there has been some work with geochemical methods to move to much higher energy thresholds. One approach extracts technium produced in molybdenite rock deposits deep underground (320 keV threshold) but unfortunately an experiment in the former Yugoslavia to extract Pb^{205} from corandite is in "bad shape". Some new, much larger laboratory experiments are under construction, notably Superkamiokande in Japan with 50000 t of water and SNO in Canada with 1000 t of heavy water. Not yet fully approved at Gran Sasso are BOREXINO and ICARUS. CERN has proposed a HELLAZ involving 12 t of gas and a Gran Sasso/Moscow collaboration is studying a 860 keV threshold radiochemical experiment based on the conversion of Li to Be and a new type of thermal detector.

Clockwise from (upper, left): E. Fiorini and M.J. Rees (on the right); P.G. de Gennes; W. Krätschmer; P. Wyder.

SOLID STATE SURPRISES

Modest Fields Offers Great Scope

The high magnetic field frontier is not as exaggerated in scale as those tackled elsewhere because the highest fields remain fairly modest (Japanese workers have obtained 280 T for a very short time using an implosive device, and the world-record for a steady-state field B remains the 31.35 T achieved in Grenoble). However, while one may be a long way from imposing major changes to the phenomena encountered, the physics, like all physics, will continue to be stimulating. **P. Wyder** (MPI, Grenoble) demonstrated this in his inimitable way by illustrating some topics. He first reminded the audience that non-linear magnetoresistance remains somewhat mysterious in spite of its notoriety, especially if it is induced in complicated shapes giving inhomogeneous current distributions. Ballistic point-contact special has recently revealed for the first time some beautifully periodic conductance fluctuations (Fig. 12), thereby showing how direct spectrographic information about the influence of electrons scattering and other phenomena on electron interference can be accessed by tuning the energy of the electrons in a magnetic field.

High-T_c superconductors with their high critical fields are a fertile ground for experiments at high fields. Some hotly debated recent work (Fig. 13) in pulsed fields of 100 T shows what is believed to be the de Haas-van Alphen effect (a magnetic susceptibility periodic in $1/B$) consistent with metal-like behaviour with a conventional Fermi surface. But one should overlook the breadth of materials that can be usefully examined. For example, the order parameter of a hard-rod polymer system has been measured in high fields using magnetic birefringence to check the statistical mechanics of the system. Another intriguing area involves the destruction of weak localization in glasses to show that strong localization of light can arise.

As 50% of all the papers published in solid-state physics use high magnetic fields there is clearly a need to keep extending the non-destructive limit. However, P.L. Kapitza who pioneered magnetoresistance studies once said, "it seems that limits are mainly fixed by financial considerations". He is probably right. Nonetheless, there is progress and Professor Wyder described the development of high-field facilities in the USA, Japan and Europe.

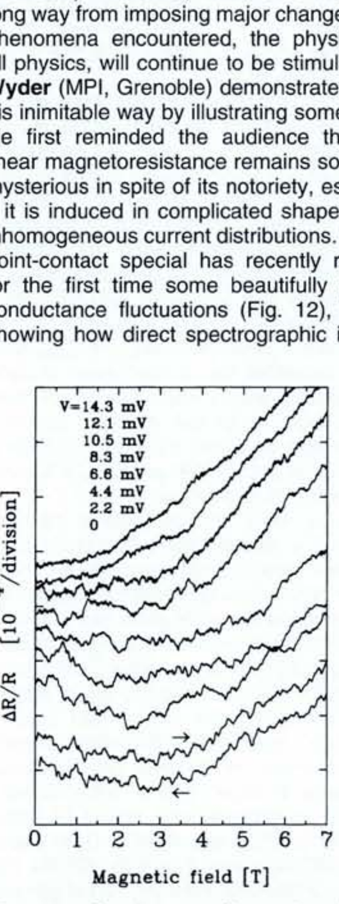


Fig. 12 — Conductance fluctuations in a ballistic metallic (Ag) point contact. [Holweg P.A.M. et al., Phys. Rev. Lett. ***67** (1991) 2549.]*

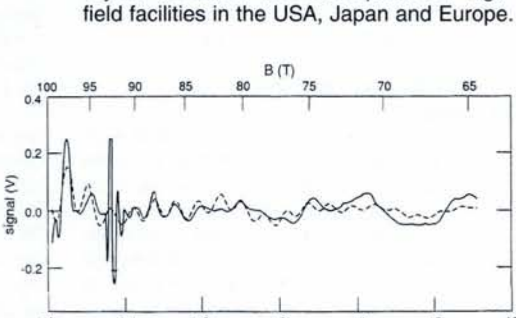


Fig. 13 — The de Haas-van Alphen effect in a YBaCuO high-T_c superconductor measured in a 100 T pulsed magnetic field. The magnetization signal plotted as a function of 1/B is periodic. [Fowler C.M. et al., Phys. Rev. Lett. ***68** (1992) 534.]*

Coming the Full Circle

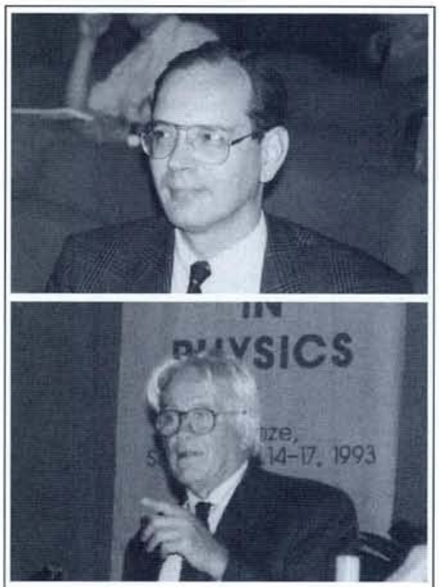
W. Krätschmer (MPI, Heidelberg) gave a fascinating insight into how the C_{60} fullerenes were discovered, and have come the full circle, before describing the perspectives. The "explosive" interest in superconducting properties (alkali-doped materials are superconducting up to ≈ 40 K) will at the very least lead to new understanding because the structures are symmetric. Novel applications are being dreamt of in exotic areas such as medicine delivery. The most important uses may however derive from the ability to synthesis new "elements" based on encapsulating atoms inside fullerenes (*e.g.*, oxidation resistant encapsulated La). Moreover, the field may extend because there have been reports recently that MoS_2 can also form closed cages (although carbon remains the only element known to do this).

The discovery of C_{60} has also brought astrophysics and chemists together. Indeed, the original aim of the research concerned interstellar dust and efforts to understand the origin of a prominent peak at 217 nm in interstellar absorption spectra. Carbon was know to exist in meteorites and the like so it was natural to attribute the peak to graphite particles and to measure the optical absorption of soot produced in the laboratory by vacuum evaporation. However, by 1982 many had lost interest in comparing the interstellar absorption curve with those for laboratory samples because there remained a large unresolved discrepancy. The breakthrough came in 1984 when workers at Exxon measured the cluster spectrum of quenched soot; peaks were found and confirmation in 1985 showed the predominance of C_{60} and C_{70}. It only took a few days to work out that one was dealing with a closed-cage structures, each differing from the next by two atoms (all the way up to large units — C_{540} has been discovered recently). Workers then returned to the absorption curves where it had been noticed previously that evaporation at higher pressures gave a series of small peaks superimposed on a broad curve. Experiments with C_{60} showed four very distinct, narrow absorption peaks in the infrared corresponding to four active modes. So it seemed that C_{60} had been in the lab samples all along. The final proof came when the fullerene component separated out from the soot gave three humped features without background.

Technical applications were by now in view, the breakthrough coming when 10-20 μm C_{60} crystals were produced by filtering and drying soot dissolved in benzene. Diffractometry revealed a close-packed arrangement of balls in rotation but identifying the atomic stucture of the balls came much later. This work, and the mass spectrum published in 1990, triggered huge activity. Chromatography techniques have since been refined to the extent that left- and right-handed forms of C_{76} have recently been isolated (comparisons of their chemical properties will be interesting). Other workers learnt how to prepare macroscopic forms such as 1 μm long "buckytubes" composed of nested cylinders. The chemical properties depend on the diameter and helicity (attractive for the chemists). Wires can be made by filling the tubes and "bucky onions" – large, irregular particles (Fig. 14) produced by bombarding soot with electrons – possibly represent the carbon particles sought all along by astrophysics.

Carbon in its Soft Forms

In reviewing physical approaches for describing the properties of polymers, **P.G. de Gennes** (ESPCI, Paris) chose to focus on interfacial behaviours found in colloid stabilization, brushes, glues, and the welding of polymers. They are difficult to describe, and he chose adhesion promoters to bond rubber to carbon black and steel wires to demonstrate his characteristic approaches. The essential question is to know if the performance is enhanced on bonding long-chain promoter molecules to the rubber network instead of leaving them free. One needs to consider cracks at the rubber-reinforcement interface, but analyzing the crack growth is complicated because the promoter molecules span the void behind the crack front. De Gennes elegantly reduced the problem to considering a single promoter molecule spanning the crack, with either a free or bound end in the rubber; the increase in interfacial strength is thus given by the ratio of the chemical to van der Waals forces.



S.B. Luitjens (upper) and G. Charpak.

INTO APPLICATIONS

The storage densities of magnetic and optical recording media continue there remorseless increase with significantly sub-μm^2 bit-areas expected by the year 2000. Such trends come from investing in a broad range of technologies of the types described by **S.B. Luitjens** (Philips, Eindhoven). Thin-film magnetic media are in principle capable of increasing storage densities because the signal output for a given velocity can be

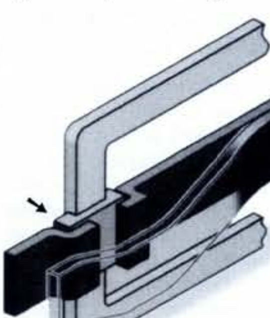
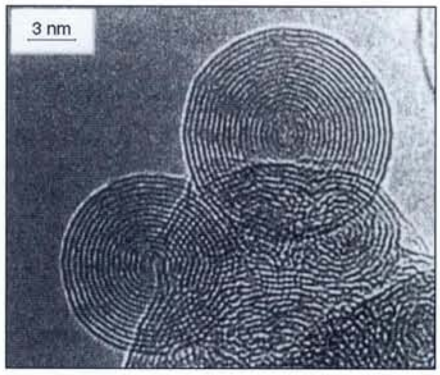


Fig. 15 — An illustration of a DCC read-write head: The magnetorestive element is indicated.



increased. However, noise is also increased so it is necessary to use small, isolated grains to circumvent exchange coupling. There are moves to replace thin-film IC heads in conventional DCC read-write heads (Fig. 15) with multilayer magnetoresistive layers exploiting the giant magnetoresistive effect. The problem is that the resistivity change achieved today is fairly small (15%) at room temperature. Secondly, the change must occur at low field, which can be achieved by introducing non-magnetic layers in the multilayer to eliminate exchange coupling. On the optical side, the most promising way to overcome the limitations in the minimum spot size of the laser beam used to "read" a track is to exploit blue light generated by II-VI based semiconductor lasers. But no one is sure when and how this will be done, so work is continuing with up-conversion and with non-linear optics where easily fabricated, periodic waveguide structures can now deliver blue beams of good quality and sufficient power.

G. Charpak (CERN), in reviewing the imaging of ionizing radiations, also showed how experimental techniques in physics are at the frontier of applications. The widespread availability of synchrotron radiation and rapid developments in detector technology are revolutionizing x-ray imaging. The wire chambers he pioneered, notably gas-filed types and avalanche chambers coupled to scintillators, are now being taken up very vigorously. Other devices include the spherical drift chamber used in Moscow for x-ray protein crystallography and high pressure, Xe-filled wire chambers for nuclear medicine used successfully elsewhere in Russia. But the most significant commercial applications probably concern avalanche detectors of high resolution and sensitivity to replace the tedious photographic imaging of radiochemically labelled electrophoresis gels.

Fig. 14 — Onion-like structure of graphitic particles obtained after electron bombardment of carbon soot. The fringes correspond to the (002) planes of graphite. [Ugarte D., Europhys. Lett. ***22** (1993) 45.]*

V. Tognetti, Chairman of the EPS-9 Local Organizing Committee (on the left) and W. Hebel, DG-XII, European Commission, Brussels.

ADVANCED COMPUTING IGNORED

Frontiers also show up at facilities, including computer systems, the subject of a stimulating overview of trends by **D.J. Wallace** (Edinburgh). He ended with a political message: that without capital investment within the EC's next Framework Programme, Europe will have difficulty remaining competitive in scientific computing. It currently possesses only 20% of the world's top-end supercomputer systems and there is not even one proposal to acquire a state-of-the-art system. Pressure comes from trends in both hardware and software: there is now increasing use of optics in communication systems, with some national systems (*e.g.*, the UK's SuperJanet) implementing optical technologies over long distances: optically amplified systems working at 5 Gbit/s are planned for 1995/6. One is now talking about optical backplanes and considerable multimedia data transfer. Regarding software, compliers for automatic vectorization have matured; tools for parallelising and generating program code are maturing; parallelism is pervasive although Europe's record in joining the high-performance computing technology chain with its clustered workstations, specialised servers, and high-speed networks linking supercomputers is "thin". Finally, one should not ignore improved algorithms as the pay-off can outweigh the benefits of system improvements ("supernatural" scaling is one challenging approach). Individual countries can take up the slack and the UK's strategy of making a parallel supercomputer available for three years is serving as a model.