INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 43 NUMBER 2 MARCH 2003

LHC quadrupole excels in tests

CLIC
Success for novel accelerating structure p6

PHYSICS
Do fundamental constants change with time? p15

NEUTRINOS
ANTARES passes twin deployment milestones p21

Covering current developments in high-energy physics and related fields worldwide

CERN Courier (ISSN 0304-288X) is distributed to member state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August, in English and French editions. The views expressed are not necessarily those of the CERN management.

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UK Mark Swaisland, CLRC, Daresbury Laboratory, Keckwick Lane, Daresbury, Warrington WA4 4AD. E-mail: m.swaisland@dl.ac.uk
US/Canada Published by *Cern Courier*, 6N246 Willow Drive, St Charles, IL 60175. Periodical postage paid in St Charles, IL. Fax: 630 377 1569. E-mail: vosses@aol.com. Postmaster: Send address change to: Creative Mailing Services, PO Box 1147, St Charles, IL 60174

Published by European Organization for Nuclear Research, CERN, 1211 Geneva 23, Switzerland. Tel: +41 (22) 767 61 11
Telefax: +41 (22) 767 65 55

Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK

ISSN 0304-288X

CERN COURIER

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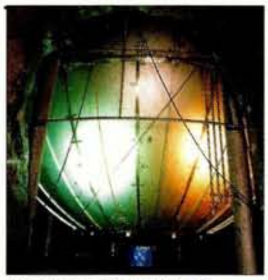
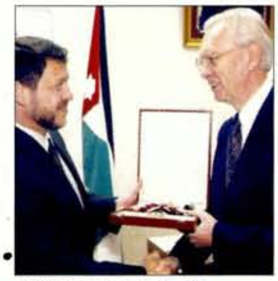
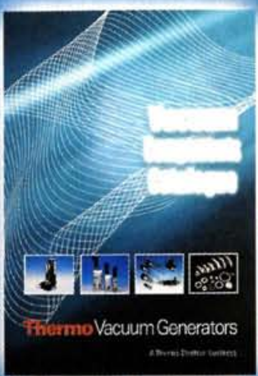

Discovery at KamLAND p7


ANTARES deployment p21


SESAME takes root p33

Cover: The team responsible for testing and measuring the performance of the first matching quadrupole magnet (MQM) at CERN. The MQMs are only one of several varieties of quadrupole that will be used in the LHC's "insertion zones", for example where the beams are brought into collision at the four experimental areas. (p5).

Introducing the Ultimate Vacuum Components Catalogue.



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CERN

LHC magnets pass two milestones

The container with the first Brookhaven-built magnet is unloaded at CERN.

The first matching quadrupole magnet leaves the cryostat after successful testing.

The new year at CERN has seen good news for two types of magnet that will be essential to focusing beams in the Large Hadron Collider (LHC). One of them, the first US-built magnet, came 6000 km by land and sea from the Brookhaven National Laboratory in New York. The other, a matching quadrupole magnet (MQM), built by UK firm Tesla Engineering, is showing exceptional performance levels.

The Brookhaven-built magnet, which arrived at CERN on 21 January, is a 10 m long, 4.7 tonne single-aperture dipole. Magnets of this type will be installed on either side of the ALICE and LHCb experiments to deviate the beams in order to make them interact and then to separate them. This first example, manufactured over a period of nine months by Brookhaven, is one of 20 magnets that the US laboratory is supplying for the "insertion regions" (where beams are deviated for various reasons), and includes four of the same type as the new arrival at CERN. The magnets are based on a technology developed by Brookhaven for its own RHIC accelerator.

LHC project leader Lyn Evans said: "Our Brookhaven colleagues have done a fantastic job in completing the USA's first superconducting magnet for the LHC to specification and on schedule. It's a great step forward for international collaboration in the construction and operation of large-scale installations for particle physics research." Indeed, Brookhaven is not the only American partner in the LHC project, to which the US is contributing a total of \$531 million (€490 million). Fermilab is building 18 "low-beta" quadrupole magnets, and the Lawrence Berkeley National Laboratory is working on the superconducting cable and feed boxes for the same quadrupoles.

The MQMs from the UK are also destined for the LHC's eight insertion zones. The first 3.5 m long superconducting MQM has been undergoing stringent operating tests at CERN, reaching a magnetic field gradient of 215 T/m from the very first time it was powered up – under normal operating conditions it will only be required to reach 200 T/m, and the ramping took place without a single quench. This excellent result validates the choice of design and the industrial techniques, so series production can now begin.

LIGHT SOURCES

LCLS gets funding as TESLA wins support

The Linac Coherent Light Source (LCLS) project at the Stanford Linear Accelerator Center (SLAC), which passed the US Department of Energy's "Critical Decision 1" process in October 2002, has been allocated \$6 million (€5.5 million) in the budget for fiscal year 2003 to start engineering design activities. The project is a proposed multi-institutional collaboration for an X-ray free-electron laser (XFEL) using electron beams from the SLAC linac, and operating in the 0.15–1.5 nm wavelength region.

The XFEL will receive a beam of electrons accelerated through the final third of the SLAC linac. The electron beam will then make a single pass through a 122 m undulator, to generate a laser-like X-ray beam 10 billion times brighter than the light currently produced at the Stanford Synchrotron Radiation Laboratory. The design and construction cost for the LCLS project is estimated at around \$220 million, and the construction schedule calls for full operation by September 2008.

In Europe meanwhile, the German Science Council has recommended DESY's TESLA project as worthy of support, in a report that assessed nine large-scale facilities for basic research in the natural sciences. In a previous evaluation statement, the Science Council had asked for further details on the superconducting electron–positron linear collider with respect to international funding and co-operation, and also for a revised technical proposal for the TESLA X-ray laser with a separate linear accelerator. DESY sent the corresponding papers to the Science Council in October.

In response to the latest report, Albrecht Wagner, chairman of the DESY Directorate, said: "We are very glad that the Science Council changed its first positive statement about TESLA to the German federal government to a recommendation, and we are looking forward to hearing the upcoming evaluations, since we have complied with the conditions posed by the Science Council." The final decision of the federal government regarding the TESLA project is expected this year.

- The Technical Design Report Supplement for the TESLA X-ray laser is now available at http://tesla.desy.de/tdr-update.

ACCELERATORS

Novel CLIC accelerating structure achieves 195 MV/m

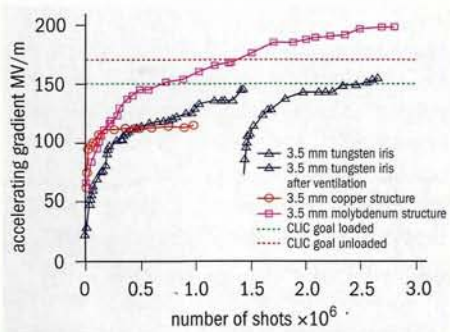
The nominal parameters for the compact linear collider (CLIC) foresee acceleration of the electron and positron bunches to an energy of 1.5 TeV by 30 GHz normal-conducting accelerating structures operating at an average gradient of 150 MV/m. Such a high gradient is desirable to limit the length, and in consequence the cost of the linacs, but it is very ambitious when compared with present-day accelerators, which run typically at gradients of around 25 MV/m. The confidence that such high gradients could be achieved was shaken three years ago, when substantial damage of the copper surfaces of prototype 30 GHz accelerating structures was discovered after operating them in the CLIC Test Facility (CTF2) at gradients of only 70 MV/m for pulse lengths of only 15 ns – the CLIC nominal pulse length is 130 ns and the achievable gradient is expected to decrease with pulse length.

Following this disturbing discovery, a vigorous programme of R&D began, which aimed to understand the origin of the problem, and if possible propose and implement solutions. Three years later, the hard work has paid off. At the end of May, a novel 30-cell test structure reached an average accelerating gradient of 125 MV/m with a peak gradient in the first cell of 150 MV/m when powered with 15 ns pulses. On inspection, the structure was found to be undamaged.

The novel features that led to the dramatically higher gradient of this structure were three-fold. First, tungsten was used to make the parts of the structure where the surface electric field is highest, and where damage was observed in copper structures. Tungsten was chosen for its high melting point and low vapour pressure, and because it is renowned for its resistance to damage from arcing. Second, a new type of power coupler – a so-called mode launcher coupler – was used for the first time to bring in and take out the power. Third, the geometry of the structure was revised to reduce the peak surface electric fields where breakdown occurs. News of this CLIC success was announced at EPAC2002, where it was very well received.

The CLIC team with a few of the novel accelerating structures, each only 10 cm long.

A 30-cell accelerating structure used in the CLIC Test Facility (CTF2), together with a copper cell (left) and a molybdenum insert.



Conditioning results from the CTF2 high-gradient tests for tungsten, molybdenum and copper.

In November, a similar structure, but this time with molybdenum, did even better and achieved a peak accelerating gradient of 195 MV/m in the first cell, and an average accelerating field of 150 MV/m – this is the nominal CLIC loaded gradient. Again, on inspection the structure was found to be undamaged.

These are very important steps forward for the CLIC team and indeed for the whole linear collider field, although it is not yet the end of the road, because the gradient must be demonstrated at the CLIC nominal pulse length of 130 ns. Still, this latest CLIC high-gradient test result is a fitting way to end the very successful CTF2 programme. CTF2 was closed definitively at the end of 2002 to make way for CTF3. The next step in the high-gradient development programme will be the testing of an 11 GHz tungsten or molybdenum iris structure in the NLCTA at SLAC next June with 200 ns long pulses. From 2004, CTF3 will be used to make high-gradient testing at 30 GHz possible again at CERN with 130 ns long pulses.

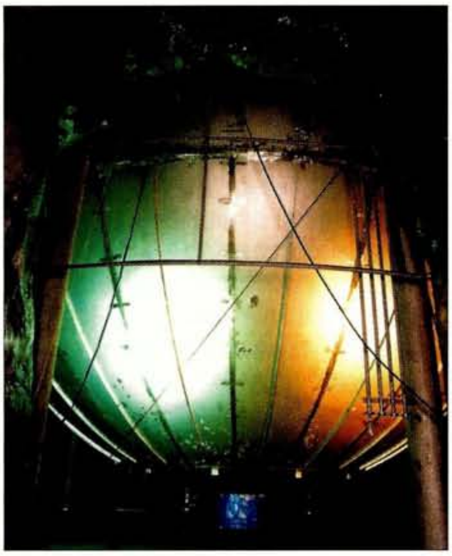
QUARKONIUM

CERN hosts first meeting of Quarkonium Working Group

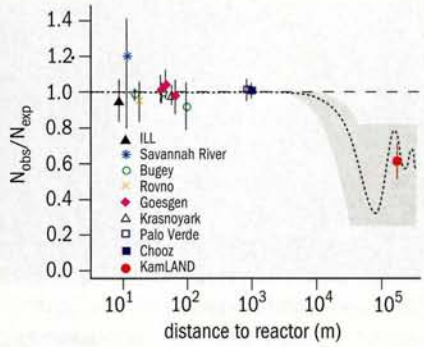
The first workshop of the recently founded Quarkonium Working Group (QWG) took place at CERN on 8–10 November 2002, nearly 30 years after the observation of charmonium – the first of the heavy quarkonia states. Almost 100 experimentalists and theorists from places as far away as Japan and Hawaii came together to discuss recent advances and open problems in the field of quarkonium physics, which should eventually also include studies of toponium. The topics covered ranged from spectroscopy and decays of quarkonium to its production in quark–gluon plasma. With 58 plenary talks, parallel talks and discussion sessions, this successful first workshop has already achieved the QWG's first goals: to bring together experts from the various branches of the field, to clarify the status of experiments and theory, and to formulate the key questions that should be addressed in the framework of the QWG. Specific projects are now being organized in sub-groups, and future meetings as well as a comprehensive write-up are planned. More details about the aims of the QWG can be found at http://alephwww.physik.uni-siegen.de/~quarkonium.

NEUTRINOS

KamLAND experiment discovers that reactor antineutrinos 'disappear'



KamLAND's 13 m diameter transparent "balloon", which is filled with 1 kton of liquid scintillator. (Berkeley KamLAND.)



The ratio of observed to expected number of electron antineutrinos from various reactor experiments, including KamLAND. The shaded region indicates a range of LMA predictions at 95% CL found from solar neutrino data, the dotted curve shows the recent best-fit LMA prediction, and the dashed line is the prediction for small mixing angles or no oscillation. (Phys. Rev. Lett. 2003 **90** *021802.)*

The first results from six months of data-taking by the KamLAND experiment in Japan indicate that electron antineutrinos from distant nuclear reactors are "disappearing" on their way to the detector. This is the first observation of such a disappearance in a reactor-based experiment. The results support evidence from solar neutrino experiments for neutrino oscillations, in which the electron neutrinos change into another type.

KamLAND, which consists primarily of a 13 m diameter "balloon" filled with liquid scintillator viewed by more than 1800 photomultiplier tubes, is located on Japan's main island of Honshu, near the city of Toyama (*CERN Courier* April 1999 p22). It is exposed to electron antineutrinos emitted from some 51 nuclear reactors in Japan, plus 18 in South Korea, at a variety of distances. While experiments detecting solar neutrinos have for more than 30 years found fewer electron neutrinos reaching the Earth than expected, there has been no evidence for a similar effect in experiments studying neutrinos from nuclear reactors. However, the mounting evidence for oscillations from experiments with solar and atmospheric neutrinos show that in these experiments, the detectors were too close to the reactors to observe an effect. Now KamLAND has found a clear deficit in the number of electron antineutrinos arriving from an average distance of about 180 km.

KamLAND detects electron antineutrinos through the inverse beta-decay process, in which an electron antineutrino interacts with a proton to create a positron and a neutron. For data collected on 145.1 days between March and October 2002, the experiment recorded 54 electron antineutrino events in the energy range 1–10 MeV, as opposed to around 86 events predicted by the Standard Model, assuming that no oscillations occur. More precisely, the ratio of the number of observed inverse beta-decay events to the expected number (i.e. without disappearance) was found to be 0.611 ± 0.085 (stat) ± 0.041 (syst), for antineutrino energies greater than 3.4 MeV.

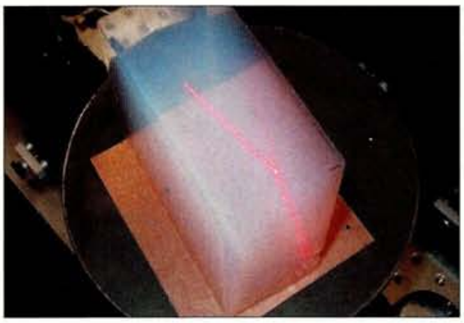
These results agree well with those of recent best-fit predictions of the large mixing angle (LMA) oscillation solutions, and indeed reduce the allowed LMA region for the oscillation parameters $\sin^2 2\theta$ and Δm^2. The best fit to the KamLAND data in the physical region for the parameters gives $\sin^2 2\theta = 1.0$ and $\Delta m^2 = 6.9 \times 10^{-5}$ eV^2. Further analysis with more data should reduce the errors and provide a higher precision measurement of these key parameters.

DETECTORS

Aerogel sees the light for LHCb detector

Particle identification is a fundamental requirement for experiments such as LHCb that are dedicated to the study of B physics. Meaningful CP violation measurements will be possible only if hadron identification is available to reconstruct specific final states with high purity, and to tag the flavour of the b-hadron with high efficiency for the many B decay modes that can exhibit CP violating asymmetries. Now a team working in Novosibirsk, Russia, is successfully making highly transparent aerogel for the LHCb RICH (Rich Imaging Cerenkov) detector, which will play a key role in particle identification.

An important optical requirement of a Cerenkov radiator is not to scatter the produced photons. Any angular dispersion caused by the radiator medium will reduce the precision on the Cerenkov emission angle. In the momentum region of 2–10 GeV/c, an aerogel radiator having an index of refraction around n = 1.030 provides a good solution. Aerogel is a very-low-density material (0.1 g/cm^3), essentially made of SiO_2, and the dominant cause of image degradation is due to Rayleigh scattering.



This block of aerogel produced in Novosibirsk shows good optical properties although 5.5 cm thick.

The feasibility of a RICH detector with aerogel as a Cerenkov light radiator was demonstrated only a few years ago, in 1997, and relies on the excellent quality of aerogel available today. Aerogel produced by the Matsushita company in Japan is currently used in the RICH detector in the HERMES experiment at DESY.

The typical transverse dimensions of aerogel tiles are 10×10 cm^2, and the typical thickness is 1 or 2 cm. It is technically very difficult to increase the thickness while maintaining the optical quality with the level of clarity needed. However, in order to achieve the required perfomance, the LHCb RICH detector needs a highly transparent aerogel radiator with a thickness of 4–6 cm.

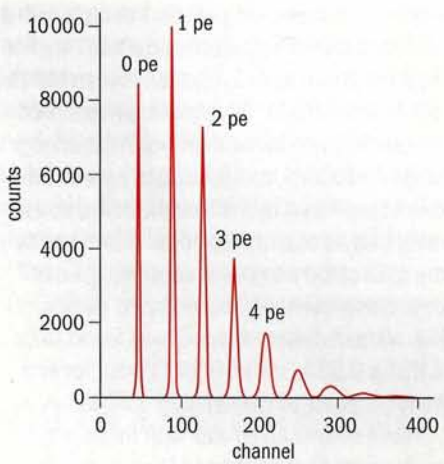
The aerogel block shown in the picture has been produced in Novosibirsk by a collaboration of the Boreskov Institute of Catalysis and the Budker Institute of Nuclear Physics, with support from a CERN–INTAS grant. It has dimensions of $10 \times 10 \times 5.5$ cm^3 and a refractive index of 1.03. Its effective scattering length for Cerenkov light at a wavelength of 400 nm is 43 mm, only 15% less than for the best thin aerogel samples.

PHOTODETECTORS

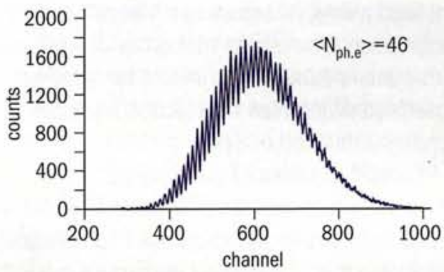
Silicon photomultiplier demonstrates its capabilities

A team from the Moscow Engineering and Physics Institute together with Pulsar Enterprise in Moscow have developed a silicon photomultiplier (SiPM), which promises a wide range of applications. The device is basically a large number ($10^3/mm^2$) of microphoton counters, which are located on a common silicon substrate and have a common output load. Each photon counter is a small (20–30 μm square) pixel with a depletion region of 2 μm. They are decoupled by polysilicon resistors and operate in a limited Geiger mode with a gain of 10^6. This means that the SiPM is sensitive to a single photoelectron, with a very low noise level of less than 0.1 photoelectron. Although each SiPM pixel operates digitally as a binary device, as a whole the SiPM is an analogue detector that can measure light intensity within a dynamic range of about $10^3/mm^2$ and has excellent photon capability.

The photon detection efficiency of the SiPM is at the level of photomultiplier tubes (PMTs) in the blue region (20%), and is higher in the yellow–green region. The device has very good timing resolution (50 ps r.m.s. for one photoelectron) and shows very good temperature stability. It is also insensitive to magnetic fields. These characteristics mean that the SiPM can compete with other known photodetectors (e.g. PMT, APD, HPD, VLPC) and may prove useful for many applications, from very low light intensity detection in particle physics and astrophysics, through fast luminescence and fluorescence studies with low photon numbers in chemistry, biology and material science, to fast communication links.



The silicon photomultiplier's photon counting capability for low-intensity light.



The pulse height spectrum from a silicon photomultiplier for a larger light burst (mean number of photoelectrons = 46).

Further reading

www.slac.stanford.edu/pubs/icfa/fall01.html.
B Dolgoshein *Int. Conf. on New Developments in Photodetection* (Beaune, France) June 2002.

ELECTRONIC PUBLISHING

JACoW accelerates publication of electronic conference proceedings

The Joint Accelerator Conferences Website, (JACoW) is a website located at CERN with a mirror site at KEK, where the proceedings of accelerator conferences are published. It is also an international collaboration in the electronic publication of accelerator conference proceedings, which has led to the development and maintenance of templates for the preparation of electronic contributions to conference proceedings. Through editor and author education, it has contributed greatly to facilitating and speeding up the publication of electronic versions of conference proceedings.

JACoW came into being following the Web publication of the proceedings of the fifth European Particle Accelerator Conference (EPAC'96) when Ilan Ben-Zvi, chair of the US Particle Accelerator Conference (PAC'99) Program Committee, proposed the idea of a joint PAC/EPAC website for the publication of the proceedings. Since then it has pioneered electronic publications in the accelerator field. The CYCLOTRONS, DIPAC, ICALEPCS and LINAC series of conferences have all joined the collaboration, with more in the pipeline. While the number of published proceedings now stands at 17, the project for scanning PAC conference proceedings from the pre-electronic era is rapidly swelling this number.

Because JACoW is not simply a list of URLs to other websites, each conference series is required to deliver a full set of files prepared in portable document format (PDF), according to JACoW specifications. A unique feature of the JACoW site is the custom interface that allows full Boolean searches in the metadata (the hidden fields in the PDF files), in addition to the standard full text search, across all papers presented at all major accelerator conferences.

The JACoW collaboration is now turning its attention to the database infrastructure requirements to run the scientific programmes of conferences – covering all actions from submission of abstracts through to submission of papers, with automated procedures for the preparation of files for publication on the Internet.

Further information

See http://www.jacow.org.

ASTROPARTICLE PHYSICS

New paperless journal echoes the spirit of JHEP

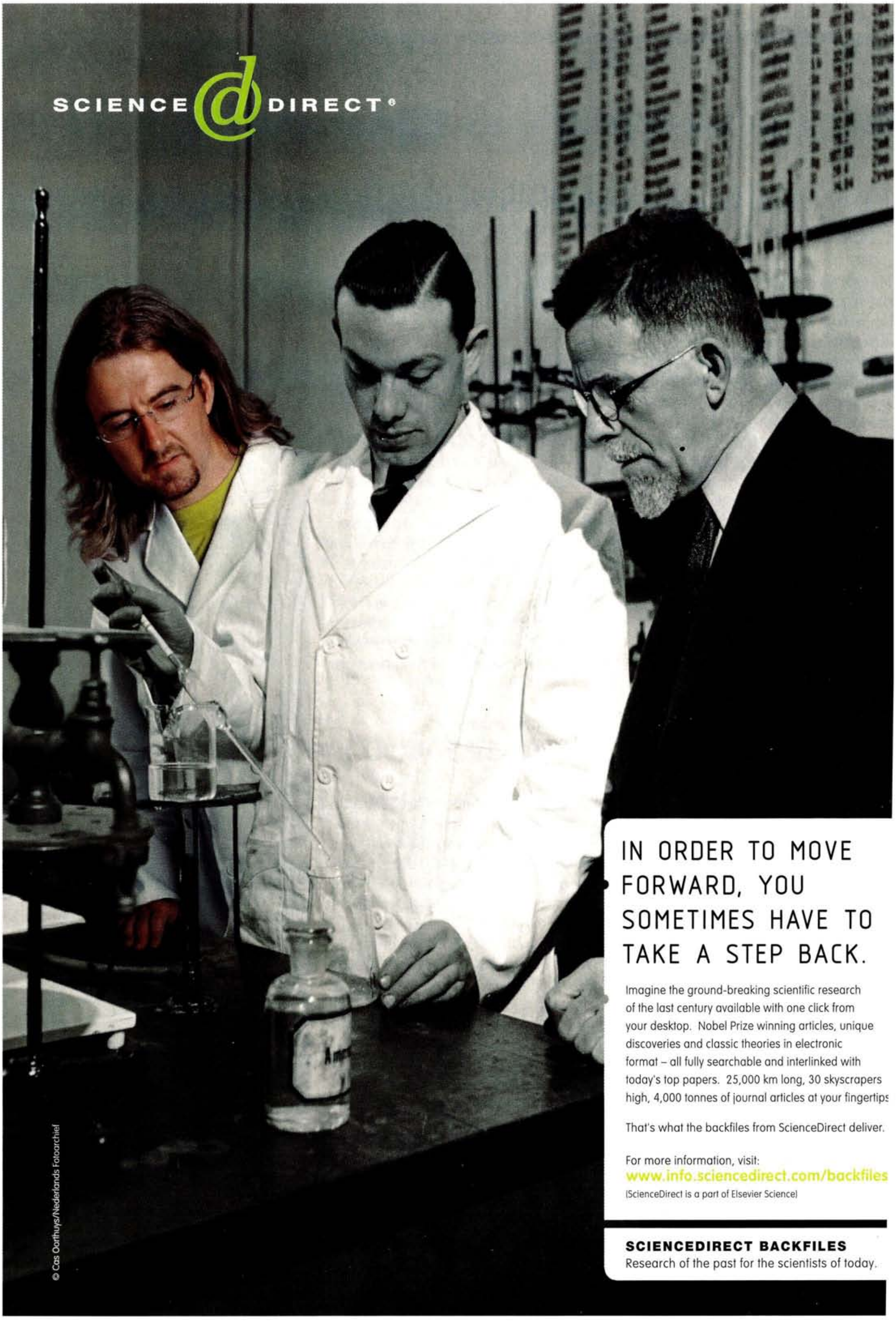
In collaboration with Institute of Physics Publishing (IOPP), the International School for Advanced Studies (SISSA) has launched the *Journal of Cosmology and Astroparticle Physics* (JCAP). The new electronic journal is a sibling of JHEP, the *Journal of High Energy Physics*, which has proved highly successful as a modern paperless peer-reviewed journal. With distinguished advisory and editorial boards, the aim is for JCAP to emulate JHEP's success.

The procedure for submitting a paper to JCAP is simple and straightforward, and is identical to that of JHEP. Software performs all the steps in the editorial procedure: the submission of papers, their assignment to the appropriate editors, the review by referees, the contacts between editors, referees and the Executive Office, the revision, proofreading and publication of papers, and the administration of the journal. Editors, referees and authors have personal Web pages, where they run the editorial procedure or check the status of the papers. The editorial work is carried out by the Executive Office based at SISSA. Accepted papers are then published on the IOPP website.

For the first year JCAP will be free for everyone, and will then be made available at a low subscription rate. In the case of JHEP, recent changes with the introduction of a low-cost subscription for institutions, mean that the costs of the journal will be spread over all countries that can contribute to its publication. ICTP pays a modest sum to ensure that developing countries get access to JHEP for free.

Further information

See http://jcap.sissa.it, or for details about submissions contact Simona Cerrator, executive editor, at jcap-eo@jcap.sissa.it.



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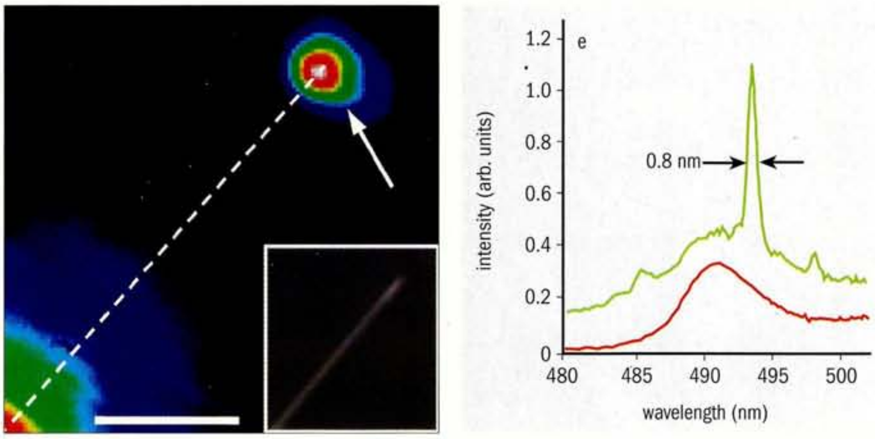
Edited by Archana Sharma

Nanolasers get compact



Left: a photoluminescence image of a cadmium sulphide nanowire excited by a laser (bottom left) shows its behaviour as an optical cavity, as light shines from its end (top right) 15 μm from the point of excitation. Inset: an image in white light illumination. Right: emission spectra (offset by 0.1 intensity units for clarity) recorded at 8 K for a cadmium sulphide nanowire laser at two different injection currents, 200 μA (red) and 280 μA (green).

Miniscule lasers that could be incorporated into silicon microchips have been created by researchers in the US. Charles Lieber and colleagues at Harvard University have fabricated single-wire lasers made of the semiconductor cadmium sulphide. These "nanowires", with a diameter of around only a hundred millionths of a millimetre, promise devices that could help make information technology faster and more compact.

Telecommunications and medicine already use semiconductor lasers routinely, but making the devices a thousand times smaller could give rise to a multitude of new applications. Such lasers are currently too big to fabricate on silicon microchips, but semiconductor nanowire lasers could solve this problem because of their small size. Various research groups have in the past made suitable nanowires – indeed, the first zinc oxide nanowire UV lasers were made in 2001. However, these require optical pumping to turn them on and off, using light from another laser; most applications require semiconductor lasers that can be driven electrically.

This critical electrical control has now been achieved by Lieber's group, using a cadmium sulphide nanowire assembled on a silicon surface, with a metal layer for an electrical contact on top. At a certain voltage, a current flows and blue-green light around 490 μm light emerges from the ends of the nanowire.

At a large enough injected current, the light is almost monochromatic – an essential characteristic of laser action. Other semiconductor materials, such as gallium nitride and indium phosphide, offer the possibility of providing laser light of different colours, in fact, spanning the optical spectrum from UV to IR wavelengths. There are still problems to solve, but the Harvard group believes that new applications, for example chemical or biological sensors, and microscopy and laser surgery, could be on the horizon.

Further reading

X Duang *et al.* 2003 Single-nanowire electrically driven lasers *Nature* **421** 241–245.

Qubits realize universal NOT logic

The electronic NOT gate changed the face of information processing. Though its direct quantum equivalent is impossible, the best possible approximation to the universal NOT transformation has now been demonstrated using photons. Quantum mechanics is radically different from classical physics, and quantum information processing differs from classical information processing. Two of the most elementary processes on a classical bit, b (equal to 0 or 1), are copying or cloning, and negation – in other words transforming b into 1 – b. But these operations are impossible using quantum bits (qubits) that are a superposition of the basic quantum states |0> and |1>.

Now, however, Francesco De Martini in Rome and colleagues have reported the first near-realization of the universal NOT transformation. The science of quantum information exploits quantum effects at the level of individual particles. Photon polarization was used for the qubits. For any input polarization, the NOT gate (as in conventional electronics) should transmit the opposite – in this case it should produce a photon in the orthogonal polarization state, for example going from vertical to horizontal polarization, or right circular to left circular. When the photon state is known, quantum NOT gates and cloning are possible, because the result of the transformation can be computed and the corresponding state engineered. But if nothing is known about the input state, this strategy is clearly impossible.

The universal NOT gate is an effort to develop quantum logic circuits and with the ambitious goal of building a quantum computer. However, quantum repeaters for quantum cryptography – the means to transmit decoding keys over large distances – will definitely use photons, and the necessary technology will involve these techniques.

Further reading

F De Martini *et al.* 2002 *Nature* **419** 797–798.

Edited by Emma Sanders

INTEGRAL sees first light

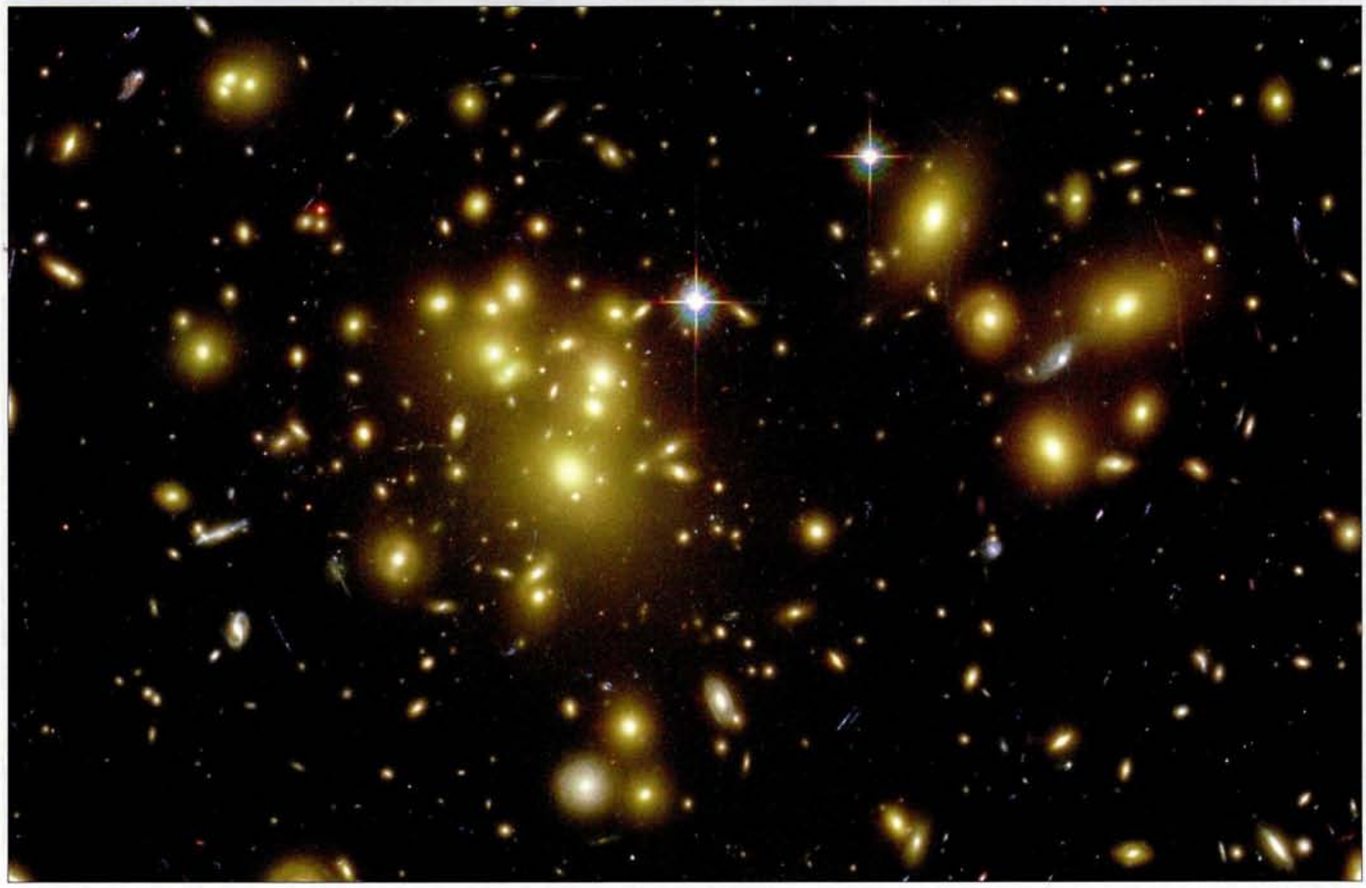
At the end of last year, the first images from the INTEGRAL gamma-ray satellite were released to enthusiastic astronomers. The first observations were of Cygnus X-1, a nearby black hole, just 10 000 light-years from Earth. Fittingly, the observations coincided with the emission of a gamma-ray burst from that very same region of sky.

Gamma-ray bursts are one of the exotic and poorly understood phenomena that INTEGRAL was launched to investigate (p48). They are by far the most powerful events known to occur since the Big Bang, and the mechanisms fuelling them are still unknown. Right from the moment of first light, INTEGRAL has shown a promise of many interesting discoveries to come.

Launched last autumn (*CERN Courier* October 2002 p10), INTEGRAL is designed to detect hard X-ray and gamma-ray sources in the energy range 15 keV–10 MeV. The satellite contains an imager and a spectrometer, plus X-ray and optical monitors. Gamma-ray sources are often highly variable, fluctuating on timescales of minutes or seconds, despite their size. This makes it crucial to record information simultaneously at different wavelengths.

INTEGRAL: on the trail of gamma-ray bursts. (ESA.)

Picture of the month



The light from these distant galaxies has been bent by a huge cluster of intervening matter which acts as a gravitational lens. The lensing helps bring the distant universe into focus, revealing faint galaxies that would otherwise be missed. The image was taken by the Hubble Space Telescope's new Advanced Camera for Surveys with a 13 h exposure time. Some of the distant galaxies in the image are thought to be twice as faint as those on the original Hubble Deep Field images, and to have a redshift greater than 6. This is a new milestone for the Hubble, improving once more our view of the early universe. (NASA/ESA.)

Are the fundamental constants constant?

Recent astronomical observations have raised the possibility that the natural constants are time-dependent. **Harald Fritzsch** considers the case for inconstant constants.

The natural constants are to some extent abnormal features of the theories considered today. On one hand they are needed to describe the theories, but on the other hand nobody understands their rather strange values. Indeed, no-one knows if they are accidents, or whether they can be calculated from some basic principles – a question that ranks in the top 10 unsolved problems for string theorists.

Spectra from the W M Keck Observatory on the summit of Mauna Kea, Hawaii, have provided evidence that α was slightly smaller in the early universe. (NASA/JPL.)

Recent observations in astrophysics suggest that α, the fine structure constant (see "The magic number" overleaf), which is of fundamental importance in describing the electromagnetic interaction, was in earlier periods a little smaller than today. A research group from Australia, the UK and the US analysed the spectra of distant objects, obtained in particular at the Keck I telescope in Hawaii. They studied around 150 quasars, some of them about 11 billion light-years away (Webb *et al.* 2001). The redshifts of the objects varied between 0.5 and 3.5, which corresponds to ages varying between 23 and 87% of the age of the universe. The team used the so-called "many multiplet" method – in particular on the spectra of iron, nickel, magnesium, zinc and aluminium – and found a value of α at early times of close to 1/137.037, as opposed to near 1/137.036, as is observed today. This is a small departure – the observations indicate $\Delta\alpha/\alpha = (-0.72 \pm 0.18) \times 10^{-5}$ – but it could have important consequences for theory.

The idea that certain fundamental constants are not constant at all, but have a certain cosmological time dependence, is not new. In the 1930s, the idea was discussed by Paul Dirac (Dirac 1937) and by Arthur Milne (Milne 1937), but with respect to the gravitational constant. Dirac wrote his article at that time during the holiday following his marriage, prompting his colleague George Gamow to remark: "That happens if people get married."

At around the same time, Pascal Jordan discussed the possibility that other constants could also be time-dependent (Jordan 1937; 1939), but he refused to consider that the constant of the weak interactions or the ratio of the electron and proton mass might be time-dependent. Later, Lev Landau considered the possibility of a time dependence of α in connection with the renormalization of the electric charge (Landau 1955).

We can also say something about the time dependence of α by studying the remains of the natural reactor found near Oklo in Gabon, West Africa, which was in operation about 2 billion years ago. The isotopes of the rare earths, for example of samarium, were produced by the fission of uranium. The observed distribution of the isotopes today is consistent with calculations, assuming that the isotopes were exposed to a strong neutron flux. The value of α that one can deduce agrees rather precisely with the value observed today. The change of α has to be smaller than about 10^{-17} per year, according to the calculations by Thibault Damour and Freeman Dyson (Damour and Dyson 1996). Taking the astrophysics values and the Oklo data together, one arrives at the curious possibility that the value of α increased in the early universe by a few 10^{-5}, but has remained constant during the past 2 billion years.

However, the significance of the Oklo data becomes less clear if, besides a change of α, changes of other parameters are also considered, for example the parameters of the strong interaction. The limit for the change in α comes from the observation that the cross-section for the scattering of thermal neutrons off samarium-149 is dominated by a nuclear resonance. The position of this resonance cannot have changed during the past 2 billion years, according to experimental data, and this limits the change of α. Because of ▷

The magic number

The fine structure constant α is given by $\alpha = e^2 2\pi/hc$, where $h/2\pi$ is Planck's quantum of action and c is the velocity of light, while e denotes the coupling constant of the electromagnetic interaction. Today the value of α is 1/137.03599976. Using the quantum Hall effect, it can be determined up to 3.7×10^{-9}. This value of the fine structure constant can be used to determine the strength of the interaction of particles at rest or at small velocities.

In collisions at high energies, α increases due to the effects of renormalization. For example, it grows to a value of about 1/128 at collision energies corresponding to a momentum transfer of the order of the W mass (80.4 GeV).

A number without any physical dimension, α was introduced in 1915 by Arnold Sommerfeld. Since then, physicists have puzzled over why this number is close to the inverse of 137. Wolfgang Pauli was so interested in the number that he eventually died in room 137 of the Zürich hospital. Werner Heisenberg was also fascinated by the number 1/137, and in his basic theory of the fundamental interactions, he constructed the number using simple numbers such as 2 and 3.

Dirac (right) – seen here in 1938 – discussed the possibility that the gravitational constant might vary with time, while Pauli (left) was fascinated with the value of the fine structure constant. (CERN Pauli Archive.)

the Coulomb repulsion in the nucleus, an increase of α would lead to an increase in the energy of the resonance. However, a change of the strong coupling constant, α_s, could easily compensate for this effect.

Observing a time dependence of α is certainly an important, if not spectacular result, but a certain measure of scepticism should be kept. If the fundamental constants really do depend on time, rather severe consequences are expected for cosmological evolution since the Big Bang. Nevertheless, the data should be taken seriously, as there are no strong theoretical arguments why the constants should really be absolutely constant.

Grand unification

In the Standard Model of the elementary particles, the overall gauge group is given by SU(3) × SU(2) × U(1), and the electromagnetic and weak interactions are described by the subgroup SU(2) × U(1). Both the Z boson and the photon are superpositions of the neutral SU(2) component and the U(1) boson. This means that the electromagnetic coupling constant e, i.e. the fine structure constant, is not a basic coupling constant. It is related to the basic coupling constant of the SU(2) theory by the relation: $e = g/2 \sin\theta_w$. Experiments give the value of the weak angle, renormalized at the mass of the Z boson, as $\sin^2\theta_w(Q^2 = M_Z^2) = 0.2113 \pm 0.00015$.

The three coupling constants of the strong and the electroweak interactions vary with energy, but they converge if they are extrapolated to very high energies (about 10^{16} GeV). This is precisely what one expects if the three interactions are unified. Such a "grand unification" is realized if the gauge groups of the strong interactions, i.e. the colour group SU(3) and the two gauge groups of the electroweak interactions, SU(2) and U(1), are subgroups of a simple group that unifies the three interactions.

Two groups are of particular interest – SU(5) (Georgi and Glashow 1974) and SO(10) (Fritzsch and Minkowski 1975). The group SU(5) has the property that the fermions of one generation are described by two representations. The group SO(10) has an interesting property: the leptons and quarks of one generation can be described by a single representation, the so-called spinor representation or 16-representation. For example, for the fermions of the first generation, this contains six quarks (u and d in three colours) and six antiquarks, together with the electron, positron, a left-handed electron-neutrino and a right-handed electron-neutrino. Note the introduction, in addition to the normal left-handed neutrino, of a right-handed neutrino, which in the normal weak interaction does not appear. However, its existence is important for the appearance of a mass for the neutrino. In fact, in the SO(10) theory, one expects in general that neutrinos have a mass, in accordance with evidence from current experiments.

The coupling constants of the Standard Model seem to converge if extrapolated to high energies. It turns out that in the SU(5) model, they do not come together at one point, but in models based on the SO(10) group a convergence can be achieved, since in those theories a new energy scale besides the unification energy plays a role at high energies. However, one can also achieve a convergence of the coupling constants in the SU(5) model, if supersymmetry is realized at energies above about 1 TeV. The contributions of the supersymmetric particles change the renormalization coefficients so that a convergence takes place at about 10^{16} GeV.

If we take the idea of grand unification seriously, it implies that the variation of α in time should go parallel to a variation in time of the unifying coupling constant g_{un} – otherwise the grand unification would only work at a particular time, which does not make much sense. Consequently we would expect that all three coupling constants g_1, g_2 and g_3, would be time-dependent. Of particular interest here is a time dependence of the QCD coupling, i.e. of α_s, since this coupling determines the hadronic mass scale and many other parameters in hadronic and nuclear physics.

Consider now the behaviour of α_s in lowest order only. It is given by the renormalization group equations as follows:

Equation 1

$$\alpha_s(\mu) \cong \frac{4\pi}{\beta_0 \ln\left(\frac{\Lambda^2}{\mu^2}\right)}$$

Here μ is a reference scale, $\beta_0 = -11 + 2/3 \times n_f$ (n_f is the number of quark flavours), and Λ_s is the QCD scale parameter.

Experiments, especially the measurements carried out at LEP, give $\alpha_s = 0.116 + 0.003/-0.005$ (exp.) ± 0.003 (theory). A typical value for the scale parameter is $\Lambda_s = 213 + 38/-35$ MeV. Of course, if α_s is not only a function of the reference scale, but also of time, then the scale parameter Λ_s also varies with time. We find for the time dependence:

Equation 2

$$\frac{\dot{\alpha}_s}{\alpha_s} = \frac{2}{\ln\left(\frac{\mu^2}{\Lambda^2}\right)} \frac{\dot{\Lambda}}{\Lambda}$$

$$R = \frac{\dot{\Lambda}}{\Lambda} \Big/ \frac{\dot{\alpha}_s}{\alpha_s}$$

The relative time dependencies are related by: $\delta\Lambda/\Lambda = (\delta\alpha_s/\alpha_s) \ln(\mu/\Lambda)$. It follows that the relative change of α_s cannot be uniform, i.e. identical for all reference scales, but must change logarithmically if the reference scale changes. We could, for example, consider a relative change of α_s at very high energies, for example close to the energy where the grand unification sets in. The corresponding change of Λ would then be larger by a factor $\ln(\mu/\Lambda) \cong 38$.

Further time dependencies

In QCD, the proton mass as well as all other hadronic mass scales are proportional to Λ, if the quark masses are neglected. In fact, the masses of the light quarks, m_u, m_d and m_s, are different from zero, but the mass terms contribute only a little to the total mass, typically less than 10% . We shall not consider these contributions, and we shall also neglect a small contribution of electromagnetic origin to the nucleon mass.

So if the QCD coupling or the QCD scale parameter changed in time, we would expect a corresponding change in time of the nucleon mass and of the masses of the atomic nuclei (Calmet and Fritzsch 2002). Such a change could be observed through a measurement of the mass ratio m_e/m_p. Since a change in the QCD parameters would not influence the electron mass, the result would be a change in this mass ratio.

Independent of the details of the unification scheme, one would expect that a change in time would in particular imply a change in time of the unified coupling constant, defined for example at the point of unification. In order to be specific, consider as an example SU(5) theory with supersymmetry, which is broken at about 1 TeV to yield the Standard Model. The change in time of the three gauge couplings is given in figure 1. The unification takes place at $\Lambda_{GUT} = 1.5 \times 10^{16}$ GeV, where the coupling constant is $\alpha_{un} = 0.03853$.

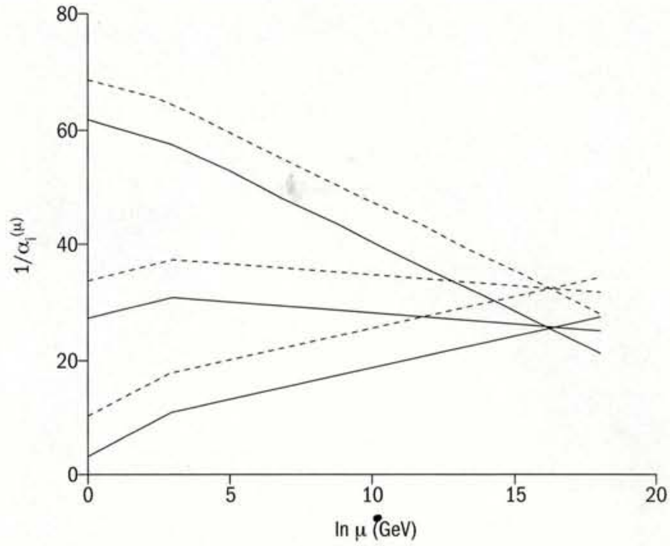


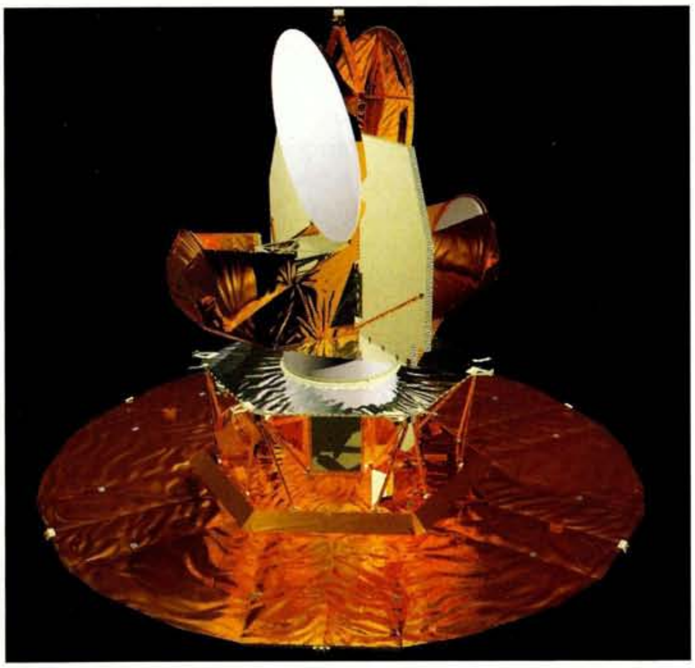
Fig. 1. The convergence of the three coupling constants in supersymmetric SU(5) theory. The dotted lines show the effect of a time variation.

A variation in time can occur through a time dependence of the unified coupling constant, but also through a time dependence of the energy at which unification takes place. In the case where only the coupling constant varies with time, one finds that the time change of α and α_s are related. In fact, both time changes are linked to each other by the ratio $8/3 \times (\alpha/\alpha_s)$, which is about 1/10. That is, the time change of the strong coupling constant is roughly an order of magnitude larger than the time change of the electromagnetic coupling constant.

In the case where the coupling constant remains invariant, but the energy at which the unification takes place depends on time, one finds that the time change of the scale Λ for the strong interactions is about 31 times larger than the time change of α, but has the opposite sign. This is interesting. While α increases with a rate of about 10^{-15} per year, Λ and the nucleon mass both decrease at a rate of about 2×10^{-14} per year. At the same time, the magnetic moments of the proton and of the nuclei would slowly increase, at a rate of about 3×10^{-14} per year.

Future observations

A change in time of the proton mass and of α could be observed through precise measurements in quantum optics. The wavelength of light emitted in hyperfine transitions, for example in the transitions that are measured in caesium clocks, is proportional to $\alpha^4 m_e/\Lambda$, which would be time-dependent via both α and Λ. On the other hand, the wavelength of light that is generated in atomic transitions depends only on α, and would vary in time accordingly. ▷



Meaurements on the cosmic microwave background from the MAP satellite will provide better limits on the time dependence of α. (NASA.)

We would expect that light emitted in hyperfine transitions should vary in time about 17 times more strongly than light emitted in normal atomic transitions, but in the opposite direction, i.e. the atomic wavelength becomes smaller with time, but the hyperfine wavelength increases.

The second is currently defined as the duration of 6 192 631 770 cycles of microwave light, which is emitted in the hyperfine transitions of caesium−133. If Λ were to change in time, it would mean that the flow of time, which is measured with caesium clocks, does not fully correspond to the flow of time tested in atomic transitions. Experiments to look for an effect of this kind will be carried out soon at the Max-Planck-Institute for Quantum Optics in Munich, under the leadership of Theodor Haensch.

If such an effect is discovered, it will be important to determine the sign and magnitude of the double ratio R (equation 2). If one obtains $R \sim -20$, it would be a strong indication for unification of the strong and electroweak interactions. Furthermore, this value would be of great interest in better understanding any changes in the constants of nature with time.

The fine structure constant α is composed of e, $h/2\pi$ and c. Thus, if α depends on time, it would mean that at least one of these numbers depends on time. Today we usually start with the hypothesis that $h/2\pi$ and c are fundamental unities, which in suitable systems can also be set to 1. Thus a change of time of α would correspond to a change of e.

In the theories of "superstrings", one has, in fact, an additional motivation that fundamental constants are not really constant. In these theories, dimensionless coupling constants such as α are related to functions of vacuum expectation values of scalar fields, which could easily depend on time. Furthermore, a time dependence could also easily arise if, besides the three space dimensions, there are more hidden dimensions.

It would be particularly interesting to find information about the coupling constants such as α or α_s in the early universe. A direct measurement is not possible, but recent measurements of the cosmic microwave background, which has its origin in the early universe, do not show within an accuracy of about 10% any time dependence of α. Data from the MAP satellite, launched in 2001, will allow us to improve this limit or to find an effect. Further hints towards a time dependence of α or α_s, or both, will have important consequences.

Further reading

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Harald Fritzsch, *University of Munich.*

Instrumentation for Measurement & Control

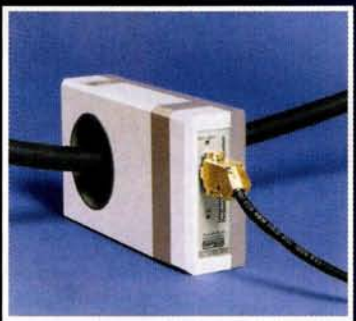
Magnetic Field

THM-7025

Application	Product	Specifications: Range	Resolution	Bandwidth
Linear sensing. Non-contact measurement of position, angle, vibration. Small size, low power.	CYH-22 1-axis Hall element	± 20mT	± 4μT	DC to 10kHz
	2D-VD-11 2-axis Hall element	User option	± 30μT	DC to 10kHz
	3D-H-30 3-axis Hall element	User option	± 100μT	DC to 10kHz
High sensitivity and accuracy for low fields. Site surveys and monitoring. Active field cancellation.	MAG-01 1-axis Fluxgate Teslameter	± 2mT	± 0.1nT	DC to 10Hz
	MAG-03 3-axis Fluxgate Transducer	± lmT	± 0.1nT	DC to 3kHz
Linear measurement. Feedback control. Mapping, quality control.	YR100-3-2 Hall Transducer, 1-axis	± 2T	± 12μT	DC to 10kHz
	3R100-2-2 Hall Transducer, 3-axis	± 2T	± 12μT	DC to 10kHz
Hand-held, low-cost, 3-axis for magnet and fringe fields.	THM 7025 Hall Teslameter, 3-axis	± 2T	± 10μT	DC
Precision measurement and control. Laboratory and process systems.	DTM-133 Hall Teslameter, 1-axis	± 3T	± 5μT	DC to 10Hz
	DTM-151 Hall Teslameter, 1-axis	± 3T	± 0.1μT	DC to 3Hz
Calibration of magnetic standards. Very high resolution and stability (total field).	2025 NMR Teslameter (total field)	± 13.7T	± 0.1μT	DC
	FW101 NMR Teslameter (total field)	± 2.1T	± 0.5nT	DC
Precision flux change measurement.	PDI 5025 Digital Voltage Integrator	40 V.s	±2E-8V.s	1ms to 2^{23}ms

Field units: 0.1nT = 1μG, 100nT = 1mG, 100μT = 1G, 1mT = 10G, 1T = 10,000G

Electric Current (isolated measurement)



IPCT

Application	Product	Specifications: Range	Resolution	Bandwidth
High sensitivity for low currents, currents at high voltage, differential currents.	IPCT Current Transducer	± 2A	± 10μA	DC to 4kHz
	MPCT Current Tranducer	± 5A	± 10μA	DC to 4kHz
Linear sensor for low-noise, precision current regulated amplifiers and power supplies.	864I-2000 Current Transducer	± 2000A	<4ppm	DC to 300kHz
	866-600 Current Transducer	± 600A	<4ppm	DC to 100kHz
Instruments for calibration, development, quality control.	860R-600 Current Transducer	± 600A	<5ppm	DC to 300kHz
	860R-2000 Current Transducer	± 2000A	<8ppm	DC to 150kHz
	862 Current Transducer	± 16kA	<5ppm	DC to 30kHz
Passive sensor for rf and pulse current.	FCT Fast Current Transformer	1:5 to 1:500	limited by following amplifier	150Hz to 2GHz
Passive sensor for pulse charge.	ICT Integrating Current Transformer	± 400nC	± 0.5pC	1μs to<1ps

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FTR

Application	Product	Specifications: Range	Resolution	Bandwidth
High resolution Input/Output modules that can be placed locally at the transducer or controlled unit. High Voltage and/or high noise environments. PC, PCI, VME, CAMAC host computer options.	DNA for DeviceNet	± 100mV to ± 10V	16 bit	DC to 150Hz
	CNA with fiber optic communication	± 100mV to ± 10V	16 bit	DC to 150Hz
	FTR fiber optic to RS-232-C			50 to 200kB

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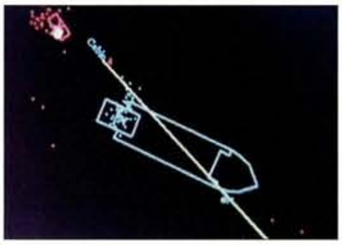
Acoustic manoeuvres in the dark


Left: the junction box on deck, showing the submarine connector plug board. Right: Connecting the cable to the junction box.




Left: real-time display from the acoustic navigation computer. Castor's position is relative to the cable lay, with the junction box current position (red box) during descent. The red spots are previous junction box positions during the ship's motion. Right: deployment of the linked "triplets" of glass pressure spheres containing photomultiplier tubes on the 60 m test line. (Papillaut/Dars CNRS and Circella INFN Bari.)

The ANTARES underwater neutrino telescope has passed twin deployment milestones on its way to implementation. **Greg Hallewell** reports.

Late 2004 will see the implementation in the Mediterranean Sea of 12 detection lines carrying more than 1000 photomultipliers at depths from 2300 to 1950 m. These underwater eyes will form the ANTARES telescope, which will observe the Cerenkov emissions of up-going muons from the conversion of high-energy neutrinos in the deep water and seabed. Such neutrinos arrive undeviated from a variety of sources of astrophysical interest, and may also be produced in the annihilation of dark-matter neutralinos. In the closing weeks of 2002, the ANTARES collaboration passed two important milestones in the preparation for the final array.

At 12.10 a.m. on 9 December 2002, the underwater electro-optical junction box – the nerve centre of the future array – touched down on the seabed south of l'Ile de Porquerolles near Toulon, France. Twelve days later, a 60 m detection line carrying photomultipliers and prototype readout electronics was successfully anchored nearby. The deployment of the junction box, which involved a 36 h boat mission, was a trickier operation, requiring the dredging and lifting of 2.5 km of the 40 km undersea electro-optical cable that had been laid to the ANTARES shore base more than a year previously (*CERN Courier* December 2001 p12).

The operations had begun in calm conditions at 8.30 p.m. on 7 December, when the GPS dynamical positioning ship *Castor 02* set out from the Foselev Marine quay at La Seyne for the 3 h trip to the ANTARES site. Aboard were a CNRS film crew, two divers and eight ANTARES personnel with their test and underwater acoustic navigation equipment.

In the early hours of the following morning, an acoustic transponder deployed over *Castor*'s side received a response from acoustic beacons attached to the undersea cable. Taking position fixes from a net of acoustic transponders on the seabed, *Castor* manoeuvred a metre at a time on a pre-planned course perpendicular to the lay of the cable, dragging a chain grapple across the seabed nearly 2.5 km below. At about 9.00 a.m., the movement of a beacon showed that the 400 m "dredging tail" extension to the cable had been successfully snagged on the first pass, and cable lifting could begin. Steadily winching at 30 m per minute, *Castor* slowly reversed 3 km along the cable lay. A little before lunchtime, the end of the cable was landed on *Castor*'s deck.

Throughout the cable lift, the ANTARES shore station team regularly checked the attenuation in each of its 48 optical fibres. With the cable on *Castor*'s deck, the optical parameters were still acceptable, so the boat team set to work connecting the cable to the junction box's titanium pressure sphere. Some 3 h later, the optical attenuations through the 16 junction box outputs had been checked and signed off. The insulation resistance of each of the 16 galvanically-isolated secondaries of the internal transformer had passed the acceptance criteria, and telemetry data were arriving back at the shore station through the undersea cable for the first time.

Weathering the storm

However, sea conditions had worsened, with torrential rain and waves lashing *Castor*'s deck. The test gear was sheeted down. Rain clouds cut short the daylight, so the remaining operations would be carried out under *Castor*'s powerful arc lamps. By 6.00 p.m., the swell exceeded 2 m. It was too dangerous to power the underwater cable to its full operating voltage with the junction box on deck, but Ohm's law and a little resourcefulness with a car battery verified the continuity and resistance of the 40 km cable.

An hour later, the junction box was hanging far out over the fantail on *Castor*'s 25 tonne crane. On shore, the telemetry from the junction box inclinometers attested to the pounding, but with 2.5 km of cable now hanging from the junction box, the deployment had to ▷

Going... going... gone. The junction box is winched from the deck, before being lowered into the water. (Papillaut/Dars CNRS.)

continue. The divers donned lifelines. Some 20 m below the surface chop they would detach the kevlar slings from the crane, leaving the junction box suspended from a transfer cable spooled on *Castor*'s deep-sea winch. The crane block was paid out, and the junction box was lowered into the swell, breaking the surface twice before disappearing into the calmer water below trough level. So far so good; telemetry data was still coming in.

The test line deployment concluded at around 3.00 p.m. on 21 December with the line anchor acoustic beacon revealing it at the correct touch-down location on the seabed.

With the junction box 400 m below the surface, the descent was paused. An acoustic beacon and anchor weight were fitted to the transfer cable, which would become the dredging tail should the junction box need to be raised in the future. A duplex acoustic release was fitted to the winch cable. From here on up, all the cable would be respooled onto *Castor*'s winch once a coded acoustic signal had triggered the release shackles. Descent continued steadily until 11.30 p.m. By then, communications with the seabed transponder net were difficult due to the excessive noise from the sea swell and the efforts of *Castor*'s positioning motors, working flat out to keep her on the precalculated cable re-laying track. Suddenly, with the junction box around 400 m above the seabed, the indicated cable tension dropped by 2 tonnes – the weight of the junction box, its dredging tail and anchor. Had the cable parted, precipitating the junction box to the seabed?

Satellite phone calls to the shore station revealed that telemetry was still arriving. Pitch and roll were nominal. The swell decreased a little and the junction box acoustic beacon revealed that it was close to its correct descent position above the seabed; the fault was in the tensiometer and not the rigging. The last 400 m were carefully paid out, and the junction box was placed on the seabed within a few metres of the planned position. Not bad for acoustic manoeuvres in the dark! The dredging tail was aligned. The undersea cable was energized to 3700 V, and the correct current measured through the junction box transformer. The acoustic release was triggered and the deep-sea cable winched back to the surface, leaving the junction box in communication with the shore.

Artist's view of the ANTARES neutrino detector. (Montanet CNRS/IN2P3.)

A rare window of good weather allowed the subsequent deployment of the 60 m test line to proceed smoothly. Following procedures developed during a rehearsal using "triplets" of empty pressure spheres, the test line deployment concluded at around 3.00 p.m. on 21 December, with the line anchor acoustic beacon revealing it at the correct touch-down location on the seabed, about 200 m from the junction box.

No further deployments were possible in the last few days of 2002. An instrumentation line carrying monitors for underwater environmental parameters including water transparency, undersea current profile and seabed seismic activity is awaiting good weather for deployment. The hook-up operations to the junction box plug board, using cables with underwater-mateable electro-optical connectors, must await the return of the *Nautile* submersible of France's IFREMER oceanographic research agency from its capping operation on the wreck of the oil tanker *Prestige* off the Spanish coast. The collaboration hopes to make these hook-ups some time in March, allowing the instrumentation to be fully tested under real conditions.

Further reading

The website of the ANTARES collaboration (France, Germany, Italy, the Netherlands, Russia, Spain and the United Kingdom) can be found at http://antares.in2p3.fr.

H Muir 2002 Into the Abyss *New Scientist* **176** (2372) 40.

Greg Hallewell, *Centre de Physique des Particules de Marseille.*

Surveying the status of Bulgarian particle physics

Bulgaria joined CERN in June 1999 as the laboratory's 20th member state. An ECFA visit took place in September 2002 to find out about particle physics in the country.

Left to right: ECFA chair Brian Foster, president of the guild of Bulgarian radiotherapists Tatiana Hadjieva, and Bulgarian ECFA delegate Jordan Stamenov.

Last September, the European Committee for Future Accelerators (ECFA) visited Bulgaria for the first time, as part of an ECFA mission to survey at first hand the status of particle physics in CERN member states. The visit was to Sofia, beautifully situated in a valley overlooked by Mount Vitosha and the Balkan range. Sofia has a history going back thousands of years, and counts the Thracian Serdi tribe, the Romans and the Byzantines among its previous occupants.

The academician Blagovest Sendov, a renowned mathematician and vice-president of the Bulgarian parliament, welcomed the committee. He recalled his own first contact with CERN; in 1986, as chair of the Bulgarian Science Foundation, he approved a grant of SwFr3 million (€2 million) for the participation of Bulgarian scientists and engineers in the L3 experiment at CERN. Sendov explained his appreciation of CERN's important role in the development of science and technology in the modern world, particularly in Bulgaria. While praising the laboratory's remarkable contributions in the domain of information technology, he recalled that the very first electronic digital computer was actually invented by an American of Bulgarian origin. John Vincent Atanasoff, who lived from 1903 to 1995, received a PhD in theoretical physics and went on to collaborate with electrical engineering student Clifford Berry, building what later came to be called ABC (the Atanasoff–Berry computer).

Following the welcoming ceremony, the status of particle physics and closely related areas was presented in a number of talks by Bulgarian scientists. A key player in the scientific research sector is the Bulgarian Academy of Sciences (BAS), which was formally established in 1911, but has its roots in a society founded in 1869. Today it is an autonomous national association, and runs a number of institutes, laboratories and other independent research centres. It funds and carries out research in collaboration with universities (primarily the University of Sofia) as well as independently. Its activities are organized in 11 departments, including physical, chemical, mathematical and engineering sciences.

Jordan Stamenov, director of the Institute for Nuclear Research and Nuclear Energy (INRNE) of the BAS, gave an overview of experimental high-energy physics in Bulgaria. The study of cosmic rays began as early as the 1950s by placing nuclear emulsions at an observatory situated on Mussala, the highest peak on the Balkan Peninsula (2925 m above sea level). Later, extended air showers in the energy range 10^{13}–10^{17} eV were studied high in the Tien-Shan Mountains of Kazakhstan. The Mussala and Tien-Shan sites are still used for a variety of cosmic-ray and astroparticle physics experiments.

Bulgarian particle physicists initially carried out their research primarily using facilities in the former Soviet Union. Bulgaria was one of the founding states of the Joint Institute for Nuclear Research (JINR) in Dubna in 1956, and has been an active partner in many experiments there. From the early 1970s, Bulgarian scientists also began participating in experiments at CERN, mainly through JINR. For example, three Bulgarian physicists and one mathematician took part in the NA4 deep-inelastic muon scattering experiment in the 1980s, as members of the JINR group in the Bologna–CERN–Dubna–Munich–Saclay (BCDMS) collaboration.

Vladimir Genchev described Bulgarian involvement with the CMS experiment in preparation for the Large Hadron Collider (LHC). Bulgarians have been involved with CMS since the beginning, initially concentrating on the software. Bulgarian physicists did the Monte Carlo simulation of the CMS hadron calorimeter, and also took part in the optimization of its design and performance. Later they oversaw the production of the calorimeter's brass absorber plates by Bulgarian industry. Bulgarians also took on major responsibility for the production, assembly and testing of 125 so-called resistive plate chambers. This is partially funded by the Bulgarian ▷

Ministry of Education and Science. Some 27 Bulgarian physicists and engineers have been involved in these efforts. Bulgarians also participate in the ATLAS project, as part of the JINR group.

Leander Litov of the University of Sofia reviewed Bulgarian participation in fixed-target experiments at CERN, such as NA48, NA49 and HARP. The Bulgarian group in HARP, for example, includes 12 people, and there are as many students participating in the experiments. Bulgarians also participate in the COSY experiments at Germany's Jülich laboratory, where they study collisions between protons and light ions. This work has been partially funded through a bilateral agreement between Germany and Bulgaria.

Fulfilling potential

Bulgaria is a young nation in terms of higher education. The St Kliment Ohridski University of Sofia was founded as a Higher Pedagogical School in 1888. In 1904, by a royal decree from Prince Ferdinand, grandfather of the current prime minister of Bulgaria, the school was transformed into Bulgaria's first state university. The University of Sofia is a leading institution for the education of young scientists, as well as for fundamental and applied physics research. ECFA delegates were impressed by the high level of scientific education of Bulgarian physicists, and by the quality as well as quantity of work they perform, in spite of a lack of resources. It was felt that there is a great deal of potential in the Bulgarian particle physics community, but not enough resources to realize it.

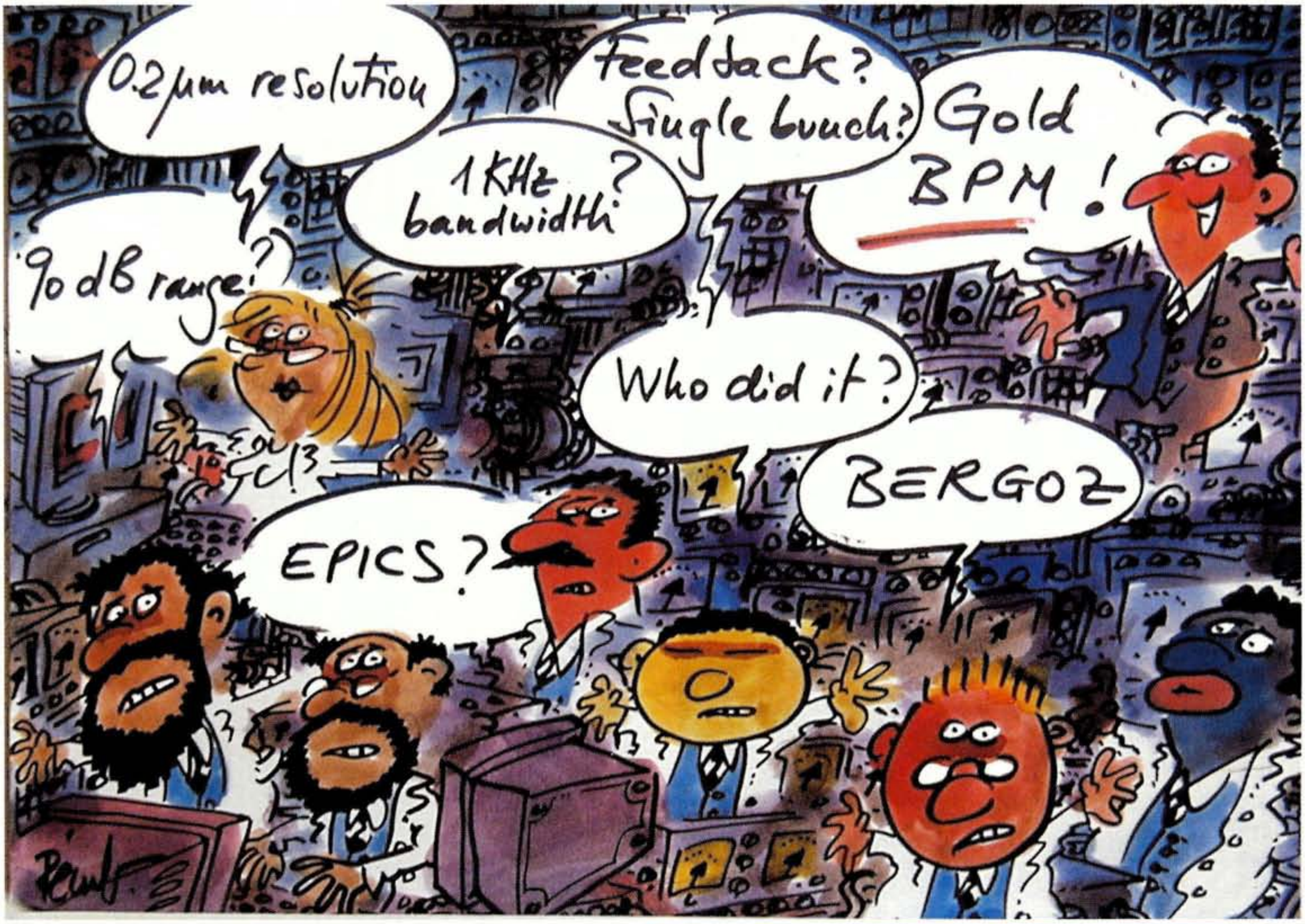
Matters related to LHC computing and the GRID project, from a Bulgarian point of view, were presented by Vladimir Dimitrov of the Faculty of Mathematics and Informatics at Sofia University. Bulgaria will not build a Tier 1 centre; a possibility that is being discussed is to create two Tier 2 centres for the Balkan countries – one in Greece and one in Bulgaria. One piece of good news is that there will soon be a 6 Mb/s data transfer line to the BAS, with the possibility of an increase to 622 Mb/s at a relatively small cost later on. It is very likely that all Bulgarian universities and research institutes will be optically connected to one another in the near future.

In Bulgaria, there are a number of small accelerators for industrial and medical applications. There is substantial know-how in accelerator physics, but funding is meagre. Furthermore, the facilities for medical physics and radiotherapy are inadequate given the health needs of the country. There is a strong wish to construct a neutron therapy facility, but this would mean overcoming obstacles related to the widespread fear of radiation in officialdom.

Matey Mateev, head of the Department of Theoretical Physics at the University of Sofia, reported on the status of theoretical physics in Bulgaria. Historically, almost all of the staff members in the field were trained at the Dubna, Moscow or St Petersburg theory schools. Research in theoretical particle physics is carried out at the University of Sofia, the BAS, the University of Plovdiv and the University of Shumen. The range of topics covered is broad, ranging from mathematical physics (for example conformal field theory) to topics directly applicable to experiments, such as the partonic spin content of the nucleon, or calculation of energy levels of the antiprotonic helium atom (studied experimentally by the ASACUSA collaboration at CERN). The Bulgarian theoretical particle physics community has strong ties with those in several other countries, in particular France, Germany, Italy, the UK and the US, as well as with CERN. Many theorists are grateful to Ivan Todorov for his pioneering leadership in creating a strong school of theoretical physics in Bulgaria.

Joining CERN in 1999 was a milestone for Bulgaria – it was essential not only for the development of high-energy physics in the country, but also for nuclear physics, electronics, informatics and other disciplines of importance for the future of the Bulgarian scientific community. This point was raised many times during the ECFA visit. The student representative, Stefan Piperov, also emphasized how he had been attracted to particle physics not only because of the fundamental nature of the subject, but also because of the opportunity to visit CERN. However, there was also a general feeling of discontent that promises given to Bulgarian physicists by the authorities had not been fulfilled. It was clear that the government faces a difficult economical situation. Nonetheless, it was also obvious that with more support, Bulgarian physicists, engineers and technicians could reach their full potential. To this end, a mutual smooth collaboration between CERN and the Bulgarian Ministry of Education and Science is of vital importance. The existing link between advanced technology and particle physics would then stimulate Bulgarian industry and technology, and be a valuable investment in the future economic development of the country.

Cecilia Jarlskog, *CERN.*



0.2 μm resolution
Feedback? Single bunch?
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1 KHz bandwidth?
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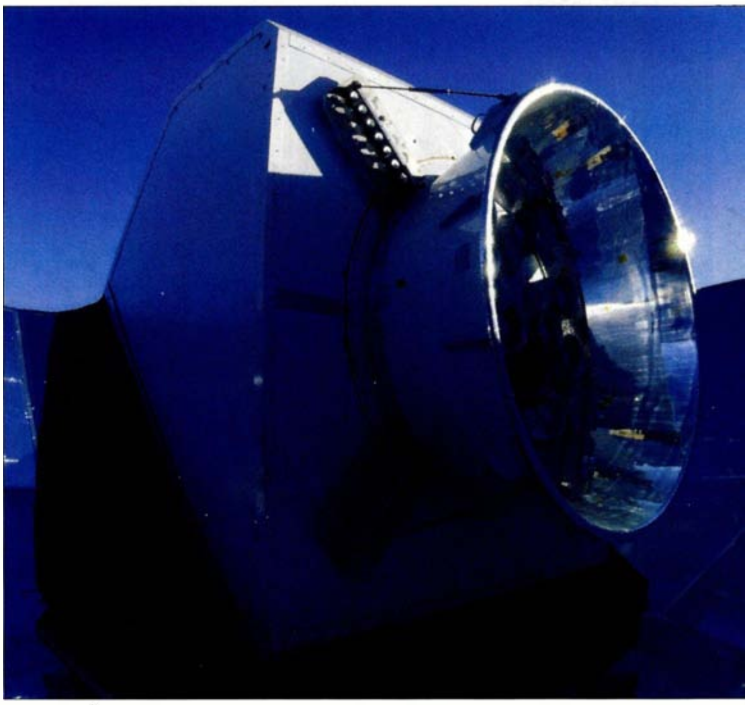
Who did it?
BERGOZ
EPICS?

Cosmic connections – fr

Two conferences last summer explored the increasing areas of common ground between t

COSMO-02 views the universe from Chicago

Christian Armendáriz-Picón and **Géraldine Servant** report from the sixth conference in the COSMO series.



New results from the DASI telescope (left), confirming the standard the intensity and polarization map (right) shows a 5 degree square portion denote the temperature of the radiation. (DASI.)

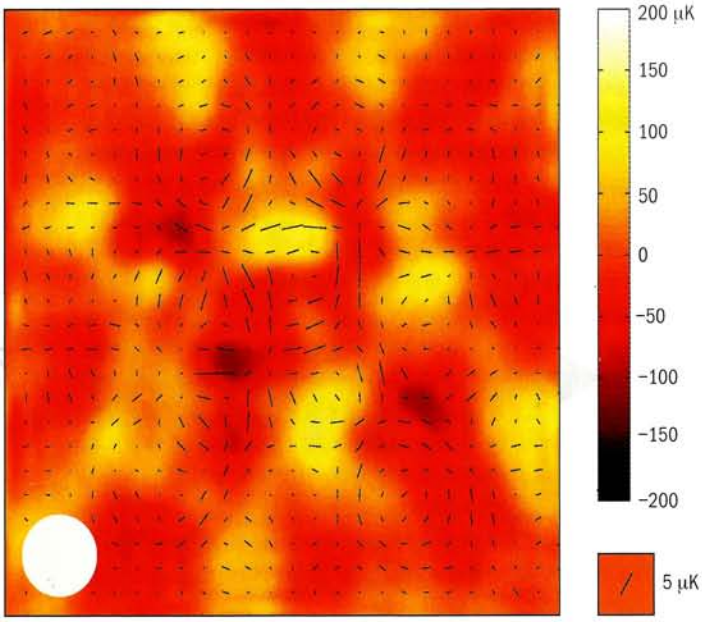
Last September, the 265 seats of Chicago's Adler Planetarium, on the Lake Michigan shoreline, were filled with participants at the COSMO-02 International Workshop on Particle Physics and the Early Universe. The conference was co-organized by the Center for Cosmological Physics at the University of Chicago, the Adler Planetarium and the Theoretical Astrophysics Group at Fermi National Accelerator Laboratory. COSMO conferences provide a forum for particle physicists, cosmologists and astrophysicists to discuss new results in the exciting and fast-moving field of particle astrophysics and cosmology. One of the new features this year was the presence of string theorists, showing that the latest cosmological observations have attracted the attention of a very large and diverse physics community.

The conference opened with a talk by Wendy Freedman of Carnegie, who addressed the recent emergence of a "standard model" in cosmology. From an observational point of view, our universe can be described by only a few parameters, such as the Hubble "constant" and the contribution of the different constituents of the universe to the total energy density. As Robert Kirshner of Harvard, David Weinberg of Ohio and Tim McKay of Michigan pointed out, a combination of the results of different cosmological observations already allows us to measure those parameters with unprecedented accuracy (by cosmological standards). Moreover, ongoing or planned projects, such as large-scale structure catalogues (2dF, SDSS), cosmic microwave background maps (MAP, Planck) and supernova surveys (ESSENCE, SNAP) will soon allow further significant reductions in the error bars. These precision measurements will help us to refine our understanding of the universe, and will certainly shed light on what is currently the most challenging puzzle for cosmologists and particle physicists – the nature of dark energy. This is currently the dominant energy component of the universe that causes its expansion to accelerate.

On the theoretical side, the standard model of cosmology rests on two pillars: cold dark matter (CDM) and inflation. In a CDM cosmology, most of the matter of the universe consists of non-baryonic, non-relativistic and collisionless particles. Numerical simulations show that the gravitational attraction between these particles yields structures – galaxies, clusters and superclusters – that agree with the ones observed in the universe, possibly up to certain discrepancies at subgalactic scales. The potential problems of the CDM scenario and the properties of some alternative scenarios, such as self-interacting dark matter or modified Newtonian dynamics, were critically discussed by Marc Kamionkowski of Caltech and Arthur Kosowsky of Rutgers. At this stage it is still disputed whether the

om dark matter to strings

physics of elementary particles and the larger-scale studies of astrophysics and cosmology.



about the origin of the CMB, were a major highlight at COSMO-02. DASI's
he CMB sky. The lines show the axis of the polarization, and the colours

Earl Lavon "Von" Freeman – a living legend of Chicago jazz (tenor) saxophone – was the star at the conference banquet, where he played with his quartet.

CDM scenario is free of problems, but as the talk by Andreas Albrecht of Davis suggested, it is fair to say that theorists continue to be in the dark regarding dark energy.

Inflation goes on and on

Inflation remains one of the cornerstones of modern cosmology. According to the inflationary paradigm, the early universe experienced a stage of accelerated expansion. As a result of this expansion, inflation produces a homogeneous and flat universe, as confirmed by cosmic microwave background (CMB) measurements. Inflation also explains the origin of the tiny primordial density fluctuations that developed into galaxies and clusters by gravitational instability. David Wands of Portsmouth described how inflation relates these primordial density perturbations to quantum fluctuations of the scalar field that drives inflation. Despite the fact that there is no theoretically preferred inflationary scenario, most inflationary models make definite predictions about the properties of these primordial density perturbations. They should be Gaussian, adiabatic and nearly scale-invariant. These predictions have been confirmed in an impressive series of experiments, and as Lloyd Knox of Davis reported, new CMB missions, such as the MAP and Planck satellites, will further test, scrutinize and constrain inflationary models.

Essentially the same mechanism that explains the origin of primordial density perturbations – quantum fluctuations of the inflation field – seems to imply that inflation will be eternal. As discussed by Alan Guth of MIT, who also delivered a widely attended public lecture at the Adler Planetarium, an inflating universe resembles a fractal. In a given inflating region of the universe, inflation has a finite lifetime, but at any given moment of time, there are always patches of the universe that continue to inflate. It is unclear whether such a prediction can be experimentally tested, but it certainly poses dramatic views on the global structure of the universe.

An important confirmation that our theoretical understanding about CMB fluctuations is on the right track came with the announcement by John Carlstrom of Chicago of the first measurement of CMB polarization by the DASI experiment. According to the standard theory, the temperature anisotropies we observe in the CMB are due to acoustic oscillations of the primordial baryon-radiation plasma. If this is true, the light that last scattered at the time of recombination – i.e. the CMB – should be partially polarized. The measurement of such polarization is a success of the standard theory, and represents the first step towards more ambitious measurements of the properties of the CMB polarization. As Alessandra Buonanno of Paris pointed out, the sea of relic gravitational waves that inflation predicts should leave a characteristic imprint on the polarization pattern of the CMB. This imprint could be used to determine the amplitude of gravitational waves produced during inflation, which in turn fixes the energy scale at which inflation took place.

Because of the high-energy scale at which inflation is expected to take place (around 10^{15} GeV in the simplest models), the primordial perturbations generated during inflation might be our only hope of probing the physics close to the Planck scale. This possibility was explored in a plenary talk by Nemanja Kaloper of Davis. Although in some inflationary models, Planck-scale suppressed corrections may leave an observable imprint in the primordial spectrum, Kaloper ▷


Participants at the COSMO-02 conference enjoy a break against a Chicago skyline.

argued that generically, such an imprint is expected to be too small to be observable in ongoing experiments. Such a conclusion was also the subject of a lively debate in the parallel sessions.

Neutrinos, neutralinos and WIMPs

The major experimental accomplishment in particle physics in recent years has been the evidence for non-vanishing neutrino masses from solar and atmospheric neutrinos. This has provided the first solid hint of physics beyond the Standard Model. While neutrino oscillation experiments provide information on the neutrino mass squared difference, the absolute scale of neutrino masses is so far unknown. To date, as Alexander Dolgov of INFN Ferrara mentioned in his talk, "astronomy opens the best way to measure m_ν." Big Bang nucleosynthesis, large-scale structure and CMB radiation constrain the contribution of massive neutrinos to the total mass density. A recent limit obtained in the 2 Degree Field (2dF) galaxy redshift survey gives an upper bound on the sum of neutrino mass eigenvalues $\Sigma_i m_i < 1.8$ eV. In the near future, the Sloan Digital Sky Survey, combined with the CMB data of the MAP satellite, should reach a sensitivity of $\Sigma m_\nu \approx 0.65$ eV. As far as sterile neutrinos are concerned, George Fuller of San Diego devoted an entire plenary talk to their effects on the dynamics of the universe and how cosmology can constrain them.

One of the fundamental unsolved questions of astroparticle physics is the origin of ultra-high-energy cosmic rays, a topic that was reviewed by Günter Sigl of Paris. To understand the acceleration and sky distribution of cosmic rays, a better knowledge of the strength and distribution of cosmic magnetic fields is needed. Sigl stressed that ultra-high-energy cosmic rays with energies above 10^{18} eV involve centre of mass energies above 1 TeV, which are beyond the reach of accelerator experiments. They thus provide a low-cost laboratory to probe potential new physics beyond the electroweak scale.

The question "How can particle accelerators directly attack major cosmological issues?" was addressed by Joe Lykken of Fermilab. The two main topics about which both theorists and experimentalists in particle physics have much to say are dark matter and baryogenesis. If supersymmetry has anything to do with the stabilization of the electroweak scale, the superparticles are expected to be seen at the LHC, and the hypothesis of a neutralino as a dark matter candidate – also discussed by Leszek Roszkowski of Lancaster – will be covered by the LHC with a great degree of complementarity with direct (elastic scattering) and indirect (signals from its cosmic annihilation) neutralino searches. The status of other supersymmetric dark matter candidates was reviewed (sneutrinos: ruled out; gravitinos: safe) as well as the recently proposed TeV mass Kaluza–Klein dark matter candidate, which will also be probed at the LHC. As for non-accelerator searches of CDM candidates, Maryvonne De Jesus of Lyon reported the results from and prospects for the numerous ongoing and planned direct searches for WIMPs via elastic scattering experiments, while Georg Raffelt of MPI, Munich, described the status of axion searches.

Regarding baryogenesis, the theory of electroweak baryogenesis in the Minimal Supersymmetric Standard Model (MSSM), which was reviewed by Mariano Quiros as well as Mark Trodden, has exciting prospects. The remaining very tiny corner of parameter space for which it works corresponds to a light Higgs and a light stop. Those should be found by Tevatron Run II if the MSSM is consistent with electroweak baryogenesis.

Other important activities led by high-energy physicists were emphasized at the conference – in particular, B physics will teach us about the sources of CP violation. Still in the domain of flavours, experiments with neutrino beams (such as MiniBooNE at FNAL) will help us to understand neutrino flavours. And finally, we heard that "electroweak precision measurements are not boring": the measurement of the anomalous magnetic moment of the muon at Brookhaven, the electroweak mixing angle by the NuTeV collaboration, and the bottom quark forward–backward asymmetry at LEP look like anomalies in the present global fit to electroweak data, and could be a sign of new physics.

Extra dimensions and strings

The field of extradimensional cosmology was well represented in plenary talks by Ruth Gregory of Durham, Lev Kofman of Toronto and Lisa Randall of Harvard. Extradimensional cosmology is very rich, but it is still in its infancy, and there is much left to explore. The evolution of the universe at late times can be described within the context of extradimensional cosmology, or in other words, the presence of extra dimensions can be reconciled with constraints from late-time cosmology. On the other hand, extradimensional cosmology at early times is much more difficult to understand. There is no experimental constraint to guide model-builders overwhelmed by an excessive freedom. Kofman reported new ideas on inflation from extra dimensions (for example colliding branes and radion potentials), as well as recent work on string signatures on cosmological observations.

Regarding attempts by particle theorists to explain dark energy with something other than a cosmological constant, Maxim Perelstein of Berkeley discussed networks of domain walls – quite generic in attempts to go beyond the Standard Model of particle physics. Another proposal to interpret supernovae data, presented by John Terning of Los Alamos, is to introduce photon–axion oscillations in an intergalactic magnetic field as a way of rendering supernovae dimmer, an explanation that does not need cosmic acceleration (but still requires a dark energy component of negative pressure).

Joe Polchinski of Santa Barbara addressed the question "Does string theory have vacua like ours, i.e. with (nearly) zero cosmological constant, a non supersymmetric spectrum and a stable (or long-lived) vacuum?" To date, there is no positive satisfying answer to this question. Polchinski also showed how the simplest string moduli potentials have difficulty in describing "quintessence".

Will string theory lead to a theory of the Big Bang? Nathan Seiberg of Princeton explained how string theorists are trying to address the problem of cosmological singularities, and presented the new challenges and recent explorations in the field of time-dependent solutions in string theory. In a very different approach, Willy Fischler of Texas presented a new cosmological model in which the primordial universe is dominated by a dense gas of black holes.

The question of whether string theory will yield the principle that determines the history of the universe was also raised by David Gross of Santa Barbara, who gave the closing talk of the conference. Gross confessed that his major feeling at the end of the conference was envy: "This is a golden age of cosmology: beautiful observations and the emergence of a standard model." He made the comparison with the situation he experienced 30 years ago when the Standard Model of particle physics was emerging. Astrophysical observations represent a testing ground for fundamental physics; experimental cosmology will provide increasingly precise tests of the Standard Model and constraints on new physics.

Further reading

Both plenary (including streaming video) and parallel talks are available online at http://pancake.uchicago.edu/~cosmo02/.

Christian Armendáriz-Picón *and* **Géraldine Servant**, *University of Chicago.*

Neutrinos lead beyond the desert

The Finnish town of Oulu, on the Gulf of Bothnia, almost at the Arctic Circle, provided a pleasant atmosphere for a conference on particle physics beyond the Standard Model.

Participants of the Beyond 2002 conference included (first row, left to right, sitting): Rabindra Mohapatra, Dick Arnowitt, Masato Morita, Hans V Klapdor-Kleingrothaus (chairman of the meeting), Yuha Peltoniemi (co-chairman); second row, from left, sitting: Dimitri Nanopoulos, Dharam Ahluwalia; second row, from left, standing: Raoul Viollier, Irina Krivosheina, Birgitt Brusila (conference secretary), Tom Kuo and Anne Green.

The Beyond the Desert 02 – Accelerator, Non-accelerator and Space Approaches conference was held on 2–7 June 2002. It was the third in the series of "Beyond conferences" that began in 1997 (*CERN Courier* November 1997 p16). Traditionally the scientific programme has covered almost all of modern particle physics, and this meeting was no exception, ranging from SUSY and extra dimensions to dark matter and neutrino mass.

The conference began with sessions on new theoretical developments in extending the Standard Model by means of grand unified and SUSY theories, followed by new results on the search for Higgses, SUSY particles, R-parity violation, leptoquarks and excited fermions at the LEP and HERA colliders. The revival of a g-2 signal for the muon deviating from the Standard Model, and its consequences for SUGRA models, were addressed by Pran Nath of Boston who, together with Dick Arnowitt of Texas, first introduced SUGRA 20 years ago. Later, extra dimensions, M-theory and fundamental symmetries were also presented. Ignatios Antoniadis of CERN, while talking about string and D-brane physics at low energies, pointed out that although no-one has ever observed strings or the space of extra dimensions where they live, the "hidden" dimensions of string theory may be much larger than we thought in the past, and may come within experimental reach in the near future.

The long-standing and very intriguing problem of dark matter in the universe, with its connection to new physics and new phenomena, was another important topic. Results and perspectives for direct dark matter experiments with scintillators (DAMA and LIBRA) and germanium detectors with big target mass (GENIUS and GENIUS-TF) were presented by Rita Bernabei of Roma and Irina V Krivosheina of Heidelberg and Nizhnij Novgorod. These are currently the only two experiments that can in principle use seasonal modulation to see (and indeed DAMA has seen) a positive signal from the interactions of dark matter particles by direct detection. Other experiments, for example with sophisticated cryogenic detectors exploiting ionization (or scintillation)-to-heat discrimination, are ▷

From left: Nikos Mavromatos, Hans Volker Klapdor-Kleingrothaus and Dharamvir Ahluwalia at Beyond 2002.

currently unable to register such a modulation in WIMP interactions because of their very small detecting mass.

Astrophysical data are becoming increasingly important for modern particle physics. For example, the excellent talk by Naoshi Sugiyama of Tokyo – "Cosmic Microwave Background: a new tool for cosmology and fundamental physics" – made it evident that an unexpectedly huge amount of fundamental information can be extracted from current research into the cosmic microwave background. Astrophysical investigations are also intimately connected with the exciting question of neutrino properties. Cosmic high-energy neutrinos can interact with relic neutrinos, producing Z-bursts which could explain the mysterious origin of extremely-high-energy cosmic rays, as Sandor Katz of Eotvos, Hungary, explained. This mechanism requires the neutrino mass to be in the 0.02–2.2 eV range, which intriguingly fits with recent results obtained from neutrinoless beta decay of germanium in the Heidelberg–Moscow experiment. Neutrinos from supernovae also figure in current theoretical investigations, as Alexei Yu Smirnov of Trieste and Moscow described.

Neutrino physics was undoubtedly the central topic of the conference. Rabindra Mohapatra of Maryland presented the modern understanding and a general view of neutrino masses and mixings. This was followed by several presentations on solar neutrinos, with Oliver K Manuel of Missouri describing the Standard Solar Model and modern experimental hints for an elemental composition of the Sun that is radically different from the usual current assumptions. Extended discussion of the experimental achievements in solar and atmospheric neutrino oscillation experiments included the Sudbury Neutrino Observatory (SNO) and its results from the recent analysis with a pure heavy water target, presented by Mike Dragowsky of Los Alamos. The consequences of the neutral current rate measured in SNO for resolving the solar neutrino puzzle were discussed by Sandhya Choubey of Southampton. SNO performed the first measurements of the total active neutrino flux, and claims evidence for neutrino flavour transformation at a 5.3 sigma level.

Global MSW analysis of the neutrino oscillation experiments favours the large mixing angle (LMA) region, and can be tested in new experiments. At the conference, the running status and prospects for the new and near-future neutrino oscillation experiments KamLAND, K2K and Superkamiokande, and new facilities such as neutrino factories and the JHF-SK project, were presented and discussed. For example, KamLAND (presented by Fumihiko Suekane of Tohoku), is a very long baseline reactor neutrino oscillation experiment with a 1000 tonne liquid scintillator detector. It can directly test the MSW-LMA solution with only six months of data, and will determine the oscillation parameters with very high accuracy if the LMA case is true. The experiment started data-taking in 2002, and the first results have been announced (p7). Rebuilding of the Superkamiokande detector began in 2002, and full reconstruction is expected by 2007, as Takaaki Kajita of Tokyo described. The physics potential and status of the second-generation proton decay and neutrino experiment ICARUS (Imaging Cosmic And Rare Underground Signals) in the Gran Sasso Laboratory were also discussed by Fulvio Mauri of Pavia and Ines Gil-Botella of Zurich.

The exact nature of neutrinos remains an exciting problem. Are these most mysterious objects Dirac or Majorana particles, and what are their masses? One of the best tools to find the answer is neutrinoless double beta decay. The evidence for observation of neutrinoless double beta decay of the isotope ^{76}Ge claimed by the Heidelberg–Moscow collaboration took a central part in the discussions. Alexander Dietz of MPI, Heidelberg, described the mathematical approach to the accurate treatment of statistics of rare events used by this collaboration. The very accurate data on the Q-value of the ^{76}Ge double beta-decay – which are crucial to the analysis and are determined from accurate mass measurements in a Penning trap – were presented by Ingmar Bergstrom of Stockholm.

Hans Volker Klapdor-Kleingrothaus of Heidelberg then outlined the present evidence for neutrinoless beta decay, as well as the general future for double beta decay experiments. The Heidelberg–Moscow collaboration fixes the effective neutrino mass in the region of 0.05–0.84 eV (95% confidence level). The important question of nuclear matrix elements for double beta decay was described thoroughly by Fedor Simkovic of Bratislava, who showed that transitions to different excited daughter states could help to distinguish between different mechanisms triggering the neutrinoless beta decay process. Important new constraints on neutrino mixing parameters following from the results of the Heidelberg–Moscow collaboration were also discussed by Hiroaki Sugiyama of Tokyo.

Still on the question of the nature of the neutrino, Dharamvir V Ahluwalia of Zacatecas, Mexico, reported on a new theoretical concept concerning massive Majorana particles and outlined the consequences for the structure of space–time. He showed that the Majorana nature of the neutrino tells us that space–time has realized a construct that is central to the formulation of supersymmetric theories. These various discussions showed that neutrinos at extremely low energies, as well as at extremely high energies, are particles that can supply us with exciting discoveries in the future. Together with the other topics, they made the conference a valuable contribution to the fruitful exchange of ideas between physicists working in particle physics, nuclear physics and cosmology.

Proceedings will be published by Institute of Physics Publishing, Bristol, UK.

Hans Volker Klapdor-Kleingrothaus, *MPI, Heidelberg, and* **Vadim Bednyakov**, *JINR, Dubna.*

PEOPLE

SLAC

Stanford to host new institute for particle astrophysics and cosmology

Physicist Fred Kavli and the Kavli Foundation have pledged $7.5 million (€6.9 million) to establish a new institute on the Stanford Linear Accelerator Center (SLAC) site that will focus on recent developments in astrophysics, high-energy physics and cosmology. The Kavli Institute for Particle Astrophysics and Cosmology will foster collaboration between faculty from Stanford's physics and applied physics departments, and SLAC. Astrophysicist Roger Blandford will be the director of the institute, and the first holder of the Pehong and Adele Chen Chair of Particle Astrophysics and Cosmology. Steven Kahn of Columbia University will move to Stanford to be the institute's deputy director, and will serve as assistant director of research at SLAC. The institute's focal point will be a new building, which will be completed in 2005. "The Kavli Institute will add new scope to SLAC's internationally recognized research programmes," said SLAC's director, Jonathan Dorfan.

Roger Blandford (left), director of the new Kavli Institute for Particle Astrophysics and Cosmology, with deputy director Steven Kahn (right) and Jonathan Dorfan, director of SLAC.

Kavli is the founder, former chairman and chief executive officer of the Kavlico Corporation, one of the world's largest suppliers of sensors for aeronautics, automotive and industrial applications. The Kavli Foundation sponsors research in cosmology, nanoscience and brain science.

SYNCHROTRON RADIATION

New international lab takes root in Jordan

Left: a marble plate to commemorate the founding of SESAME was unveiled by King Abdullah II of Jordan (right) and Koïchiro Matsuura, director-general of UNESCO. Right: Herwig Schopper (right) receives his medal from the King.

The formal establishment of SESAME (Synchrotron Radiation Light for Experimental Science and Applications in the Middle East) took place on 6 January at the Al-Balqa' Applied University at Allan in Jordan, the site of the new facility (*CERN Courier* October 2002 p24). The ceremony, attended by the Jordanian King HM Abdullah II and the director-general of UNESCO, Koïchiro Matsuura, established SESAME as an independent international laboratory, with founding members Bahrain, Egypt, Iran, Israel, Jordan, Palestine and Turkey. At the same time, SESAME's Interim Council was transformed into the definite Council, with Herwig Schopper re-elected as president, and the two vice-presidents, Khaled Toukan of Jordan and Dinçer Ulkü of Turkey, also re-elected. King Abdullah also presented Schopper with a medal in appreciation of his efforts in setting up SESAME.

APPOINTMENTS

On 14 October 2002, **Dominique Guillemaud-Mueller** succeeded Sydney Galès as director of the French Institut de Physique Nucléaire (IPN) in Orsay, becoming the first woman to head any of the IN2P3 laboratories.

Guillemaud-Mueller began her scientific career at the IPN and then took part in the start-up of GANIL in Caen from 1982 to 1988. After returning to the IPN, she began to specialize in the study of nuclei far from the valley of stability and exotic beams, becoming one of the pioneers in this field.

Since taking on different responsibilities in the laboratory and at national and international levels (scientific secretary to the Scientific Council of IN2P3, member of the CNRS National Committee and of NUPECC, the Nuclear Physics European Collaboration Committee), Guillemaud-Mueller has applied her energies to future projects in her area of specialization, such as SPIRAL2 at GANIL and EURISOL (European Isotope Separation On-Line), the second-generation European exotic beams project.

Guillemaud-Mueller is taking over the reins of a laboratory that has a leading role in many areas. Scientifically, IPN's inolvement has included major collaborations such as ALICE at CERN and AUGER in Argentina. The laboratory is also participating in experiments at TJNAF (US) and GSI and MAMI (Germany), as well as at GANIL in Caen. Technically, its contribution to accelerator research is on a large scale (cryogenics and accelerator cavities), and it is contributing to major ongoing particle physics projects such as LHC and TESLA.

The Council of the European Space Agency (ESA) has announced the appointment of **Jean-Jacques Dordain** as its next director-general. He will succeed Antonio Rodot, whose term of office ends on 30 June 2003. Dordain obtained an engineering degree from the Ecole Centrale in 1968, and has held several positions at the Office National d'Etudes et de Recherches Aérospatiales (ONERA). In 1977 he was selected by CNES as one of the first French astronaut candidates. He joined ESA in May 1986, and has held several senior positions there, most recently as director of launchers.

Praveen Chaudhari is to be the next director of the Brookhaven National Laboratory, from 1 April. Chaudhari has 36 years experience as a scientist and senior manager of research at IBM, where he was responsible for IBM's science programmes both in the US and and at the Zurich Research Laboratory, Rüschlikon. During this time, scientists at the Zurich laboratory received Nobel prizes in physics for two consecutive years – in 1986 for developing the scanning tunnelling microscope, and in 1987 for discovering high-temperature superconductivity in a new class of materials. In 1991, Chaudhari returned to full-time research. He has worked in many areas, including the properties of amorphous solids and thin films, quantum transport in disordered systems, and on a magnetic monopole experiment.

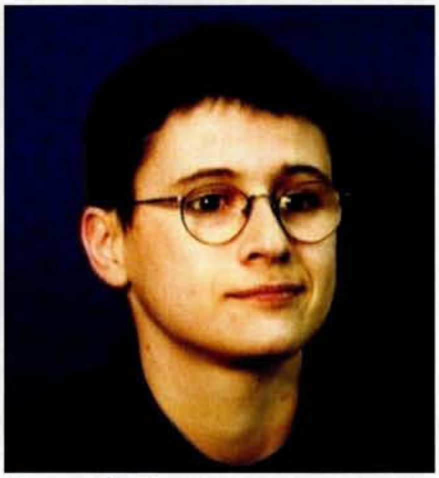
NEW PRODUCTS

Thales Computers has announced the introduction of the PMC-SIO – an octal serial I/O PCI mezzanine card (PMC) with eight ports to support a mixture of synchronous and asynchronous protocols. The board, which has four ESCC and four UART ports, is designed for applications requiring extensive serial I/O for managing and monitoring peripherals. See http://www.thalescomputers.com.

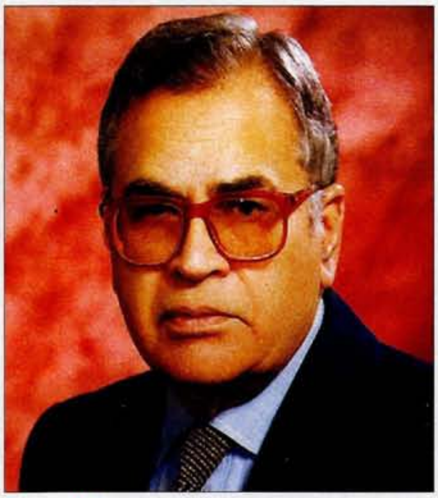
VAT have released a new concept in UHV all-metal right-angle valves. The new VAT Series 54 valve uses a silver-plated stainless steel seal in the form of a conical washer. The force applied to the seal is mechanically preset in the valve, and so overcomes the problem in conventional valves that the torque applied by the operator affects the performance of the valve. A mechanical stop allows the user to be sure that the valve is closed without any concern about actuator torque or position. The valves give excellent pumping performance in molecular flow conditions. For further details e-mail uk@vatvalve.com, or call +44 (0)1926 452753.

PRIZES

On 26 November 2002, **Richard Garwin** (centre) was in Paris to receive the greatest annual honour of the French Academy of Sciences – La Grande Medaille (*CERN Courier* October 2002 p30). Garwin became well known in 1957 for his discovery, with Leon Lederman, of parity violation in muon decay, and in 1960 he came to CERN to lead the g-2 experiment. He is seen here at the ceremony in Paris with **Valentine Telegdi** (left) and well known French physicist and 1997 Nobel prize winner, **Claude Cohen-Tannoudji**.



Emmanuelle Perez has been awarded the "medaille de bronze du CNRS", which is given once a year to a young physicist from CNRS. In 1993, Perez joined the Saclay group working on H1 at DESY, where she laid the ground for later work on leptoquarks and exotic particles with her thesis on the search for supersymmetric particles at H1. She has since been a convenor of the H1 BSM group and an active coauthor of the THERA proposal to study electron–proton scattering at TESLA. She now divides her time between D0, Fermilab, and leading the H1 Saclay group.



Riazuddin, the distinguished theorist and director of Pakistan's National Centre for Physics (NCP), was among the recipients of the ECO 2002 Awards. The awards were presented by the Turkish president Ahmet Necdet Sezer at the 7th Summit Meeting of the Economic Co-operation Organization (ECO), held in Istanbul on 14 October 2002. Riazuddin was rewarded for his valuable contributions in the field of science and technology.

ECO consists of Afghanistan, Azerbaijan, Iran, Kazakhstan, Kyrgistan, Pakistan, Tajikistan, Turkey, Turkmenistan and Uzbekistan, and is dedicated to regional economic development and co-operation.

On 23 January, **Steve Myers** (left), director of CERN's new Accelerator and Beams Division, received the 2003 Duddell Medal of the UK Institute of Physics from **David Wallace**, the institute's president. This particular medal was instituted as a memorial to William du Bois Duddell, the inventor of the electromagnetic oscillograph. It is awarded annually to a person who has contributed to the advancement of knowledge by the invention or design of scientific instruments, and was presented to Myers in acknowledgement of his work as head of the commissioning group for LEP.

HEPP call for 2003 prize nominations

The EPS HEPP Board is calling for nominations for its three prizes – the Young Physicist Prize, the Gribov Medal and the Outreach Prize. This year the prizes will be awarded at the International Europhysics Conference on High Energy Physics on 17–23 July in Aachen. Information on the prizes, together with a list of former winners, can be found on the HEPP Board website (http://eps-hepp.web.cern.ch/eps-hepp/prizes.html).

Nominations for the Young Physicist Prize and Gribov Medal should be sent to Michel Spiro at CEA-SACLAY, DAPNIA, F-91191 Gif-sur-Yvette Cedex, France (e-mail spiro@hep.saclay.cea.fr), and nominations for the Outreach Prize should be sent to Jorma Tuominiemi (e-mail jorma.tuominiemi@cern.ch), all before 15 April 2003.

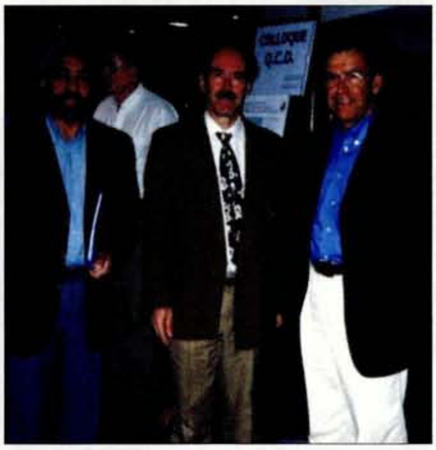
Weisskopf commemorative issue online

A special issue of the *CERN Courier* dedicated to the memory of Victor Weisskopf has just gone online at the *CERN Courier* website (cerncourier.com – click on "Special Issues"). A limited number of paper copies are available on a first-come, first-served basis from the CERN library. To request a copy, fill in the form at http://weblib.cern.ch/publreq.php, or write to Scientific Information Service, CERN, CH-1211 Geneva 23, Switzerland.

Directors and heads of department of the French Atomic Energy Commission (CEA) visited CERN on 17 December to learn more about the laboratory's current research activities. Their itinerary included the LHC magnet test area, where **Philippe Lebrun**, now head of CERN's new Accelerator Technology division, explained the work in progess. Here Lebrun (right) is talking with the director of the CEA's Saclay Laboratory, **Jean-Pierre Pervès** (centre), **J Y Gascoin** of the CEA (left) and **Joel Feltesse**, chairman of CERN's Scientific Policy Committee (behind).

H S H Prince Radu of Hohenzollern-Veringen of Romania (right), who is also the Romanian Government's Special Representative for Integration, Co-operation and Sustainable Development, paid a brief visit to CERN on 29 November 2002. He met with Romanian scientists working at CERN, and visited the Microcosm exhibition, where he is pictured with his personal adviser **Cornel Comsa**.

Two former directors of the Scuola Normale in Pisa, Italy, **Luigi Radicati di Brozolo** (left) and **Emilio Picasso**, were in Rome on 12 December 2002 for a meeting they had organized to honour the memory of Gian Carlo Wick, who died in 1992. The meeting, held at the Accademia Nazionale dei Lincei, began with a welcome by Edoardo Vesentini, the academy's president, and was chaired by Picasso. Radicati, Bruno Zumino, Maurice Jacob and Jack Steinberger talked of their memories of Wick, and of his work on field theory.



The 9th Montpellier International High-Energy Physics Conference in Quantum Chromodynamics (QCD 02) was honoured for the second time by the participation of **Gerard 't Hooft** of Utrecht (centre), seen here with conference chairman **Stephan Narison** (left) and **Max Levita**, the vice-mayor of Montpellier. 't Hooft presented his new result on linear confinement as an analytical approach to the IR regime of nonperturbative QCD. He also actively followed different talks and the related animated discussions. The next conference in the series will be held in Montpellier on 2–9 July 2003.

OBITUARIES

William Mitchell 1925 – 2002

Photo: Oxford PPU.

Sir William (Bill) Mitchell, FRS, who died last October, presided over the CERN Council in a period during which LEP I produced wonderful data, preparations for the LEP upgrade continued, and Council took a major step towards approving the LHC.

Bill took a wartime undergraduate degree in physics from Sheffield University. After a doctorate from the University of Bristol, and a brief period with the Metropolitan Vickers Company, he joined the University of Reading. He was to stay for 27 years, helping to build, almost from scratch, a large and thriving physics department with broad research interests. He served the university as head of department, dean of science and deputy vice-chancellor. In 1978 he moved to Oxford as Dr Lee's professor and head of the Clarendon Laboratory. Here his administrative and leadership skills proved invaluable in guiding a large established department.

Bill's research interests were wide-ranging, with a particular focus on the effect of defects on the electrical, optical and other properties of solids. His optical interests led to his becoming a consultant to the diamond industry and chairman of the Diamond Research Fund for many years. However, his main contribution to scientific research was in neutron scattering, where he pioneered the use of reactors to study the properties of materials. He was instrumental in organizing the growing community that realized the enormous potential of these techniques. As chairman of the Neutron Beam Research Committee of the Science Research Council over many years, he made sure through his energy and vision that the UK community was at the international forefront. He therefore took the lead in negotiating an equal partnership for the UK with France and Germany in the Institut Laue Langevin in Grenoble, and supported the creation of the spallation neutron source ISIS at the Rutherford Appleton Laboratory.

This involvement with the research councils at various levels made Bill a clear choice for chairman of the Science and Engineering Research Council (SERC) in 1985. The five years that followed were not easy, but he fought a determined and skilful campaign to preserve as far as possible the budgets and independence of the SERC, while maintaining a balance between the funding of central facilities and small grants in support of university research. The creation of university-based Interdisciplinary Research Centres was an important Mitchell innovation.

Bill was a sympathetic European. He nurtured many collaborations with colleagues from the continent, and served as vice-president of the European Science Foundation from 1990 to 1992. He was also sympathetic to "big science", and under his chairmanship the attitude of SERC and the UK towards CERN was relatively positive.

As chairman of the SERC, Bill led the British delegation at the CERN Council. His effectiveness and personality impressed the other delegates sufficiently that they elected him as president, soon after he retired from the SERC. Carlo Rubbia was director-general throughout Bill's presidency. When they both left office at the end of 1994, the Dutch delegate Jan Bezemer, praising their contributions, said: "The energies of their different characters and backgrounds interacted strongly to the great benefit of the organization, a partnership which could not be more fittingly described than by the famous French expression 'cohabitation'."

Bill presided over the admission of Poland (1991), Czechoslovakia and Hungary (1992) and (separately) the Czech and Slovak Republics (1993) as member states of CERN, and of Russia and Israel as observer states (1991). While welcoming new members, Council was also very much occupied with relations with existing member states that were experiencing difficulties in paying their subscriptions, and Bill skilfully steered Council towards a consensus resolution of these difficulties.

As president, Bill led the CERN Council towards the approval of the LHC. He achieved this despite financial difficulties in a number of member states and pressure on the CERN budget from compensating the EUROLEP consortium for a large cost overrun in constructing the LEP tunnel.

He strongly promoted the special LHC Council session of December 1993, which was attended by senior science policymakers from the member states and a number of non-member states, as well as the delegates to Council. The next day he persuaded Council unanimously to adopt a resolution that contained the very important statement that "Council – following presentations of both the needs of the science and of the nature of the proposed machine...as well as of the preliminary indication of costs – agrees that in all these respects the LHC is the right machine for the advance of the subject and of the future of CERN." The resolution went on to ask the director-general to provide a detailed proposal before the end of 1993 "so that Council may move towards a decision on the LHC".

This resolution was a major step towards the approval of the LHC, and is Bill's major legacy to CERN. The director-general designate duly presented a full proposal to the last session over which Bill presided, in December 1993. At this session, Council confirmed its earlier affirmation of the desirability and importance of the LHC, and also its intention "to seek to move to a decision during the first half of 1994" (in the event, the LHC was approved in December 1994).

Bill's European sympathies were undoubtedly enhanced by his happy (second) marriage to Margaret Davies who, as professor of French at Reading, had her own wide range of contacts in the French academic community. It also fitted his interest in food and wine, which was displayed by the ready hospitality which he and Margaret offered to their friends.
Roger Elliott and Chris Llewellyn Smith, Oxford University.

Pierre Jacquinot 1910 – 2002

French atomic physicist Pierre Jacquinot passed away on the night of 21–22 September 2002. Born on 10 January 1910, Jacquinot joined the CNRS in 1933. In 1942, he became professor of physics at the University of Clermont-Ferrand, moving to the University of Paris in 1946. In 1951, he became head of the Orsay laboratory, founded by Aimé Cotton, and which now bears Cotton's name. There, Jacquinot developed techniques in atomic spectroscopy. With his student, Pierre Connes, he developed the Fourier transform spectrometer, with the initial goal of probing atoms more deeply. This instrument has since gone on to enjoy applications in a wide range of fields in physics, notably in space, where it allows satellites to characterize atoms, molecules and ions in the interstellar medium and the atmospheric environment.

In 1962, Jacquinot became director-general of the CNRS, a position that he held until 1969. During this period he worked towards greater links between the CNRS and the universities, establishing the first CNRS associated laboratories in universities.

Jacquinot returned to the Aimé Cotton laboratory in 1969, and remained there as its director until 1978, during which time he was also a professor of the University of Paris XI. His research during this period was devoted to high-resolution laser spectroscopy. A notable success was his observation of the resonance line of the element francium at CERN.

Jacquinot received the CNRS gold medal in 1978, and was also president of the French Physics Society and the Academy of Science.

Photo: D Fautret, CNRS.

Jörg Tutas 1959 – 2002

Jörg Tutas, head of the projects section at Deutsche Börse Systems, and a former researcher at CERN, died as the result of a sports accident on 31 October 2002. After pursuing the early part of his career in research, Tutas joined Deutsche Börse Systems in 1999, becoming a project manager in 2000 and, from March 2001, managing the entire section of almost 100 members. Tutas put the knowledge of methods, processes and teamwork that he gained in international physics projects to excellent use. He managed the reorganization of the networks department, the redesigning of processes within the Y2K project, and he coordinated the implementation of infrastructure for a derivatives exchange system in Chicago (CBOT) to mention just a few. Tutas also set a trend at Deutsche Börse Systems in that he was one of the first high-calibre physicists to join; many have been appointed since.

Tutas held a doctorate from the Technical University in Aachen (RWTH). His thesis "Muons in the H1 detector" describes the development and realization of a novel read-out system for streamer chambers and a trigger system for events containing muons. After gaining his doctorate in 1991, he taught at RWTH until 1994, at Heidelberg University until 1995, and again at RWTH until 1998. During this time Tutas also conducted research at CERN and DESY.

Tutas leaves a wife and two young children.

Renie Adams 1920 – 2002

Lady Renie Adams, widow of Sir John Adams, former director of projects and former director-general of CERN, died on 30 September 2002.

Lady Adams had a unique impact on CERN. In the early 1970s she noticed that many newcomers' wives faced great difficulties in adapting, which could lead to severe family and social problems. To help them, she proposed creating opportunities for them to meet and to help each other. With strong determination, she managed to convince a small circle of friends to help her in this task, and in 1974 the CERN Women's Club was born. In addition to general meetings, some 30 other activities were offered in various areas, including languages, sports and handicrafts. Interest and success were immediate, and the present vitality of the club attests to her foresight.

Lady Adams' special charm was due to her great simplicity and her warm presence, and she will be deeply missed by all those who knew her.

Jenny Van Hove-Jacquemain.

LETTERS

CERN Courier welcomes letters from readers. Please e-mail cern.courier@cern.ch. We reserve the right to edit letters.

Oppenheimer and the bomb

I was very interested to read Nina Byers' article "Physicists and the decision to drop the bomb" (*CERN Courier* November 2002 p25), which states that it was unclear where Robert Oppenheimer's sympathies lay as to whether the bomb should have been used for military purposes. Without being in a position to answer the question myself, I can nonetheless report on a conversation I had with him.

My friendship with Oppenheimer went back to the time when I was France's representative on the United Nations Atomic Energy Commission (1946–1947), which had been assigned to submit proposals for the international control of nuclear energy. He was clearly the most outstanding scientific personality on that body. I do not remember at that time discussing with him the decision to destroy Hiroshima and Nagasaki, but I do recall having talked about it when he and his wife Kitty came to Fontainebleau for a brief stay with me and my wife, probably in the early 1960s. During a walk in the forest, he suddenly stopped and asked me: "François, was it right to drop that bomb?" I answered that if the world had not been shown that a bomb dropped from an aircraft could exterminate 100 000 human beings in a trice, nobody, whether politicians, the military or the diplomats, or above all, public opinion, would have understood what men of science knew – namely that we were entering a totally new phase, when mankind had the means of destroying itself. Was it not legitimate to think that so far at least, the terror unleashed by the deaths of a 100 000 inhabitants of Hiroshima had prevented the outbreak of a third world war, which would have caused tens of millions of deaths and wreaked irreparable destruction? "I hope you are right," he answered. This conversation showed that whatever Oppenheimer's opinions may have been before the bomb was dropped, he was afterwards obsessed by the responsibility of scientists in international life. Did he not show these misgivings when he wrote the words: "Science has known sin"?
François de Rose, Paris.

MEETINGS

The next **Crimean Conference on New Trends in High-Energy Physics**, co-organized by the Bogolyubov Institute for Theoretical Physics (Kiev) and the Joint Institute for Nuclear Research (Dubna), will be held in Alushta, Crimea, Ukraine, on 24–31 May 2003. Applications should be sent to Crimea-2003, BITP, Kiev 03143, Ukraine; e-mail crimea2003@gluk.org. Tel: +380 44 2669123; fax: +380 44 2665998. Further details are available at http://www.gluk.org/hadrons/crimea2003/.

The 5th International Workshop on Neutrino Factories and Superbeams (NuFact 03) will be held at Columbia University, New York, US ,on 5–11 June 2003. For more information, see http://www.cap.bnl.gov/nufact03/.

CAPP 2003 – a Workshop on Cosmology and Particle Physics – will be held by the CERN Theory Division at CERN, Geneva, Switzerland, on 12–17 June 2003. Further details are available at http://wwwth.cern.ch/capp2003/capp2003.html.

The Rencontres de Blois 2003, Physical Cosmology – New Results in Cosmology and the Coherence of the Standard Model will be held on 15–21 June 2003 at the Chateau de Blois in the Loire Valley, France. This year the meeting aims to capitalize on the publication of the first results from the Microwave Anistropy Probe (MAP) and a data release by the Sloan Digital Sky Survey (SDSS), and so will provide a comprehensive review of the field and an opportunity to discuss at length the status of present and future research efforts. For more information, see http://blois.in2p3.fr/2003/.

The 14th International Colloquium on Plasma Processes, CIP 2003, will be held on 29 June – 3 July 2003 in Antibes, France. Organized by the French Vacuum Society, the CIP meetings bring together researchers, engineers and equipment manufacturers, in particular to connect new trends in plasma engineering to the properties of surface coatings. Further information can be found at http://www.vide.org/cip2003.html.

The Joint 6th ICFA Advanced & Novel Accelerators and 29th ICFA Advanced Beam Dynamics Workshop on Laser-Beam Interactions is being held on 7–11 July 2003 at St Catherine's College, Oxford, UK. The workshop aims to bring together news of recent advancements in laser and accelerator technology. For further details, see http://www.clf.rl.ac.uk/news/meetings/index.htm.

The 10th QCD-Montpellier International Conference (QCD 03) will be held at the Palais des Congrés le Corum, Montpellier, France, on 2–9 July 2003. This conference typically involves about 100 physicists, both experimental and theoretical, and provides the opportunuity for young physicists to present a contribution at an international level. For further information, see http://www.lpm.univ-montp2.fr:6714/~qcd/.

The CERN Accelerator School and the Paul Scherrer Institute will hold a course on **Synchrotron Radiation and Free-electron Lasers** on 2–9 July 2003 at the Seehotel Waldstätterhof, Brunnen, Switzerland. The course is intended for staff in laboratories, universities and companies manufacturing related equipment. For further details, see http://schools.web.cern.ch/Schools/CAS.

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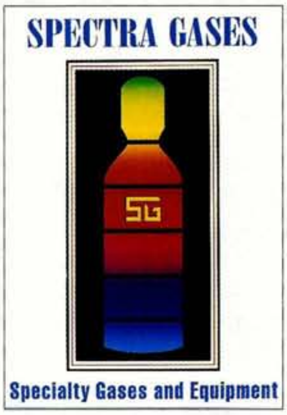

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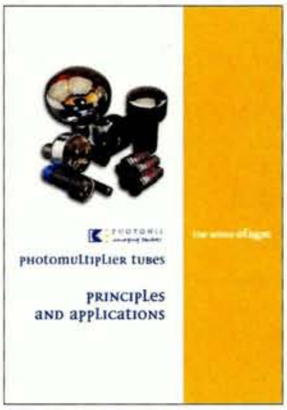

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BOOKSHELF

Flash! The Hunt for the Biggest Explosions in the Universe by Govert Schilling, Cambridge University Press, ISBN 0521800536, £18.95 ($28.00).
The Biggest Bangs: The Mystery of Gamma-Ray Bursts, The Most Violent Explosions in the Universe by Jonathan I Katz, Oxford University Press, ISBN 0195145704, £18.95 ($28.00).

Our understanding of fundamental physics has historically been closely tied to observations of the cosmos. These two books tell the unfinished story of one of the greatest challenges in contemporary astrophysics: the origin of gamma-ray bursts (GRBs), which appear to be the most energetic events in the universe. It's an exciting story and well worth telling, especially to the lay public.

In 1687, Isaac Newton published his universal theory of gravitation. For well over 200 years it reigned supreme, because it appeared to describe completely all of the observed motions of the planets and other astronomical objects in the heavens. As it turned out, of course, even this enormous advance – achieved by "standing on the shoulders of giants", as Newton famously remarked – is by no means the entire story. And what a story it has turned out to be. For even though Newtonian dynamics works most of the time, it lacks the capacity to describe – let alone predict – many of the gravitational phenomena that are at the frontiers of research in astrophysics today.

In 1915, Einstein published his general theory of relativity. In attempting to explain a discrepancy between theory and observation in the perihelion of Mercury, and by incorporating into Newtonian dynamics his special theory of relativity, Einstein created a dynamics that revolutionized our understanding of the universe. Earlier, in 1905, Einstein taught us that energy and mass are equivalent, and he introduced the concept of space–time. Then in 1915, he showed that the stress-energy tensor of space–time was a response to its curvature – or, in John Wheeler's phrase, "matter tells space–time how to bend, and curved space–time tells matter how to move." Einstein's theory went on to predict the existence of phenomena such as the bending of light in a gravitational field, gravitational radiation, neutron stars and black holes, among others. Here, as in much of modern science, the truth really is stranger than fiction.

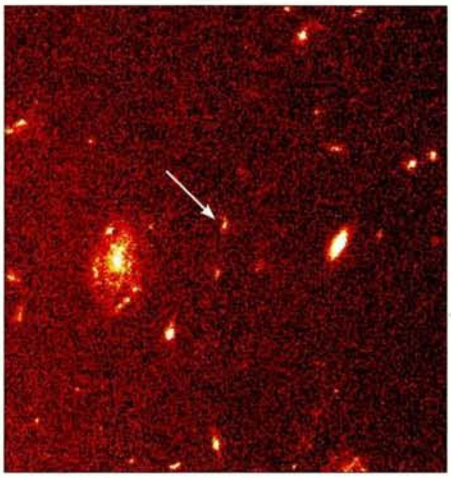

Image of the sky around GRB 971214 taken in 1998 by the Hubble Space Telescope about four months after the burst, which was as bright as the rest of the universe. The arrow marks the host galaxy, about 12 billion light-years from the Earth. Photo courtesy of S R Kulkarni and S G Djorgovski (Caltech), the Caltech GRB Team and NASA/STScI.

Gamma-ray bursters are one of the strangest phenomena of all. They were discovered by accident in the late 1960s, using satellites created to search for violations of the nuclear test-ban treaty. Since then they have been a source of great mystery, and have had their share of scientific competition and controversy. We now know that GRBs, which occur at a rate of about one per day and are uniformly distributed over the sky, are at cosmological distances and must be by far the most energetic phenomena in the universe since the Big Bang itself. However, reaching these conclusions took 30 years and the combined efforts of the worldwide astrophysical community, using a panoply of the most modern instruments and theoretical developments, as well as rapid communication via the Internet and the Web.

Visual and highly accessible, Schilling's book is a masterpiece of lay scientific reporting. He is the author of more than 20 previous books and hundreds of articles on astronomical subjects (it shows; the prologue alone is almost worth the price of the book). Beginning with the initial discovery of GRBs by Ray Klebesadel and Roy Olson circa 1970, the reader is artfully led down the path that science often takes – one of tantalizing data, missteps, blind alleys, wishful thinking, raging competition, broken dreams – and for some, great success. Along the way we meet all of the major players in the GRB drama, and are skillfully introduced to all of the relevant scientific history, theoretical concepts and experimental findings. By the end, we've learned how it was determined that GRBs are uniform across the sky (from the BATSE detector on the Compton Gamma Ray Observatory), how it was determined that GRBs are at cosmological distances (by learning, using the BeppoSAX satellite, how to observe GRB afterglows at optical and radio wavelengths, which in turn allowed the determination of redshifts), and how it was concluded that these objects are so enormously energetic.

On these last issues, the fact that GRBs wink in and out of existence so quickly made it imperative to share the position data from BATSE and BeppoSAX as rapidly and broadly as possible, so that the afterglows would be bright enough for spectral analysis. The Internet and the Web provided the means to do this, and the data provided the basis for the fully automatic wide-angle optical search systems known as LOTIS and ROTSE. The theoretical constructs discussed include the relativistic fireball model and magnetars, among others. My only quibble is that given the obvious care that the author devoted to his task, it's too bad the proof-reading was not better, as there are quite a few typos. However, the book is very well translated from the Dutch, and makes for superb reading.

Jonathan Katz's book is differently oriented. Rather than spend as much time on the historical aspects, he devotes a great deal of effort to elucidating the science surrounding GRBs, as well as the technical details of various detection systems. My opinion is that while these parts are very well done, it is all rather too much for a lay reader. Instead it might be very useful for classes of undergraduate physics or astronomy students. The kinds of explanations that Katz provides are not often found in the textbooks, and would provide excellent supplementary information. However, there is a significant amount of complaining about NASA and NSF decision-making, as well as gratuitous remarks about other people's careers. This material does nothing to advance the book's main purpose, and would have been much better left out.

Both books contain very useful glossaries, guides to other sources and literature, and are well indexed. Each has a great deal to offer to its respective audience.
Robert Eisenstein, CERN and the National Science Foundation.

VIEWPOINT

Understanding the physics of the universe

A new institute at Stanford comes at just the right time, says **Roger Blandford**, future director of the Kavli Institute for Particle Astrophysics and Cosmology.

This is a great time to be an astrophysicist. Over the past 30 years, almost all of the roughly 70 octaves of the electromagnetic spectrum accessible for study have been opened up. Telescopes using new technologies have expanded our view of the cosmos far beyond what we see in the single octave available to traditional optical astronomy. The size, age and shape of the universe have been measured, and its black holes, neutron stars and extrasolar planets have been catalogued. We are on the threshold of using cosmic rays, neutrinos and gravitational waves to find new sources, and we are encountering a world of extremes. We must contemplate the diffuse intergalactic medium, as well as singularities with a nominal density more than 120 orders of magnitude larger. Similarly, we infer a difference in magnetic field strength between intergalactic space and the field in "magnetars" that ranges over 30 orders of magnitude.

Over the same period, the Standard Model of elementary particles has been largely completed. Almost all of the standard particles have been detected, and their properties fitted into a pattern. It is easy for physicists to take this for granted, but describing this framework surely ranks as one of the greatest scientific accomplishments of all time. Furthermore, the intellectual connection of this model to the equally rich fields of nuclear, atomic and condensed matter physics is well developed.

Now, in both astronomy and physics, the scientific focus is shifting from asking "what?" to trying to understand "why?" We want to understand why galaxies have the regular properties that are observed locally, just as we want to understand such things as the electron–proton mass ratio. In many cases, researchers from the two disciplines seem to be looking at the same problem from different perspectives (as the conference reports on p26 show). I expect that closer collaboration between the fields will lead to exciting advances in many areas where they intersect.

For example, astronomers have discovered that roughly seven-eighths of the matter in the universe is in a "dark" form whose properties

they do not recognize. Meanwhile, physicists suspect that there is a whole new family of hitherto undetected supersymmetric partners to the standard particles. Both communities have concluded that they are probably discussing the same thing. In another instance, physicists are developing the theory of supersymmetric strings and its generalization as a tool for understanding the basis of the Standard Model, while astronomical measurements of the expansion of the universe have revealed the presence of "dark energy", which strikes at the heart of string theory.

Recently, cosmic rays have been discovered with energies as large as 50 J – 10 million times more energetic than can be made at particle accelerators. Astronomers are divided as to whether these particles come from black holes and neutron stars, or if they derive from exotic matter left over from the Big Bang. If the former is correct, then the means by which the particles are boosted to these energies may be similar to some advanced concepts that have been developed for future particle accelerators. If the latter is correct, then nature is performing experiments for our benefit that we will never be able to carry out on Earth.

Finally, the technology and methodology of astronomical observation has changed from individual acquisition and scrutiny of mainly photographic images and spectra. The field now relies mainly on large teams of astrophysicists using modern, solid-state detectors which produce terabytes of digital data that must be processed, manipulated and archived – just as in particle physics experiments.

It is therefore clear that astronomers and physicists will be working together increasingly on everything from equations to electronics. However, this poses some interesting sociological challenges, because historically the two communities have worked in quite different ways. Physicists are used to designing active experiments, while astronomers are used to performing passive observations. The present time represents an extraordinary opportunity to build a facility capitalizing on the rich scientific heritages of astronomy and particle physics, and the complementary strengths that they bring to the emerging science at their interface.

Physicist Fred Kavli and the Kavli Foundation have pledged $7.5 million (€6.9 million) to establish an institute that will focus on recent developments in astrophysics, high-energy physics and cosmology. The new Kavli Institute for Particle Astrophysics and Cosmology will be located in a new building at the Stanford Linear Accelerator Center (SLAC), and will open its doors in 2005. I am honoured to have been chosen as the inaugural director. Steven Kahn of Columbia will join me as deputy director and assistant director of research at SLAC (p33).

Initially, we intend to follow a balanced growth plan with theory, computational astrophysics and phenomenology on one hand, and experimental astrophysics and high-energy observing on the other. We will draw upon existing strengths at Stanford in theoretical (especially high-energy) physics and astrophysics, gamma-ray and X-ray astronomy, gravitational physics, microwave background instrumentation and underground physics.

Part of the excitement of the field is that it is impossible to predict where it will be in five years' time and what its scientific focus will be. What is clear is that the time is right to build a world-class centre.

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