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DIRECTORY ISSUE

A conversation with Pierre-Gilles de Gennes
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Direct detection of non-baryonic dark matter
Atom interferometry
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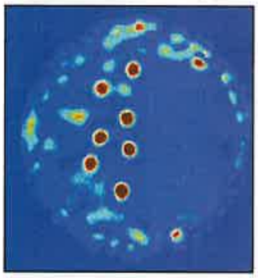

▲ PAGE 136
Cavity solitons in a VCSEL

▲ PAGE 153
The *human engine*, and how to keep it cool

▲ PAGE 157
A conversation with Pierre-Gilles de Gennes

FEATURES

REPORTS

NEWS, VIEWS AND ACTIVITIES

contents

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Atom interferometry

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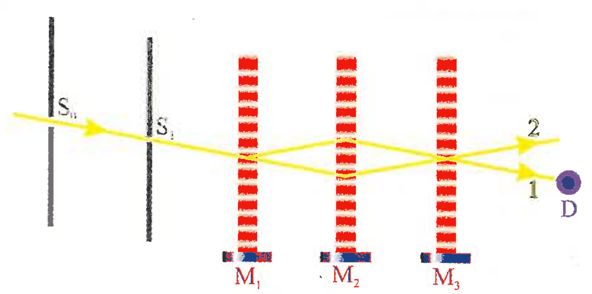
Historical overview [1]

In 1924, Louis de Broglie generalized to material particles the wave-particle duality, introduced by Einstein for the photon, and gave the formula relating the wavelength λ to the particle momentum p ($p = mv$ in the non-relativistic approximation): $\lambda = h/p$. This discovery, derived from theoretical considerations, was rapidly confirmed by matter-wave diffraction experiments:

- in 1927, Davisson and Germer observed the diffraction of electrons on the surface lattice of a metallic crystal;
- in 1930, Estermann and Stern made a beam of helium atoms diffract on the surface of a NaCl crystal.

These experiments were then extended to inelastic diffraction and to neutron diffraction. Such techniques allow the measurement of the local order and give access to the dispersion relation of the surface or volume elementary excitations. These probes (electrons, neutrons, helium atoms) are complementary to X-rays, their interactions with matter being different. Besides, the early diffraction experiments have opened the way towards the realization of matter-wave interferometers, but it took a long time before two majors difficulties were overcome:

- for most matter waves, the accessible values of wavelengths are far shorter than a nanometer. For instance, in our interferometer, lithium atoms ^7Li, with a velocity of 1060 m/s, have a de Broglie wavelength $\lambda = 54$ pm, ten thousand times smaller than that of visible light;
- there is no natural mirror or beam-splitter for matter waves. Reflection on most solid surfaces is inelastic with a large probability and the small elastic component is not coherent because the surface roughness, large with respect to the wavelength.



▲ **Fig. 1:** Scheme of a three grating Mach-Zehnder interferometer. After collimation by the slits S_0 and S_1, the matter wave travels through the diffraction gratings which are either material gratings or laser standing waves created by reflection of traveling waves on the mirrors M_1, M_2 and M_3. A detector D is placed on one of the two outputs of the interferometer, labeled 1 and 2 in the figure. The interference signals on both outputs have opposite phases.

A simple generalization of optics was not possible. In 1952, Marton and coworkers built a Mach-Zehnder electron interferometer using electron diffraction from three very thin metallic crystals. However, electron interferometry did not develop much, probably because of the extreme sensitivity to stray electric fields.

Concerning neutrons, apart from an interferometer similar to a Fresnel bi-prism built in 1962 by Maier-Leibnitz and Springer, all neutron interferometers are based on successive Bragg reflection on three gratings (see Fig. 1): the so-called "perfect crystal neutron interferometer", using three gratings cut in the same silicon crystal, was first realized by H. Rauch and coworkers in 1974. This apparatus shows excellent performance and its use is mostly limited by the need of a thermal neutron source. Moreover, neutrons are essentially insensitive to electric fields and interact only weakly with matter, which also reduces the range of possible experiments. In this context, the development of atom interferometry considerably broadens the field of matter-wave interferometry.

Birth of atom interferometry

The experiments of I. Rabi, later modified by N. F. Ramsey, represent atomic analogs of polarization interferometry in optics, the internal states of the atom (or the molecule) playing the role of the polarization states of the photon. With light, such an experiment simply consists of putting a birefringent plate between two polarizers. We will not discuss here this type of experiment, which allowed in particular the outstanding development of atomic clocks. In the following, we will focus on experiments which are the atomic analogs of optical interferometers where the two paths followed by the wave are spatially separated. The first experiments, dating back to 1991, were already very precise:

- a Young double slit experiment was realized by O. Carnal and J. Mlynek using an atomic beam of metastable helium [2];
- D. Pritchard and coworkers built a Mach-Zehnder interferometer using a sodium atomic beam and diffraction from material gratings [3];
- an interferometer based on Ramsey fringes in saturated absorption was built by J. Helmcke and coworkers for a calcium beam [5], following an idea by Ch. Bordé [4]. This apparatus allowed a demonstration of the Sagnac effect for atomic waves;
- a Mach-Zehnder interferometer using cold sodium atoms and laser diffraction was built by M. Kasevich and S. Chu [6]. This interferometer served to measure the local acceleration of gravity g with a relative uncertainty on the order of 10^{-6} [6].

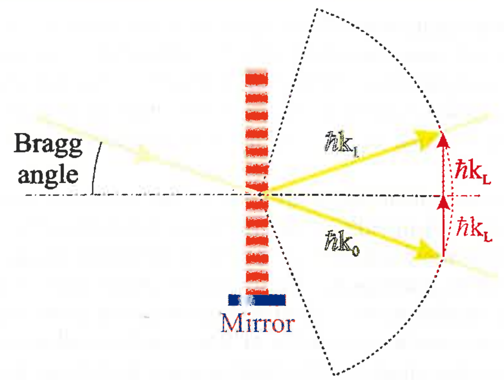
This research field has developed very rapidly since 1991 (see [7] and the book "Atom interferometry" [8]): various atom interferometers have been built, most of them of the three-grating Mach-Zehnder type, as in Fig. 1.

Atom diffraction

The coherent manipulation of matter waves made of atoms (or molecules) is based almost only on diffraction. Two main techniques can be used: diffraction from material gratings and diffraction by laser standing waves.

Diffraction from material gratings

Many interferometers are based on micro or nanostructures. Apart from the Young slits used by the group of J. Mlynek, the main tool is the grating cut through very thin films using nano-



▲ Fig. 2: Diffraction of a matter wave in the Bragg regime: one photon is absorbed in one of the two traveling waves forming the standing wave and is emitted by a stimulated process in the other traveling wave. During this process, the kinetic energy of the particle (hence the modulus of the atomic wavevector) and the total momentum are both conserved.

lithographic techniques. The grating period ranges between 100 and 300 nm. They allow the diffraction of atoms (Na, He, etc.), small molecules (Na_2, H_2), small helium clusters (J. P. Toennies and his group developed a very original mass spectrometry technique based on diffraction from a grating to study these fragile clusters) as well as large molecules (the group of A. Zeilinger and M. Arndt has observed diffraction and interference effects with C_{60}, C_{70}, $C_{60}F_{48}$ and even a biomolecule, a porphyrin). The fact that diffraction from material gratings is universal is very interesting, but this versatility is counterbalanced by two drawbacks. The gratings are difficult to produce and very fragile. Moreover, the diffraction efficiency is rather low and the only adjustable parameters, the period and the open fraction of the grating, do not allow a full optimization of the diffraction efficiency. Finally, the attractive van der Waals interactions between the grating and the atomic wave makes this diffraction process not well adapted to ultra-cold gases.

Diffraction by light

In 1933, P. Kapitza and P. A.M. Dirac proposed to diffract electrons from a standing light wave. The process can be explained by momentum conservation between the scattered photon and the diffracted particle: one photon is absorbed in one of the two traveling waves creating the standing wave and is emitted by a stimulated process in the other traveling wave. During this process, the particle receives the momentum of two photons; in the Bragg geometry, where the light wavefronts are the analogs of the crystal planes in X-ray diffraction, this momentum transfer does not modify the kinetic energy of the particle (see Fig. 2).

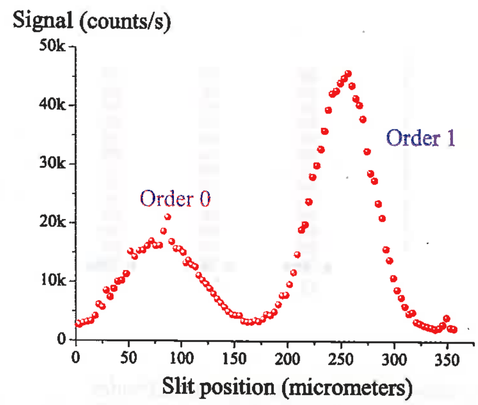
In the 1960's, this theoretical idea was generalized to atoms which is particularly interesting because atom diffraction can be achieved with low light intensities (typically a few tens of mW/cm^2) thanks to the atomic resonance phenomenon. However, the first observation of atom diffraction peaks was made only in 1983 by the group of D. Pritchard. Since then, several variants of laser diffraction have been developed, in particular Raman diffraction, a process during which the atom changes its internal state by absorbing and emitting photons with different frequencies. Raman diffraction is widely used, especially with cold atoms, because it allows the direct and diffracted beams to be distinguished through their internal states. In all cases, one has to avoid spontaneous emission so that the diffraction process remains coherent: indeed, spontaneous photons can break the coherence of diffraction by giving some spatial information on the atomic path. The simplest way is to use a laser frequency slightly different from the atomic resonance frequency, but some other tricks can be used.

In the Bragg geometry represented in Fig. 2, diffraction can be described as a Rabi oscillation between two levels of a quantum system, one level representing the incident atomic wave and the other one the diffracted wave. The diffraction probability can thus be varied between 0% and 100% simply by adjusting the intensity of the interaction (which is proportional to the laser power density divided by the laser frequency detuning from atomic resonance) or the interaction time; such a versatility is ideal to build the mirrors and beam-splitters of a Mach-Zehnder interferometer. Figure 3 shows an example of atomic diffraction observed with our apparatus.

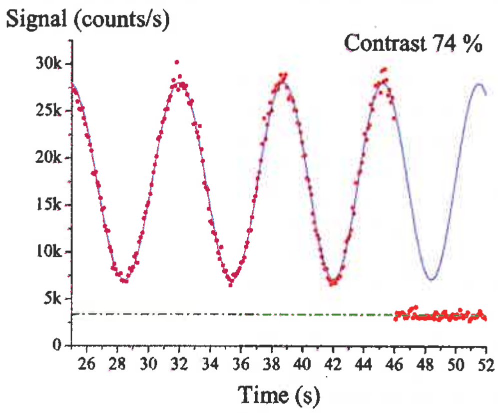
Our interferometer

Our interferometer [9] is similar to the one of D. Pritchard [3, 8]: in both apparatuses, near the second grating, the two atomic paths are sufficiently separated so that a perturbation can be applied on only one atomic path. For this purpose, the separation of both arms at this point has to be as large as possible: it is 100 μm in our apparatus, whereas for most experiments done by D. Pritchard and coworkers, this separation was only 55 μm. These values may seem small, but, in both cases, they represent millions of de Broglie wavelengths!

We chose to use lithium (its smaller mass leads to a larger wavelength, 54 pm in our present experiment) and laser diffraction: to the resonance wavelength of 671 nm is associated a grating period of 335 nm and a first order diffraction angle of 160 μrad. In our interferometer as in the one of D. Pritchard, the distance between consecutive gratings is about 60 cm. One has to collimate the atomic beam far better than the diffraction angle: this is done by two narrow slits. Our interferometer is thus pretty long: between the source and the detector, the lithium beam travels over 340 cm! The main difficulties of this experiment are the high precision needed for the alignments and the weakness of the output atomic flux (a few tens of thousand atoms per second).



▲ Fig. 3: Bragg diffraction of a lithium atomic wave by light. The intensity in the diffraction orders 0 and 1 is recorded by moving the detector. The laser standing wave has been adjusted to give a high diffraction probability into the first order. In a separate experiment, we have verified the absence of other diffraction orders, in agreement with the theory of Bragg diffraction



▲ **Fig. 4:** Atomic interference fringes recorded by moving the position of the third grating of the interferometer. Each point corresponds to a counting time of 0.1 s. Once the background signal (recorded on the right of the figure) has been removed, the measured fringe contrast is 74%.

Figure 4 shows fringes recorded by sweeping the position of the third grating: the fringe contrast of 74% is worth noticing as it is the best ever obtained with a hot atom interferometer. The measured phase noise (about 17 mrad for a measuring time of 1 second) gives an idea of the achieved sensitivity.

Measurements based on atom interferometry

A wide range of high sensitivity measurements can be achieved with atom interferometers.

Atomic and molecular physics properties

By applying a perturbation on one of the two atomic paths inside the interferometer, the phase shift and the attenuation of the corresponding wave by this perturbation can be measured on the interference signal. Such experiments have been made by the group of D. Pritchard and more recently by the group of J. P. Toennies. The main interest is either a direct access to quantities which are difficult to measure, for example the electric polarisability of atoms or molecules, or the access to new quantities, such as the index of refraction of gases for atomic waves.

Inertial effects

Because of the Sagnac effect, a rotation of the interferometer induces a dephasing of the fringes. Compared with laser gyrometers, the sensitivity is considerably larger as it scales like the total energy of the interfering particle. The corresponding gain is equal to the ratio of the total energy of the atom to the energy of the photon, *i.e.* $mc^2/\hbar\omega \approx 10^{10}$! However, this comparison overestimates the gain, because the detected flux and the area of the interferometer are assumed to be the same for both types of gyrometers. After a first demonstration of the Sagnac effect with atomic waves by J. Helmcke and coworkers in 1991 [5], a very high performance apparatus has been built by the group of M. Kasevich [10] achieving a sensitivity of 6×10^{-10} rad/s$\sqrt{\text{Hz}}$. Spatial applications are under development (HYPER project of ESA);

Atomic interferometers are also sensitive to accelerations. This sensitivity has been used to develop high precision measurements of the local acceleration of gravity and of its gradient. The experiments, which involve a cold atom interferometer using the geometry of an atomic fountain, were performed by the groups of S. Chu at Stanford University [11] and of M. Kasevich at Yale. Measurements of the gravitation constant G are in progress in the group of M. Kasevich and in the group of G. Tino at Firenze. Finally, the group of M. Kasevich is developing the prototype of a compact accelerometer based on atom interferometry.

Fundamental constants

The present efforts concerns the measurement of the fine constant structure a. With a set-up similar to the one used as an accelerometer, S. Chu and coworkers have measured very precisely the photon-recoil frequency $\hbar k^2/2M$ of a Cesium atom. Combining this value with independent measurements of the Rydberg constant R_∞, the proton-electron mass ratio m_p/m_e and the Cesium-proton mass ratio M/m_p provides a determination of α with an accuracy of 7.4 ppb [12] through the relation $\alpha^2 = (2R_\infty/c) \times (m_p/m_e) \times (M/m_p) \times (h/M)$.

Prospects

The progress in cooling and in the manipulation of cold atoms, particularly the availability of Bose-Einstein condensates and the development of atom lasers open extremely rich prospects for atom interferometry. Not only the de Broglie wavelength is greatly enhanced for cold atoms, but also, with respect to the experiments described here, the new feature is the existence of coherent sources of atomic waves and the possibility of non linear and coherent interactions between atomic waves. The revolution induced by these new possibility is somewhat similar to the one opened for ordinary optics by the advent of the laser and it should lead to numerous and fascinating developments in the near future.

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features

Direct detection of non-baryonic dark matter

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A dark universe

In 1933, Fritz Zwicky, observing the velocity distribution of galaxies in the Coma galactic cluster (Fig. 1), found a dynamic mass hundred times higher than could be inferred from its luminosity [1]. Far from vanishing in the light of more and more numerous and precise observations, this hidden mass problem has been confirmed as a key problem of contemporary cosmology. During two decades, a number of high precision observations, at various astronomical scales (rotation curves of spiral galaxies, dynamics of galaxies within clusters, X-ray emission of the hot intra-cluster gas, luminosity of distant type Ia supernovae, temperature anisotropies of the cosmic microwave background) have finally led to an impressive agreement on the mass-energy balance of our universe. We are now entering a new period of general consensus about a standard cosmological model (for a recent review see [2] for instance). The space is flat (rather than curved) which can be expressed by $\Omega = 1$, where Ω is a density parameter normalised to the critical density. The matter contribution to this density is about 30% ($\Omega_M = 0.27 \pm 0.05$), and most of the energy in the universe today appears as a gravitationally self-repulsive "dark energy" of totally unknown nature, accelerating the expansion of the universe ($\Omega_\Lambda = 0.73 \pm 0.05$). Baryonic matter, i.e. "ordinary" matter (protons and neutrons) which constitutes stars and galaxies, amounts to a few percent ($\Omega_B = 0.046 \pm 0.007$), in agreement with the theory of the Big Bang nucleosynthesis. Most of the matter in the universe (approximately 85%) is then non-baryonic and dark (since luminous matter only contributes to $\Omega_{lum} \cong 0.005$). The two dominant components in our universe, dark energy and dark matter, are presently not understood and are both of a very mysterious nature!

One of the most favoured hypothesis is that this non baryonic dark matter is constituted by a new type, still undiscovered, of elementary weakly interacting massive particle, which could explain the observed structures of our universe[1]. Generically called WIMPs, acronym for Weakly Interacting Massive Particles, these hypothetical particles would appear as thermal relics from the Big Bang era during which they were created, now trapped in the gravitational potential of galaxies and clusters of galaxies. It appears as a fascinating coincidence that, in order to develop a cosmologically relevant density parameter, of order unity, these WIMPs must have annihilation cross sections typical of the electroweak interactions. Fortunately enough a wealth of WIMP candidates are offered by Supersymmetry extensions of the Standard Model of Particle Physics [3], rather generically present in supergravity and superstring theories, that allow the unification of the four fundamental interactions. A rich spectrum of new elementary particles is predicted by Supersymmetry and in a large class of supersymmetric models, the lightest supersymmetric particle (generally supposed to be the neutralino) becomes stable. Note that this lightest superparticle, not observed at the LEP collider, must necessarily have a mass greater than 40 GeV. On the other hand, in order that its relic density remains consistent with the observed Ω_M, its mass must be < 1 TeV.

> this hidden mass problem has been confirmed as a key problem of contemporary cosmology.

This scenario is however still hypothetical since Supersymmetry has not been experimentally discovered. If the dark matter halo of our Milky Way is made of neutralinos, their detection in terrestrial detectors should be possible and the most satisfying proof of the WIMP hypothesis would be direct detection of these particles. The study of the rotation curve of our Galaxy indicates a dark matter density of about 0.3 GeV/cm^3 in the solar vicinity, the mass equivalent of 0.3 proton/cm^3. The contribution of baryonic dark matter to this halo, under the form of massive and compact halo objects, has been found to be negligible. As our solar system travels through this halo of neutralinos with a velocity of about 220 km/s, a flux of several millions of neutralinos per square meter and per second is crossing the Earth. This number is amazing, but, as we will see, the detection is not easy!

▲ Fig. 1: With a size of a few tens of millions of light-years, the Coma Berenices cluster of galaxies contains more than 1000 galaxies. From a measure of the kinetic energy of these galaxies, F. Zwicky showed that it is hundred times more massive than one can infer from its luminosity. (Image: Omar Lopez-Cruz & Ian Shelton/NOAO/AURA/NSF)

Direct detection principles

Neutralinos are coupled to matter through the weak interaction. This involves a (very low) probability for elastic scattering of a neutralino from nuclei of the material of a terrestrial detector [3]. Despite the huge number of dark matter particles crossing the detector in a time unit, the probability of scattering is so tiny that the detection rate is extraordinary low.

More quantitatively, for a given density and a given velocity distribution of neutralinos in the galactic halo and in the case of a dominant coupling independent of the nuclear spin, the event rate R is proportional to the product σA^2 where σ is the elastic scattering cross-section and A the nucleus mass number. The value of the cross section is predicted by the theory, but the values of many theoretical parameters are still unknown and the predictions allow a very broad domain of values: the allowed values of σ, normalised to the proton, spread over 7 orders of magnitude, from 10^{-48} to 10^{-41} cm^2. The corresponding event rate,

[1] Neutrinos were once attractive candidates for non-baryonic dark matter. But recent experiments give evidence of a very low neutrino mass: they cannot significantly contribute to Ω_M. Moreover they are "hot" relativistic particles, and "hot" dark matter leads to much more diluted structures in the universe than can be observed.

▲ Fig. 2: *(Left)* A 320 g phonon-ionisation Germanium cryodetector from EDELWEISS. *(Right)* A 100g phonon-ionisation Silicon cryodetector from CDMS. Note the photolithographically-fabricated thin film on the surface, which acts as the phonon sensor.

in a germanium crystal and for a neutralino mass of say 50 GeV varies from 5.10^{-7} to 5 event per kilogramme of detector and per day. At these ultra-low signal levels the task of the background reduction in the detector is a very demanding challenge: construction of shielding against external radioactivity, drastic selection of ultra-low radioactivity materials, protection against cosmic radiation in underground laboratories. Moreover, the recoil energy induced from galactic neutralinos is low, below 100 keV, and the shape of the recoil energy spectrum is exponentially decreasing. Most of the signal is lost if the detector energy threshold is > 10 keV and the usual shape of any detector background can easily mimic the signal.

Fortunately a number of signatures exist which can help to disentangle the signal from the background and to confirm its galactic origin. First of all neutralinos induce nuclear recoils in the detector, while most of the background particles (X and gamma photons, electrons from beta decays) create recoiling electrons in the detector through electromagnetic interaction. If the detector is able to discriminate between nuclear and electron recoils a drastic reduction of the background can be obtained. As we will see, most performing detectors (phonon and ionisation cryogenic detectors) presently achieve a background discrimination factor of more than 99.9 %, on an event by event basis. This discrimination is inefficient against neutrons which, as neutralinos, induce nuclear recoils through elastic scattering and mimic an eventual dark matter event. However neutrons will suffer multiple interactions in the detector with a high probability, which is not the case of the weakly coupled neutralinos.

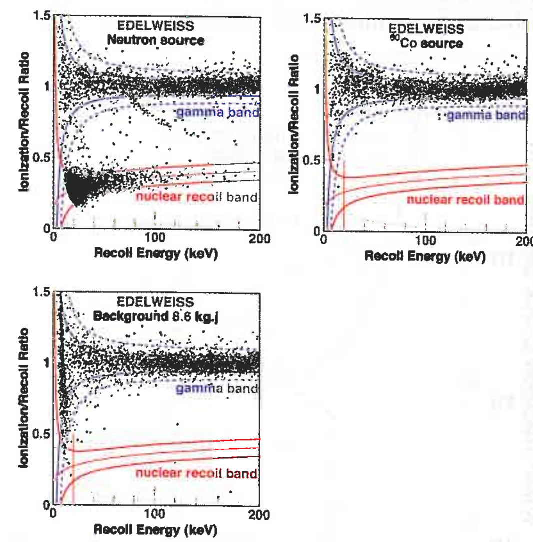
Discovering such a weak ripple requires robust statistics on the signal...

A direct signature of the astrophysical origin of a signal is given by its annual modulation: the Sun moves around the galactic centre with a velocity of about 220 km/s, while the Earth revolves around the Sun at a velocity of about 15 km/s that is added in summer and subtracted in winter, resulting in a sinusoidal modulation of the neutralino flux impinging on a terrestrial detector. The resulting event rate modulation is weak, of the order of 5% at most between June and December. Discovering such a weak ripple requires robust statistics on the signal and this type of detection is reserved to very massive detectors of the order of 100 kg or more. Moreover a number of key experimental parameters (energy calibration, detection efficiencies, possible seasonal modulation of the backgrounds, . . .) must be maintained under control at a level much better than 5 % over very long periods, a very difficult task.

To conclude one can try to give a composite picture of the ideal dark matter detector. It is very massive (100 kg or more) to provide evidence of an eventual annual modulation of the signal, but constructed in a segmented form to eliminate multiple interactions which can not arise from neutralinos. Each detector module has a very low nuclear recoil energy threshold (10 keV or lower) and must discriminate, with a very high efficiency, the nuclear (signal) from electron (background) recoils. Ideally various target materials are used to take advantage of the event rate dependence on A^2 as an additional signature. The internal and environmental backgrounds must be maintained at very low levels, including the neutron background: a deep underground site insuring the most efficient suppression of cosmic muons is highly desirable, as well as vetoes to tag the few residual muons able to generate neutron showers. And, last but not least, the detector having to continuously work over very long periods of time in a rather inaccessible site, a very reliable technology is required. As one can suspect, this ideal detector does not yet exist, but various groups actively pursue this goal, using various approaches.

Experimental strategies

A first group of experiments use "classical" detectors of nuclear physics, Germanium semiconductor diodes or NaI scintillators. These techniques have been pushed to the highest technology and design standards, but an efficient nuclear recoil discrimination is missing. Germanium diode experiments (HDMS [4], IGEX [5], ...) have succeeded in operating under ultra-low background conditions (of the order of 0.05 event/keV/kg/day at 15 keV recoil energy) and HDMS has for a long time presented the highest sensitivity to neutralino dark matter. Large mass experiments are proposed, using new shielding designs and background reduction techniques. The DAMA [6] experiment uses a large mass of NaI

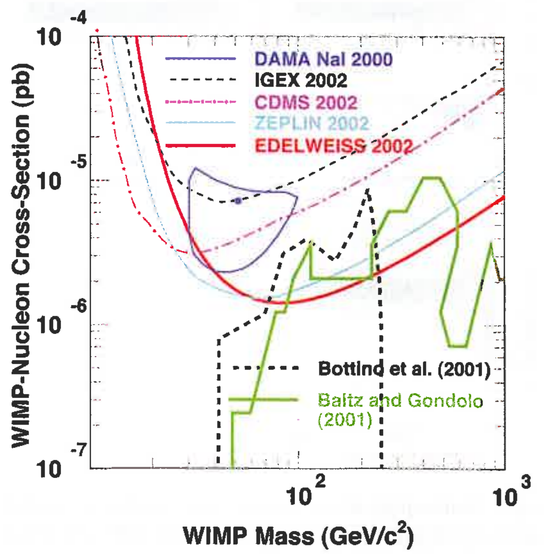


▲ Fig. 3: Distributions of the discrimination parameter (ratio of the ionisation signal to the recoil energy) from data collected in the centre fiducial volume of an EDELWEISS Ge detector. As expected no event is found in the nuclear recoil band when the detector is illuminated by a γ-photon source. The blue lines define the 90% and 99.9% efficiency bands for photons (centered on 1 by construction) and the red lines the 90% efficiency band for nuclear recoils. The hyperbolic green curve corresponds to a 3.5 keV ionisation energy threshold and the vertical red line to a 20 keV recoil energy threshold.

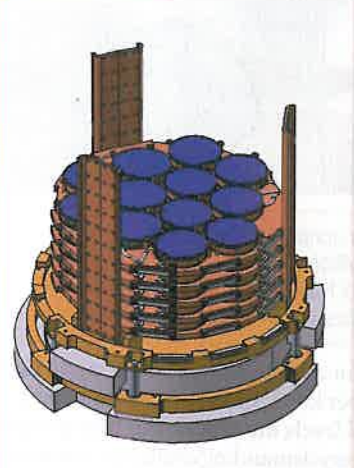
scintillators: nine modules for a total mass of about 90 kg. An upgrade to a total mass of 250 kg is under way. It is the only experiment that has claimed evidence for a WIMP detection. After 4 years of detector running (58000 kg.day of data accumulation) an annual modulation has been displayed in the signal and explained in terms of a WIMP of mass around 50 GeV and of (spin independent) cross section on the proton of 7.2 10^{-42} cm^2. This highly discussed result has not been confirmed by the other experiments which have recently reached the very high sensitivity level required.

NaI scintillators allow a limited nuclear recoil discrimination, the shape of the light pulses looking different for nuclear recoils and for electron recoils. But the effect is small at the energies of interest, near the threshold. Enhanced discrimination capability exists for liquid Xe scintillators, used also by the DAMA group and in the ZEPLIN [7] experiment; the pulse shape discrimination is however purely statistical. One has to extract from an experimental distribution of the decay times of the scintillation pulses the ones corresponding to nuclear recoils.

Efficient nuclear recoil discrimination, on an event by event basis, is only allowed by very recent technologies offering two readout channels for a single event. Cryogenic detectors, working at milli-Kelvin temperatures, have in common a phonon (or heat) channel that measures the energy deposition independently of the nature of the recoiling particle. For cryogenic phonon-ionisation experiments (CDMS [8], EDELWEISS [9]) the second channel measures the deposited charge (different for nuclear or electron recoils), accomplished by the use of semiconductor crystals, Germanium and also Silicon for CDMS (Fig. 2). These experiments have already produced physics results and are among the most sensitive dark matter searches. For cryogenic phonon-light experiments (CRESST [10], ROSEBUD [11]) the second channel is a scintillation measurement. A large range of scintillating materials is available, an interesting feature for the project of using targets



▲ Fig. 4: The present spin-independent sensitivity limits of direct detection experiments. The limit cross-section on the proton (in pbarn, 1 pbarn=10^{-36} cm^2) is given as a function of the WIMP mass. Closed contour: allowed region at 3σ CL from the DAMA annual modulation data. Two regions spanned by some of the supersymmetric model calculations of [12, 13] are also shown.



◄ Fig. 5: Drawing of the EDELWEISS-II detector setup. Up to 120 Ge detectors of mass 320 g (the blue plates) can be accomodated in a compact hexagonal arrangement at 10 mK. The grey plate, made of ultra-pure archeological lead, shields the detectors from the radioactivity of the dilution cryostat (not shown).

with different mass numbers. First results of CRESST, using 300 g $CaWO_4$ modules, are expected in a few months. Also cryogenic but at a much higher temperature (165 K) the ZEPLIN-II experiment will use liquid Xenon as a target. In addition to the scintillation signal in the liquid phase the charges produced in the liquid (more efficiently by electron recoils) are drifted in the surrounding gas phase where they are detected. An experimental device with a target mass up to 30 kg is under construction.

Edelweiss

As an illustration, a detailed description will now be given of the EDELWEISS experiment that represents to date the experiment with the best sensitivity for the spin-independent coupling and neutralino masses greater than about 50 GeV. The EDELWEISS collaboration, an association of seven French laboratories, has developed cryogenic phonon-ionisation Germanium detectors. The experimental site is the Laboratoire Souterrain de Modane in the Fréjus Tunnel under the French-Italian Alps. The 1780 m rock overburden results in a 2.10^6 reduction of the cosmic muon flux (4 muons/m^2/day).

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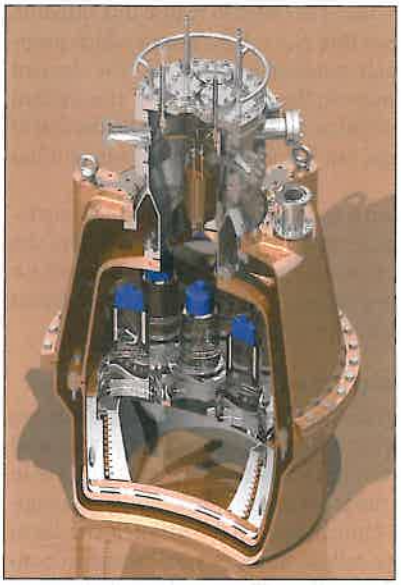
Three detectors are mounted in a dilution cryostat made of selected materials of very low radioactivity and protected from the radioactive environment by various shields. According to Monte Carlo simulations of these shields, based on the measured neutron flux in the experimental hall (1500 neutrons/m^2/day for $E > 1$ MeV), the rate of neutron scattering events above 20 kev is expected to be of the order of 0.04 per kg and per day. This number of nuclear recoils (which mimic true neutralino interactions) determines the ultimate sensitivity of the experiment in the present configuration.

Each detector is a 320g cylindrical Ge monocrystal, 70 mm in diameter and 20 mm in height (the most massive Ge cryodetector today), working at a temperature of about 20 mK. A very sensitive thermal sensor (Neutron Transmutation Doped germanium crystal) glued on the target measures the temperature rise induced by a particle interaction (phonon signal). The plane sur-



▲ Fig. 6: Drawing of the ZEPLIN-II scintillation detector. The liquid xenon is in the lower part of the thermally insulated vessel, surrounded by photomultipliers to detect the light pulses.

faces are metallized for simultaneous charge collection using a bias tension of a few volts (ionisation signal). The top electrode is divided into a central part (defining a fiducial volume) and a guard ring to identify and eliminate events occuring near the detector edges, whose charge collection is rather imperfect (electric field inhomogeneities).

As a nuclear recoil is much less ionising that an electron recoil, the ratio Q of the ionisation energy to the recoil energy is used as a discrimination parameter, on an event by event basis. A proper normalisation of the energies measured from the heat and ionisation channels leads the Q-values for gamma interactions to spread around 1 while the Q-values for neutrons are around 0.3. The scatter plots of Q versus the recoil energy E_R are presented in Fig. 3 for three cases: ^{252}Cf neutron (and also gamma ray) source, ^{60}Co γ-ray source and 54 days of low-background physics data. From the dispersion of the neutron data is obtained the *nuclear recoil band*, defined as the region in the (Q,E_R) plane where 90% of the nuclear recoils are expected. The Q-values recorded in the presence of a γ-ray source show that more than 99.9% of the gamma background is rejected (ie events lying out of the nuclear recoil band).

As to the low-background physics data, most of the events exhibit Q-values around 1 (as expected from gamma interactions) while no event is observed in the nuclear recoil band between 20 keV (the experimental threshold) and 100 keV (upper energy relevant for neutralino masses below 10 TeV) for a total exposure based on two different detectors of 11.7 kg.days. At 90% confidence level (CL), the experimental nuclear recoil rate is thus below 0.2 event/kg/day. The results are interpreted in terms of an upper limit (at 90% CL) on the neutralino-proton scattering cross-section shown in Fig 4. Using a somewhat idealised model of the galactic dark matter halo (spherical and isothermal) an event rate can be calculated. Comparison with the measured one gives the limit of the interaction cross-section above which a signal would become visible in the detector. In Fig. 4 the 3σ contour corresponding to the event detection in the DAMA experiment is shown: within this contour the blue point marks the central value of that measurement at $M = 52$ GeV and $\sigma = 7.2\ 10^{-42}$ cm^2. The EDELWEISS results are incompatible with the existence of such a neutralino. While 9.8 nuclear recoils should have beeen observed between 20 and 64 keV, none are observed. The Poisson probability of such a fluctuation is only 0.006%. Furthermore the EDELWEISS data start to probe some of the supersymmetric models predicting the highest interaction rates.

A look at the future

The direct detection story is obviously not concluded, and we have to explore more deeply the domain of the allowed cross-sections. Most of the future experiments aim to reach a sensitivity of about 10^{-44} cm^2. This limit does not imply only simple scaling of existing technologies but new advances in many fields.

A jump in the mass of the detectors is planned: CRESST-II, about 10 kg, using cryogenic phonon-light $CaWO_4$ modules of 300g; CDMS-II, about 7 kg, using cryogenic phonon-ionisation modules of Ge (250g) and Si (100g); DAMA with a new assembly of NaI scintillating crystals for a total mass of 250 kg; EDELWEISS-II, about 7 kg in a first phase, up to 30 kg in the final version, using cryogenic phonon-ionisation Ge modules of 320 g (Fig. 5); ZEPLIN-II with 30 kg of scintillating liquid Xe (Fig. 6). At present by far the best discriminating detectors, phonon-charge cryogenic detectors will attempt to further improve their rejection performances by identifying surface events, which might be confused with WIMPs by their incomplete charge collection. This is the strategy followed by the CDMS-II and EDELWEISS-II experiments, in proposing to use thin film thermal sensors to identify and reject surface interactions. On the other hand, the background rejection capabilities of the phonon-light rejection scheme will soon be explored by the CRESST-II and ROSEBUD experiments in real low background conditions; similarly, more efficient rejection capabilities of liquid Xe using a two-phase experiment will be tested in the ZEPLIN-II experiment. Finally a thorough understanding and control of the neutron background is required; large area active muon vetoes are therefore being studied, with the objective of limiting the residual neutron rate to about 10^{-3} evt/kg/day above 10 keV. At the European level, a collaborative effort is at present initiated to design a direct detection experiment at the one-ton scale, that is required to achieve a sensitivity to WIMP interactions at the 10^{-46} cm^2 level.

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features

Cavity solitons in a VCSEL: reconfigurable micropixel arrays

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Encoding optical information in space

For quite a few years, scientific and technological advances have made commonplace the possibility of encoding information in the modulation of light beams. Several techniques have been investigated to optimise such methods in the temporal domain or in its dual counterpart, *i.e.* in the radiation spectrum, with a procedure similar to encoding information in our voice. On the other side, encoding information in space is an everyday task we accomplish, with a wealth of technical means, when we "write". It all amounts to getting control of a homogeneous support, and breaking its translational symmetry with suitable procedures and tools (*e.g.* a pen on a sheet of paper, a photographic impression on a photosensitive surface).

Light, and particularly coherent, highly directional and controllable beams are suitable to encode information in space, especially due to the intrinsic parallelism of linear wave-like propagation. In optics, a widely exploited way to encode information in space makes use of arrays of micropixels, each emitting or transmitting a bright spot (see Box 1a). The price to pay of course is the rigidity of the array wherein the "units" are arranged, similar to what we have when we use a typewriter. Rigidity is a limitation indeed: beyond handwriting, educators make use of an even more flexible support, the blackboard, where writing/erasing, changing the layout of the encoded information etc. is even easier than with ink and paper. One might even dream of a blackboard where you can grasp an already jotted formula and "carry" it across a couple of panels without destroying it or what else you already wrote. To overcome the rigidity constraint, one may think of using as homogeneous support (blackboard) the transverse cross-section of a single broad area laser beam. However, in most laser beams the transverse configuration corresponds to a spatial mode of the laser cavity, whose parts are all correlated in space, and you cannot "act" to break its symmetry in one side, without having some other place in the beam changing its intensity profile in an unwanted manner. What we need is to find a "sign", an elementary structure of light that can be used as a minimal alphabet, can be "written" and "erased" and remains independent of what happens to the rest of the radiation profile, no matter what we do somewhere else in the homogeneous support.

A concept that comes to mind in order to realise this situation is that of spatial solitons (see Box 2), *i.e.* light beams which propagate without changing their transverse profile [1]. The element we miss in this case is, however, the persistence of the written "symbol". It can be transmitted to a receiver, or even forwarded to a downhill processing stage, but it does not remain where it has been "written".

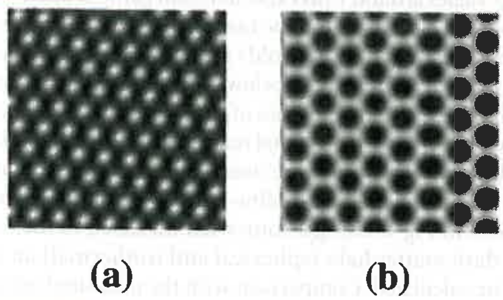
In this paper we focus on a special class of soliton-like structures which occur in optical systems with cavities, where the feedback action of the mirrors make the elementary structure for encoding information (a bright light spot) a stationary, persistent solution of the device emission profile.

Cavity Solitons as self-organised pixels

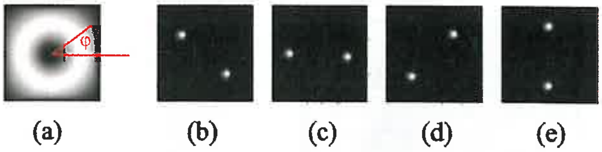
It is well known since the late 80s [2] that an optical system can spontaneously quit emitting a homogeneous field profile and form spatial patterns in the intensity profile, as it happens in hydrodynamics and other fields of science where spatially extended systems come into play. Optical pattern formation is similar to the formation of convective rolls in fluids or spiral waves in nonlinear chemical reactions. While there the spatial coupling occurs via convection and diffusion, in optics the basic mechanism is diffraction. Such phenomena were predicted and experimentally observed in several classes of optical systems [3].

When this occurs in a nonlinear resonator, the pattern forming instability emerges from the coupling of the nonlinear medium response, diffraction, and the dissipative/feedback action of the mirrors. The system loses its translational symmetry, and as long as its new spatially modulated phase is sustained by some form of energy intake, the optical system will keep on emitting a pattern which may be a regular lattice such as, for example, a hexagonal aggregate of bright light peaks or a honeycomb lattice (see Fig. 1). As such, this "global" structure is not a proper means to encode information: the pattern is a highly correlated structure, similar to a transverse mode, even if it is boundary independent. The light spots are there, but they are not individually addressable.

Nevertheless, this problem can be circumvented by realising a situation that, in the general field of pattern formation, is called "localised structure" [4]. This phenomenon generally arises under conditions of coexistence between two stationary states, one of which is homogeneous in space, the other patterned. As it happens, under appropriate conditions it is possible that a small portion of the pattern is embedded in a homogeneous background corresponding to the homogeneous profile. If the pattern is a hexagonal lattice one can try to reduce the modulated "island" coexisting with the homogeneous emission to its minimal ele-



▲ Fig. 1: Numerical simulation for an optical nonlinear resonator showing (a) a hexagonal pattern, (b) a honeycomb pattern in the field intensity profile.



▲ Fig. 2: Two cavity solitons perform a uniform rotary motion (b)-(e), along the crater of a doughnut-shaped holding beam (a), under the action of the angular gradient (numerical simulation).

ment, namely the single dots of the lattice. In the optical case, one will thus have a bright intensity maximum isolated in the background, and it will show no correlation whatsoever with its surroundings up to a minimal distance which is generally comparable to its own diameter [5]. This is what we call a Cavity Soliton (CS) and it can be realised immediately that it bears several substantial differences from the usual concept of a spatial soliton: for example, CSs may arise and be stable even in the presence of a self-defocusing nonlinearity. CSs can be individually written and erased by shining suitable laser pulses into the optical cavity containing the nonlinear medium (see Box 1b). An additional bonus of CSs is their capability of drifting across the transverse section of the optical system under the action of phase or amplitude gradients in the holding beam. CSs experience an Aristotelian force: their speed is proportional to the force, which in this case is created by the gradient [6]. In particular, the maxima of the phase/amplitude profile represent equilibrium positions for the CS.

In this way, CSs can be set in motion in a controlled manner. Figure 2 shows the case of a holding beam that has the shape of a doughnut mode (Fig. 2a). Two CSs exhibit a circular motion along the ring-shaped region where the intensity of the doughnut mode (which is shaped like the crater of a volcano) is maximal. The motion is induced by the fact that the phase of the doughnut mode varies as exp (± iφ), where (is the angle (see Fig. 2a), which creates a constant phase gradient along the crater, and the direction of motion is determined by the ± sign.

If, instead, one tailors the holding beam in such a way that it displays a periodic phase modulation (Fig. 3a), this constitutes the immaterial support for an array of CS pixels (Fig. 3b,c and d), which can be individually set on and off by shining laser pulses. By varying the phase landscape, one can reconfigure the CS array, and by suitably introducing further gradients CSs can be brought to controlled interactions. It is certainly an attractive feature to make more and more flexible the all-optical stage of some optoelectronic devices which are presently employed such as smart pixel arrays and serial/parallel converters.

The possibility of controlling CS motion can be exploited for practical applications. In addition to reconfigurable optical memories and serial-to-parallel converters, examples of possible future applications are signal amplification, realisation of cellular automata, pattern recognition and optical tweezers.

A review of the fundamental and applicative features of CSs is though outside the scope of this contribution and the reader is referred to the bibliography (see [7] and references quoted therein).

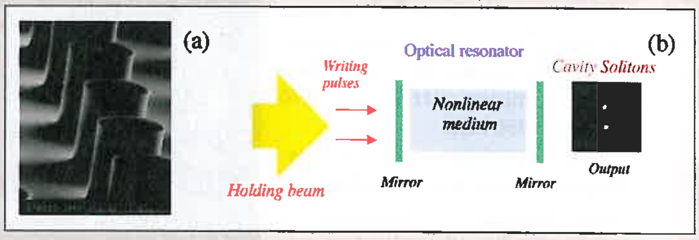
Cavity solitons in semiconductor microresonators: experimental demonstration and theoretical interpretation

Experimental observations of CSs have been achieved in the past in various nonlinear optical materials, *e.g.* in photorefractive resonators and lasers with saturable absorbers, as well as in other systems with feedback utilising liquid crystals or atomic vapours. In all these cases, however, the cavity was macroscopic and the media characterised by slow response times.

But unquestionably, credible applications in the fields of optoelectronics and photonics require the use of miniaturised devices and fast nonlinear materials, as can be obtained by using semiconductor microresonators. Theories for this configuration [8] had to consider fundamental physical mechanisms, peculiar to

Box 1

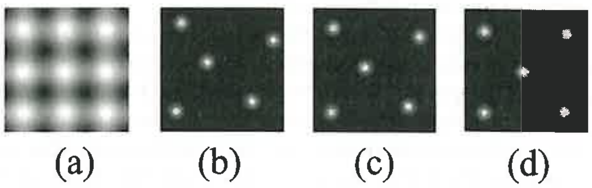
Rigid vs plastic pixels: etched microresonators and self-confined cavity solitons



(a) In etched arrays of micropixels the elements ('symbols') are arranged in spatial configurations, where the photo/litho/chemical/ etching of the material ensures the confinement of the elementary unit as well as its independence of the others. See J.L. Oudar, T. Rivera, R. Kuszelewicz, F. Ladan, *Journal de Physique III*, 4, 2361 (1994). Photo: courtesy R. Kuszelewicz.
(b) An alternative way to encode information makes use of a special class of soliton-like structures (CSs) which occur in optical systems with cavities.

When the system operates in conditions of CS stability, it is extremely simple to theoretically/numerically control the CS as a self-assembled pixel. An external "holding" beam is injected into the cavity, its intensity corresponding to the regime of coexistence between the patterned and the homogeneous state. In order to create a CS, one adds a short and narrow "writing" pulse to the holding beam, aimed at a certain transverse point (x,y). Provided that the pulse is in phase with the holding beam, its intensity locally increases the field and finally provides the system with the energy necessary to access the patterned branch. In the output intensity profile, one readily observes the formation of a bright peak. As the CS is a subset of a stable solution, when the pulse dies off, the peak indefinitely persists where it has been excited, as though the pulse drove a channel along the resonator axis, which becomes self-sustained by the mirrors' feedback action. It is of course straightforward to shoot more pulses at different locations of the transverse section of the system and turn on as many CS as the resulting distances between them will keep below the interaction range.

In order to switch a single CS off, with no consequences on the other CSs, it suffices to locally bring the system to a regime where the patterned state cannot persist any more. This is obtained by shooting at the location where a CS lies, an "erasing" pulse similar to the "writing" one but with opposite phase with respect to the holding beam. The local intensity thus decreases and the system precipitates to the homogeneous state, thus restoring homogeneity where the CS was.



▲ Fig. 3: In a periodic phase modulation (a), the maxima of the profile work as equilibrium sites for cavity solitons. (b), (c) and (d) illustrate the self-assembling behaviour of CSs; (b) Initial condition: five CSs are excited at some positions; (c) each CS is moving towards the nearest local phase maximum, (d) final condition: the CSs are placed at phase maxima of the array.

the semiconductor optical response and to the microresonator architecture.

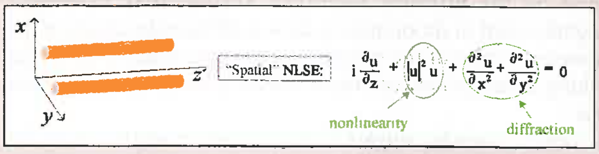
From an experimental viewpoint, however, the realisation of CSs in semiconductor microcavities is a hard challenging task because of the small spatial and temporal scales, and the need for realising a broad area device with a reasonably uniform illumination and electrical pump current.

Although the phenomena of light localisation, *i.e.* candidates for CSs, had been reported [9], a clear-cut demonstration of objects that can be controlled independently of each other has been achieved only recently [10]. This goal was reached thanks to the close collaboration of four groups in the framework of the European ESPRIT Basic Research Project PIANOS (Processing of Information with Arrays of Nonlinear Optical Solitons). Experiments were carried out on a large number of samples, progressing in time towards optimisation of the device architecture, via a continuous interaction among the experimental (Nice), material (Ulm) and theoretical groups (Bari and Como). The device is a large area Vertical Cavity Surface Emitting Laser (bottom-emitter VCSEL, 150 μm diameter) injected by a coherent field generated by a high power edge-emitter laser, whose wavelength is tunable in the range 960-980 nm.

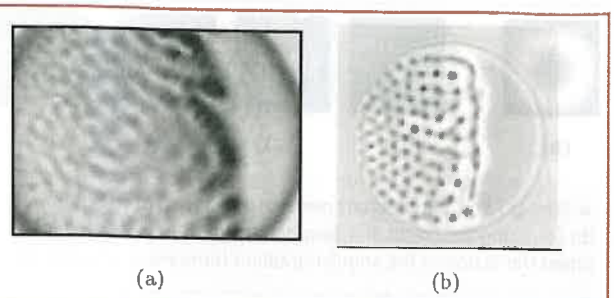
The VCSEL works as an amplifier and is kept slightly below the lasing threshold. A typical time-averaged transverse intensity profile of the VCSEL driven by the holding beam is shown in Fig. 4. One observes a homogeneous area on the right-hand side of the sample, and a patterned region on the left. As indicated by the numerical simulations, the most appropriate region to generate CSs lies immediately to the right of the line which separates the homogeneous and the patterned area.

Box 2

Spatial Soliotions



Spatial Solitons are light beams that propagate with undistorted shape, as a result of a perfect balance between diffraction, which tends to spread the beam, and the self-focusing action induced by the interaction with the nonlinear medium in which the beam propagates. In Kerr media they can be described by a Nonlinear Schroedinger Equation (NLSE).

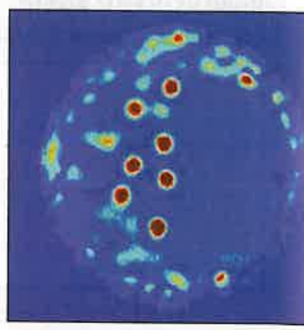


▲ Fig. 4: Time averaged transverse intensity profile of a VCSEL driven by a coherent holding beam. (a) experiment, (b) numerical simulation. A patterned region appears on the left, a homogeneous domain on the right.

Starting with no spot, the writing beam (power about 50 μW, compared to 8mW for the holding beam) is capable of generating a high intensity spot when it is in phase with the holding beam, as predicted by theory. When the writing beam is removed, the bright spot remains on indefinitely. After writing one spot, the writing beam is applied again in a different position, causing a second CS to turn on and persist after the writing beam is extinguished. This procedure has been improved with respect to the results reported in [10], where only two CSs were switched on, and presently up to 7 CSs can be independently excited in the sample (Fig. 5). This improvement is due to the introduction of a misalignment of the holding beam, so that the spatial region where the parameter values allow the existence of stable CSs is consequently enlarged.

As for turning the CS off, the writing beam must be aimed at an existing CS and its phase must be varied by π so that when it is injected, it destructively interferes with the broad holding beam and locally depletes the sustaining field; this causes the CS to disappear, and when the writing beam is turned off, the spatial intensity distribution becomes exactly the same as it was at the beginning of the experiment.

The CSs in Fig. 5 can be controlled independently; however technical reasons due to the alignment precision of the writing beam do not allow all of them to be switched on and off: the erasing procedure works perfectly with 4 of the CS in Fig. 5, while three of them can only be switched on at present. This writing/erasing experiment was repeated at several values of the pumping current from 270 mA up to 350 mA.



▲ Fig. 5: Seven cavity solitons have been excited in the transverse plane by the injectio of a coherent writing beam.

This unambiguous demonstration of CS stability and control in semiconductor microresonators opens up a broad applicative scenario for innovative optoelectronic devices based on CS properties. As an example, using the drifting properties of CS the fanning in and out of an optical signal could be much easier, as well as the serial/parallel conversion. On the other hand, the problem of ensuring high levels of homogeneity and sample smoothness in the growing phase must be addressed in the future to achieve viable devices in photonics.

The most pressing short-term issue of this research involves a development of optical control techniques on the holding beam to ensure proper CS manipulation.

Acknowledgements

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Intense soft X-ray matter interaction: Multiple ionization of atom clusters by free-electron laser radiation

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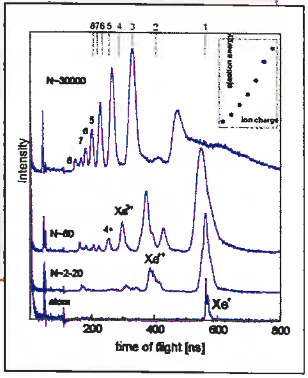
Fourth-generation light sources based on free-electron lasers (FEL) will provide intense, short-wavelength radiation for a wide range of applications in physics, chemistry and biology. Large scale FELs are proposed that could be used to generate pulses of hard X-rays. The FEL at DESY, a proof-of-principle project [2], has begun operation at far-ultraviolet wavelengths and initial results are presented in this paper [2]. Xe clusters are illuminated with intense FEL pulses of 98 nm wavelength. Here, unexpectedly strong absorption of the laser radiation by Xenon clusters was observed, resulting in the explosion of the clusters and the ejection of high-energy, multiply charged ions. For the first time, we were able to observe such a highly nonlinear interaction between matter and soft X-rays below 100 nm. So far, most work in the field of nonlinear processes was restricted to infrared, visible and ultraviolet light from lasers [3].

The FEL at DESY is operating in the regime below 100 nm wavelength[4] and offers new scientific opportunities. The understanding of the interaction of short-wavelength, short-pulse radiation with matter is essential for all future experiments. In a first series of experiments, the ionization of Xe atoms and clusters was compared. While Xe atoms become only singly ionized by the absorption of single photons, absorption in clusters is strongly enhanced. On average, each atom in a large cluster absorbs up to 400 eV, corresponding to 30 photons. The clusters are heated up and electrons are emitted after sufficient energy is acquired. There is some evidence that the photo absorption of ionized clusters at 100 nm is too efficient to be explained by straightforward models of collision induced absorption. The results will have strong impact on our understanding of radiation damage. A key issue for future studies will be the extrapolation to short wavelengths and to identify the absorption processes in the nm to Å regime. The latter will be important because X-ray lasers could take snapshot pictures of the atomic structure of single biomolecules [5].

The experiments were performed by irradiating atoms and clusters with ~100 fs long FEL pulses at 98 nm wavelength and a power density of up to $7*10^{13}$ W/cm^2. The resulting ions are detected with a time-of-flight mass spectrometer. Thanks to the high laser intensity, mass spectra with a high signal-to-noise ratio can be recorded in a single shot of the FEL.

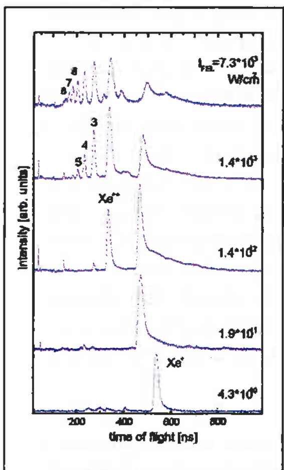
▶ **Fig. 1:** Time-of-flight mass spectra of ionisation products of Xe atoms and clusters. The spectra are recorded after ionisation with soft X-rays with 98 nm wavelength at an average power density of $2*10^{13}$ W/cm². After irradiation of clusters, highly charged ions are observed. The mass peaks are rather broad and displaced with respect to the calculated flight times indicated by bars in the uppermost part of the figure. This indicates that the ions have high kinetic energy. The number N of atoms per cluster is given in the figure. The kinetic energy of the ions as a function of the charge for N=1500 is displayed in the inset.



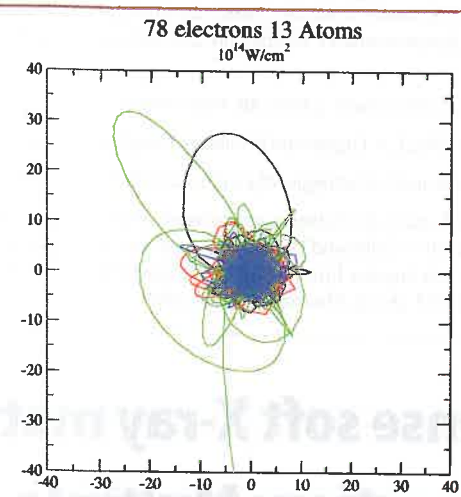
TOF mass spectra for different clusters sizes recorded at $2*10^{13}$ W/cm² are shown in Figure 1. The most striking result is the surprisingly different ion signal from atomic and cluster beams. While only singly charged ions are observed after irradiation of isolated atoms, atomic ions with charges up to +8 are detected if clusters are irradiated. The clusters absorb many photons and completely disintegrate into singly and multiply charged ions. The mass peaks are very broad, indicating that the ions have a high kinetic energy. This can be understood in terms of a Coulomb explosion process. The population of different ion states and their kinetic energy strongly depends on the power density. This is shown in Figure 2 for clusters comprising 1500 atoms. At the highest power level of $7*10^{13}$ W/cm², charge states up to +8 are detected. The strong dependence on the power density is a clear sign that optical non-linear processes dominate the ionisation of the clusters at the power levels used.

The average kinetic energy per ion strongly varies with its charge state and the cluster radius. For Xe^{7+} kinetic energies more than 2 keV were observed. The high energies are a clear signature of a Coulomb explosion [6]. From the results it is concluded that an energy of up to several hundred eV per atom is taken from the FEL beam. Coulomb explosions of clusters are not a new phenomenon [7,8] and have been already induced with infrared (IR) light. It is agreed that the experimental findings are explained by field ionisation of the atoms and the clusters by the strong electric field of the IR laser [9,10]. The dramatic effects observed when clusters are exposed to short-wavelength radiation are somewhat surprising because the Coulomb explosion starts at 10^{11} W/cm², which is much lower than the power density needed to induce a Coulomb explosion in the IR. Classical model calculations for the movement in charged clusters show that the ionization process at short wavelength is due to the absorption of many photons heating the cluster and subsequent electron emission (see Figure 3). The experimentally determined absorption of the clusters is 3-5 times larger than predicted by the classical calculation. The steps of the ionization process are illustrated in Figure 4.

The absorption of short-wavelength radiation and subsequent ionisation differs considerably from that in the optical spectral range. A absorption and ionization start by single photon absorption as described by quantum mechanics. After many unbound electrons are created, a plasma is formed. There is evidence that already at 100 nm quantum mechanical modelling of the absorption processes including resonant electronic transitions becomes important. Going to shorter wavelengths will enhance this trend. The results show that the VUV-FEL has opened up a new and exciting field of non-linear physics and they are a first step towards experiments in the nm and Å range.



◀ **Fig. 2:** Time-of-flight mass spectra recorded after irradiation of Xe clusters comprising 1500 atoms as a function of the power density. The power density is given in the figure. The spectrum at the bottom is recorded at a reduced gain of the FEL. The intensity of highly charged ions increases with increasing power density. Experimental details: The intrinsic pulse energy of the ~ 100 fs long SASE-FEL pulses [1] typically varies between 1.5 and 25 µJ. The spectra with a power density of $1.9*10^{11}$- $7*10^{13}$ W/cm2 are taken with pulses of 25 µJ energy. The power density could be lowered by moving the cluster beam out of the focus to 10^{10} W/cm² at 1.5 µJ.



▲ **Fig. 3:** Classical simulations of the electron motion and ionization for Xe_{13} clusters with soft X-rays. Electron trajectories were calculated for 100 fs long pulses of constant intensity. The position of the ions is that of the neutral cluster and kept fixed during the simulation. The scale is in Å.

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The human engine: How to keep it cool

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We don't usually think of ourselves in that way, but each of us is an engine, running on sustainable energy. It differs from ordinary engines in more than just the fuel. The human engine cannot be shut off, for instance: it keeps idling even if no work is required. That is needed to keep the system going, to keep our heart pumping, for example, and to keep the temperature around 37 °C. Because – and here is another difference – our human engine works only in a very small temperature range.

It's interesting to look at this a bit more quantitatively. Our daily food has an energy content of 8 to 10 MJ. That, incidentally, is equivalent to a quarter of a litre of gasoline, barely enough to keep our car going on the highway for about 2 minutes. Those 8 to 10 MJ per day represent just about 100 W on a continuous basis. Only a small fraction is needed to keep our heart pumping, as we can easily estimate from a pDV consideration (p being on the order of 10 kPa and DV on the order 0,1 litre, with a heart beat frequency around 1 Hz).

In the end, those 100 W are released as heat: by radiation, convection and evaporation. Under normal conditions, sitting behind our desk in our usual clothing in an office at 20 °C, radiation and convection are the leading terms, and evaporation gives only a small contribution. Until we start doing external work, on a home trainer, for example. The energy consumption goes up, and so does the heat production. Schematically, the total energy consumption Ptot and the external work Pwork is shown in the figure, where an efficiency of 25% has been assumed. Thus, if we work with a power of 100 W, we increase the total power by 400 W, and the heat part by 300 W.

Now the body must try to keep its temperature constant. That's not trivial: if we don't change clothing, or switch on a fan to make the temperature gradients near our skin somewhat larger, the radiation and conduction terms cannot change much. They are determined by the difference between the temperature of our skin and clothing on the one hand, and the ambient temperature on the other. When working hard, we raise that difference only slightly: due to the enhanced blood stream, our skin temperature will get closer to that of the inner body. But the limit is reached at 37 °C.

Fortunately, there is the evaporation term. Sweating is our rescue. And drinking, of course. Each additional 100 W of released heat that has to be compensated by evaporation, requires a glass of water per hour: 0,18 litre/h, to be precise. The various terms are, again schematically, shown in the figure.

One conclusion: Heavy exercise needs evaporation. Don't try to swim a 1000 m world record if your pool is heated to 37 °C . You might not live to collect your prize: Where would the heat go?

Our very latest model

Denis Weaire, Trinity College Dublin Ireland

For most of us the ethics of work practices are something that biologists have to worry about. After all, you don't have to cut up a dog to diagonalise a Hamiltonian. Nevertheless are conscious of very high standards in the conduct of research. For example, we present out findings (fairly) honestly, we readily accept their overthrow by others, we give freely of our time to the running of conferences and journals, and we encourage and nurture the new members of the profession.

In the matter of research proposals, which bring no prize for finishing second, there is an awkward tension between due modesty and a persuasive presentation. To survive we must draw a discreet veil over our deficiencies and offer our better profile to the world. Here there is a certain elasticity in our claims to virtue. It is understood, particularly by the reviewers.

This tendency is in danger of being stretched to breaking point by the growing use of consultants to write proposals that are elegantly tailored to the wishes of the granting body. The common wisdom is that Framework Programmes 5 and 6 are readily accessible only by this method. Certainly it is now explicit that scientific brilliance is necessary but not sufficient.

What distinguishes these programmes from their predecessors is the increasing intrusion of socio-economic criteria. Most of us, when asked to detail the direct societal benefits of our research, fall back on stammering platitudes or Faraday's immortal defence: what use is a baby? *Nul points.*

Enter the consultant with a bulging briefcase of buzzwords. *Et voila!*

In the process of transformation from ugly scientific duckling to smooth commercial swan, it is likely that something will be lost. In a word, innocence. The system of business ethics is very different from ours. Self-promotion rather than self-denial is its stock-in-trade. Manifest dishonesty (vide recent events in the U.S.) is frowned upon, but one may float freely in the grey area of unsubstantiated and imaginative claims. That's business.

Within its proper domain this highly successful system is best left alone, but what will be the consequence of its introduction into the world of academic physics? Will our research become a pursuit of convenient half-truths, backing up the spurious novelty and usefulness of the "latest model"?

Erratum

Professor J. Indeku has brought to our attention that the Edited version of the talk delivered at the Physics Teaching Forum, [EPN vol 34/3 page 98] organised on March 16th, 2002 in Brussels by the National Committee for Physics of the Belgian Royal Academy of Sciences needs to be completed with the following text:"in collaboration with the Belgian Physical Society. This article is reproduced from the original version published in Physicalia Magazine (Belgian Physical Society), vol 24, n° 3, p.139-149 (2002)."

A place of pilgrimage—the Coimbra Physics Museum

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Most physicists look back to Galileo and Newton as the founders of their subject, but their ideas took time to diffuse throughout Europe during the century of the Enlightenment. Portugal, a country that was rich and powerful at that time, was closely in touch with the most important centres of scientific culture, and followed the trend towards the establishment of physics as an academic discipline

So when the Marquis of Pombal (1699–1782) (Fig. 1), the authoritative prime minister who directed the reconstruction of Lisbon after the earthquake of 1755, reformed the University of Coimbra, studies in Natural Philosophy were considered indispensable. So was a "Cabinet" of physical instruments and demonstrations. Today it is the Physics Museum of the university, and it may be visited either personally or virtually (http://www.fis.uc.pt/museu/index.htm). This unique museum exhibits include a wide variety of scientific instruments of the 18th and early 19th centuries.

We describe here the work of some Portuguese scientists of that time, and the inception of the new Faculty of Philosophy with its Physics Cabinet.

Influences from abroad

After a long life Newton died in 1727, having enjoyed the recognition of his contemporaries, including the Portuguese who were in London at the time. Some of them knew Newton personally, through his Presidency of the Royal Society.

▲ Fig. 1: Marquis of Pombal, the Portuguese Prime Minister from 1750 to 1777.

The adoption of Newtonian Philosophy in Portugal benefited much from the emigration to England in 1721 of Jacob de Castro Sarmento (c. 1691 – 1762). A Jew pursued by the Inquisition, he had studied Medicine at the University of Coimbra. He belonged to the group of the so-called "estrangeirados" ("foreigners"). These were Portuguese who emigrated due to religious, political or intellectual persecution. Sarmento became Fellow of the Royal Society in 1730. He translated in Portuguese one of Newton's works on tides. "Theorica verdadeira das mares, conforme à Philosofia do incomparável cavalhero Isaac Newton," published in London in 1737 ("True theory of tides, following the Philosophy of the incomparable Gentleman Isaac Newton") is the first Portuguese translation of Newton's works. Coimbra has an English microscope, made by Culpeper and dated 1731, that was donated by Sarmento (Fig. 2).

▲ Fig. 2: The microscope made in London by Edward Culpeper in 1731, and offered to the University of Coimbra by Jacob de Castro Sarmento.

Another "foreigner" who exerted a notable influence on the Portuguese development in the 18th century was John Hyacinth of Magellan (1722 – 1790) who studied at the Monastery of Santa Cruz, in Coimbra. (He was a remote relative of the navigator Magellan). After having left Portugal in 1756, he lived in France, before taking up residence in London in 1764. Renouncing Portugal, he declared that he did not want to live under a government that was not assuring personal freedom. In England he collaborated and maintained correspondence with the most famous European scientists of his time, such as James Watt. He promoted English scientific instruments made in England throughout the continent. His reputation extended from Lisbon to S. Petersburg, and even to the United States. Magellan was member or corresponding member of various scientific academies and societies, including those of Lisbon, Brussels, Paris, S. Petersburg, Berlin, Philadelphia, Haarlem, and London. He also collaborated with the Portuguese crown, sending collections of instruments of Astronomy, Physics, Navigation, and other subjects, whose construction he had supervised. The Cabinet of Physics in Coimbra benefited from his inside knowledge of the best builders of English instruments. There he sent a set of Physics and Astronomy instruments, some incorporating improvements made by him. The most important piece is the Atwood machine that is still displayed (Fig. 3). There is also a splendid pendulum clock.

▲ Fig. 3: The Atwood Machine sent from London by John Magellan.

The teaching of science before the 1772 reform

The first half of the 18th century was marked in Portugal by a significant advance of science, in particular astronomy. Under King D. João V (1689-1750), who ordered the construction of the baroque Library of the University of Coimbra, new astronomical instruments were acquired. This king had a fondness for the exact sciences, expressed in his financial support of the creation of a Cabinet of Experimental Physics at the House of Necessidades, occupied by the Oratorians. S. Felipe Neri had founded, in Rome, in 1565, the Congregation of Oratorians, which had always taken an interest in the religious and literary education of young people. In Portugal, it settled in downtown Lisbon, in 1667, at the House of Espírito Santo and subsequently moved to the Hospice of Our Lady of Necessidades (nowadays the Ministry for Foreign Affairs). The Marquis of Pombal initially accepted the pedagogical work of the priests of Oratorio, as a partial replacement of the Jesuits he had expelled in 1767. Later he accused them of teaching pernicious doctrines, and the classes at the House of Necessidades were closed. They reopened in 1777, when the king D. José I (1714 - 1777) died and Pombal fell from power.

D. Jose I had been attending Physics demonstration sessions at the house. A contemporary author recounts:

The Hospice of Necessidades was provided with various instruments, in part by the generosity of His Majesty who has founded that house, in part by his incomparable Son and in part by the very Congregation. The cabinet where these instruments were kept was the delightful theatre where Father Teodoro entertained His Majesty King D. Jose and his court with the innocent and admirable spectacles of Nature and where the same king D. Jose with his attendance and sharp observation frequently honoured the physical experiments done by Father Teodoro and even with his royal hands many times manipulated the machines, trying curiously the phenomena which were expounded.

So the Physics cabinet not only served to support the Physics lessons but also to entertain and instruct the king: modern researchers please note.

The first volume of "Philosophical Recreation or Dialogue on Natural Philosophy", by Teodoro de Almeida (1722 - 1804) (Fig. 4), appeared in 1751. While it was not a textbook, its author was a pioneer in the development of scientific culture in Portugal and Spain. He was strongly attacked by conservative figures, in particular some Jesuits, who accused him of heresy. In some domains, his pedagogical and scientific activity between 1745 and 1760 anticipated by a quarter of a century the reform of teaching that occurred in Coimbra in 1772.

▲ **Fig. 4** Teodoro de Almeida, a forerunner of Physics in Portugal.

The most cited authors at the time of the creation of the teaching of Experimental Physics in Coimbra—such as Musschenbroeck, s'Gravesand, Desaguliers and Nollet—were fundamental references to Almeida.

The whereabouts of the instruments utilized by Almeida in his lessons is unknown. The same is true of the apparatus of the astronomical observatory existing at the same school, which was equipped and used by João Chevalier (a Portuguese Oratorian priest who, as an exile, was not only a founding member of the Royal Academy of Belgium, in Brussels, but also became its elected president).

Under Pombal all those who did not bend before state power were threatened. A victim of persecution, Teodoro de Almeida was obliged to flee. In France he corresponded with António Ribeiro Sanches, a Portuguese medical doctor of Jewish origin who became doctor to Catherine II at the Russian court and was one of the inspirers of Pombal's reformation of sciences. Despite being abroad, Almeida still exerted a strong influence on Portuguese culture. After his return he published in 1784 "Physical-mathematical letters from Theodosio to Eugénio...," as a complement to the "Recreation". He was one of the founders of the Royal Academy of Sciences in Lisbon, in 1780.

Pombal's reformation of science studies

The 18th century saw a fierce controversy between Oratorians and Jesuits, the former considered to be modernisers, in opposition to the traditional attitudes of the Jesuits. But the tragic fate of the Oratorians was similar to that of Jesuits. Intellectuals not considered conducive to the implementation of a new scientific and pedagogical culture were to be eradicated, and this extended, paradoxically, to the main antagonists of Aristotelian thought. After much persecution the House of Necessidades was closed down.

This coincided with a project to create in Lisbon the College of Nobles, aiming at the education of aristocrats. The college, founded in 1761 but started up five years later, was part of Pombal's project of education reform. In spite of political patronage to the foundation of the College of Nobles and of the hire of an Italian professor, Giovanni Dalla Bella (1730-1823), from Padova, and the creation of a Cabinet for Experimental Physics, the project was unsuccessful. All of the equipment was transferred in 1773 to Coimbra to equip the new Cabinet in what was then a Jesuit College (Fig. 5). Dalla Bella also moved to Coimbra.

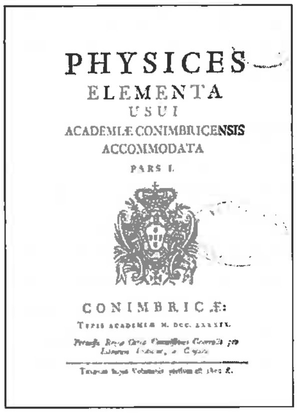
▲ **Fig. 5:** The "Colégio de Jesus", where the Physics Cabinet of the University of Coimbra was installed in 1772. Nowadays is the place of the Physics Museum and the Natural History Museum.

Already in 1772 the School of Philosophy of the University of Coimbra had been created, so the Cabinet found a natural home there. The new school of Philosophy complemented a new school of Mathematics, with students attending both. The value and modernity of the Cabinet was recognized (it was said to be bigger than that in the University of Padova) as one of the most relevant accomplishments of Pombal's reformation of the University.

The promoters of the new teaching system condemned the "miserable" Jesuit teaching system. Its stagnant tradition included the prohibition of the works of Galileo, Descartes, and Newton from the College of Arts of Coimbra, according to a determination of the Dean of that college in 1746.

The new syllabus of Experimental Physics was in line with that of the best European schools. The *Physices Elementa*, in three volumes (1789/1790), written in Latin by Dalla Bella, was one of the first works arising from the Reformation of the University (Fig. 6: the digital version is in http://www.fis.uc.pt/museu/dbella/dallabellaindex.html).

The transformation of the educational system was to lead Portugal out of its isolation from the scientific development of the rest of Europe. The role of D. Francisco de Lemos, Brazilian-born assistant bishop of Coimbra, was crucial. A protégé of Pombal, he had studied Canonic Law at the University. In 1770 he was


PHYSICES
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▸ Fig. 6: The "Physices Elementa" of the Italian Giovanni Dalla Bella.

appointed Rector and two years later Reformer of the University of Coimbra. In his "General Report on the Status of the University" Francisco de Lemos clearly expressed the need for a modern course of Philosophy, in order to keep up with international trends and be able to contribute to new knowledge.

The Reformer expressed very clearly his opinion on the influence the university should have in the country's development. According to him, the study of the sciences should contribute to a better knowledge of natural wealth, bringing new resources to industry and trade. The experimental teaching should bring the development of new arts and factories. In the above mentioned Report, he wrote:

If His Majesty... promotes these ideas, the establishment of Natural Philosophy will be perfect and therefore the Kingdom and the Landlords will manifest the richness which was deposited by Nature; and therefore industry will have large material to exercise; and therefore new branches of trade will be formed; and therefore new arts, new manufactures and new factories will be created; and the existent ones will be perfected.

It was imperative to invest in the area of Natural Philosophy. The examples of the other states must be followed. Besides Dalla Bella, the Italian Domingos Vandelli was hired as teacher at the new Philosophy School. Pombal travelled to Coimbra to supervise the reformation of the university, to which new buildings and equipment were given. An Astronomical Observatory and a Chemical Laboratory were established, together with the creation of the Cabinet of Experimental Physics at the Philosophy School.

The University's Statutes of 1772 stated that:

...students should not only observe the execution of the experiments with which the truths, known until the present moment are demonstrated, but also acquire the habit of making them with the sagacity and skill required of the Explorers of Nature.

The Cabinet was to show the purpose of Experimental Physics, its origin and its progress, and the experimental method.

The Physics Cabinet was equipped with six hundred items. Most were made in Portugal but many were ordered from manufacturers of international repute—George Adams, Benjamin Martin, John Dollond, Edward Nairne, Edward Culpeper, Francis Watkins, James Champnes, etc. Each instrument had a specific conception consistent with the syllabus of Dalla Bella as laid out in *Physices Element*. Between the foundation of the Physics Cabinet and the approval of Dalla Bella's book, the adopted textbook and guide to the construction of the Cabinet was Musschenbroek's *Introductio ad philosophiam naturalem*. Dalla Bella's book followed that of Musschenbroeck in many respects.

Unfortunately the glow of the enlightenment in the second half of the 18th century soon faded in Portugal, and the 19th century was a period of decline. But that is another story...

A visit to Coimbra

The Physics Museum of the University of Coimbra, whose premises are in the original building of the Physics Cabinet, impresses the visitor with not only the scientific but also the artistic value of its objects. The building, originally the College of Jesus, was reconstructed from 1773 to 1777. Just in front of it there is a building originally projected to be a Chemical Laboratory—probably the first building in the world which was constructed for such a purpose.

The Physics Museum shows a permanent exhibition of scientific and didactic instruments from the 18th and 19th centuries in two rooms and an old lecture theatre, which maintains its original atmosphere. In one of the rooms is a recreation of the Physics Cabinet of the late eighteenth century, showing some instruments which are unique (Fig. 7). In the second room, many instruments from the 19th century, mainly from the first quarter, complete the exhibition. The collection should be a place of pilgrimage for the modern European physicist.

▸ Fig. 7: The Chinese magnet of the Physics Cabinet consists of a large block of lodestone weighing 12 kg. Its precise origin is unknown, although tradition says that it came from China as a gift from the Chinese Emperor to the Portuguese King D. João V.

Although the latter part of the 19th century is today seen as a period of decline from such glorious beginnings, Coimbra continued to acquire state-of-the-art instruments from abroad. A few years ago, the European Physical Society sponsored a visit by experts to help identify those items and encourage their conservation. This has now been accomplished, and visitors can also view the later collection, in the reserves, by appointment.

Further reading

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Photo credit

Photos 2, 3 and 7: José Pessoa, Arquivo Nacional de Fotografia.

A conversation with Pierre-Gilles de Gennes

Interview by George Morrison and Etienne Guyon

At the end of June 2002, in the superbly renovated setting of the venerable *Collège de France*, two scientific days were organised to celebrate the many and varied scientific contributions of Pierre-Gilles de Gennes on his retirement from 26 years of directorship of the *Ecole Supérieure de Physique et Chimie de Paris*, the school where Pierre and Marie Curie had carried out their work on radioactivity. Four half-day sessions were devoted to each of the locations where de Gennes had worked: *Saclay*, where he made his initial research with Abragam on magnetism after studies at *Ecole normale supérieure*; *Orsay*, where he developed his theoretical interest in superconductivity and liquid cr ystals, while at the same time setting up important experimental 'groups'; the *Collège de France*, where he is still professor and where he set up the internationally recognised laboratory on soft condensed matter, in particular on polymers; and, finally, ESPCI, which has recently seen the addition of biology to its traditional teaching in physics and chemistry and where much of his distinctive teaching style was initiated and given its expression.

This then was the opportunity to interview him in the informal and free style which is his hallmark and to share some of his provocative, even sometimes contentious, thinking and reflections on a life in physics.

'Low energy' physics and chemistry are less and less distinct domains: do you think that the research structures properly adapt themselves to this situation?

I certainly see the necessity of blending physics and chemistry together. I get very nervous when I hear, for instance, a young theorist talking about a certain material with no idea of how it has been made, either industrially or in the laboratory. In this way he may miss some very important features, for instance a distribution of lengths in a polymer which creates a significant signature in some mechanical properties.

One should also have a certain vision of what are the chemical tools and chemical abilities. If you propose a new object, a new form of matter, you should know whether it will be hard to make, will be a long, tedious chemical process or a relatively traditional synthesis? Will it be cheap or expensive? For these reasons we need a working relation between physics and chemistry. This existed in the past. People as abstract as Wigner knew about the colour of this or that crystal in nature. He knew about real materials although his world was very different. It's a good example.

Do you think chemists should have some physics knowledge?

Yes, and I tried to do this at the *Ecole de Physique et Chimie*. We want chemists who work with a purpose and who will understand the purpose. People have built beautiful molecules just for the aesthetics. I think we must go beyond that and aim at some interesting properties. A good example was when we were in the queue at the Orsay cafeteria with a visiting American professor, Bob Meyer, from Harvard. We were discussing smectics, an interesting form of liquid crystals; Bob came out with the notion that if we looked at tilted smectics and added on chiral molecules with a definite chirality, then they should show a ferroelectric moment, we would have a liquid ferroelectric. This idea is beautiful; we went back to the laboratory after lunch and talked to the chemists. Six weeks later they had produced the first liquid ferroelectric. It's very important that chemists have a precise aim, and know the links between property and structure.

So along the same lines, would you think that one should reconsider the way physics and chemistry are taught, not only at university but leading up to it?

I am deeply unhappy about two courses in the standard teaching of chemistry in France. One course is *chemical thermodynamics* that is taught in an utterly boring way. It gives you an education that is useful only for some very rare purposes. If one is interested in gas reactions in rockets, then possibly thermodynamics would be needed, but if one is a synthetic chemist in organic chemistry, or in bio-chemistry, then the interesting question is finding a good catalytic system, a good solvent medium, and that is utterly different. On the other hand, the chemical message on thermodynamics is often transmitted in such a way that it does not give a good feeling about concepts such as entropy, chemical potential and the basics of electro-chemistry. So I have been complaining about the teaching of thermodynamics.

The second case is the *nature of the chemical bond*. Again I'm thinking specifically of France, where the poor young students get overloaded with complicated orbitals, and 'cookbook recipes' about which orbital is better and so on. The real principles of what makes a chemical bond are mainly lost. Apart from some exceptions, these things are taught with far too much formalism and far too little insight. It can be a pure delight to teach chemists by just keeping major ideas and dropping a lot of junk.

I am also struggling here to make the course of quantum mechanics for physicists simpler. I find it far too complicated because most of my students will go on to work in companies where they only need a simple culture in quantum mechanics, not the details of perturbation theory.

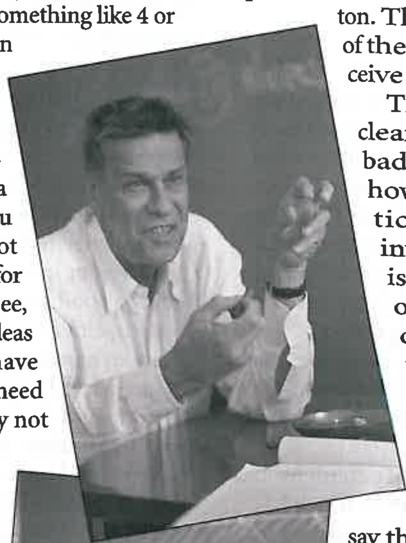
I have been trying to reduce and simplify the physics taught to first year students. About two years ago I realised that we were forcing far too much on them. They had to learn not only the basics in quantum mechanics, statistical physics, organic chemistry and an introduction to biology (our four major items), but also a little bit of mathematics and computer science, and on top of that to take other courses such as telecommunications—a beautiful course, but highly specialised; there is no reason to overload the first year with it.

You make very clear your concern for education but, perhaps surprisingly, for a theoretician, you are known to be especially concerned with experimental training. Should one be surprised at this?

Personally I'm frightfully clumsy. I tried to do semiconductor physics for one year when I was twenty and I barely survived. I was pulling out germanium crystals in a hydrogen atmosphere and the hydrogen did not explode in my year—it exploded the year after, with fortunately no casualties. I have been consistently very poor in experimentation but at least I have learned one thing through a very nice, nearly accidental happening. I was in a training system that included physics, chemistry and biology and they sent me for a short period to a marine biology laboratory. There, for the first time in my life, I learned to look at things. For instance, to look for a certain little animal that is a little bit rare, a variety of scorpion, or something like that, to grab it without damaging it and put it in a little droplet of paraffin wax. Then, with a very simple magnifying glass to look at it and two needles to open it, I had to draw all that I saw. This was a major moment of my education. I really thank the people who sent me there.

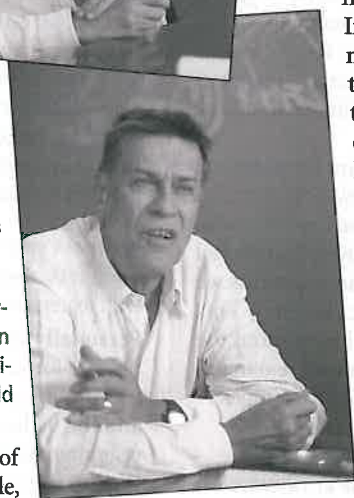
But why are you promoting experimental training?

I found my experience in the laboratory so traumatic that I concluded that theory is the easier part of the physicist's game! If I take a typical group in our soft matter activity, what will be the composition of such a group? There will be something like 4 or 5 permanent research people. One may be in optics, one may be in electronics, another may be in atomic force microscopy, then there would be one or two graduate students and *half a theoretician*. I would say the optimum ratio is around 0.5 theoretician for a group 5 to 10 people. This really works. You need this small fraction of a theoretician; not only to help to understand things or to ask for new experiments but often to act as a busy-bee, that hops from group to group transferring ideas which very often the groups would not have exchanged so freely. I'm convinced that we need theory but not in large doses and preferably not as a closed club. I am very worried by what I call the 'chess club attitude' where you have beautiful chess problems and it's a delight for all members to enjoy these remarkable solutions, but this chess world is such a closed world. My instinct is to avoid the chess club.



So does this mean that you are unhappy with the training situation at high school level?

Absolutely, but I would distinguish here the situation in Latin countries and the Nordic countries. The Latin countries have had from ancient times, probably from the Roman Empire, an education where we define principles and after that we go to general laws, theorems, and possibly at the very end of the course a few applications are mentioned, very late in the process. This is not only true in science it is true in everything. Why did 'we' have the French Revolution? It resulted from this typical theoretical attitude, while the British at the same time were intelligently having the Industrial Revolution. We have an intrinsic weakness which comes from our Latin education.



Something that is happening in Britain, and I understand that it is the same in France, is the decline in student numbers entering physics, chemistry, and engineering. How would you attempt to arrest it—or should one just leave it to market forces?

I am worried. This really brings us to the problem of the public attitude to science, because young people, in deciding at high school whether to take a scientific direction, are very influenced by what they see and hear. Now what they see is a strong criticism of science. The ecology movement is mostly built on elementary school teachers and high school teachers. This is reflected in the way that our children tend to see, for instance, chemistry as something that is very aggressive, dangerous, explosive, poisonous and so on. They don't perceive the real problems and the real goals.

An example that I often use is glass. For the French general public, glass is one of the most clean, beautiful products of nature and should be respected as such. Now if you look at the actual facts, to make glass you need a lot of energy, far more than in making plastic. In addition, a classical glass factory has a huge oven where kerosene is burnt to provide the high melting temperature; it is burnt in air and you make nitrogen oxides by the ton. These nitrogen oxides have polluted the lower valley of the Seine for around 50 years. The public doesn't perceive that.

This is a good example because the wise reaction is clearly not to say "Oh, I have discovered that glass is bad so I won't buy glass", the good reaction is to think how can I improve on the process. Now for that particular problem the solution has been found by intelligent efforts in physics and chemistry. The trick is based on new methods that allow the separation of oxygen from nitrogen at a low price. This changes the future of glass factories. To improve the situation, the good reaction was to do more science, not less. The public doesn't perceive that.

Another factor is pointed out by teachers who are involved just before entry to our Ecole (which is two years after high school); they teach basic mathematics and physics, etc. They say that the French system has slipped and now, roughly ten years after the beginning of the slip, the students at the same nominal level have integrated *one year less* of culture than before.

A third aspect is that our civilisation is growing up in front of screens. Children spend a large part of their life in this way, making them very passive in a certain sense. In front of a computer screen they receive far too much information without really digesting it. They have on the Web an immense capacity for finding data on any subject, but their reaction is to zap from one topic to another, not in any depth. The big difference is that they're not taking notes, and that probably makes for a serious crisis.

In France we have had this beautiful effort in elementary schools, initiated by Georges Charpak, that tries to show simple experiments to the teachers and students, giving them practice at observation and experimentation. On the other hand, the teachers come from special units called IUFM (*Institut Universitaire de Formation des Maitres*). In these, the part devoted to physics is diminishing. The strong emphasis is on what they call didactics, a purely formal educational part that mixes in a little bit of the psychology of group action, and so on. And the net result is zero!

Can we move on to your own personal style of physics? You have the reputation of being a 'fashion maker' in creating new approaches on classical subjects with a strong interaction between physics, chemistry, mechanics, etc. What new, possibly open, subjects do you envisage today for yourself?

I have been interested in glues for a number of years. It is an interesting and delicate topic because glues are really a mixture of many sciences—physics, chemistry, and mechanics. The inventions usually came from the chemists, the measurements from the mechanics, and the physicists are beginning to present a simple view on how a glue works—which is important because up until recently it was cookbook recipes. Now we begin to have general lines of thought to present to students so that if they are facing a new situation where no recipe is available, they can construct their own proposal. That's the ambition, but we should still be very humble about our progress. We have helped to understand what I would call 'soft glues', for instance materials which are tacky, used in book binding, shoe binding, etc. On the other hand the strong glues like epoxy glues that we buy in the supermarket, I don't understand them yet.

I am very impressed by the chemical imagination. The example that I often quote are 'anaerobic glues' for metals. They are adjusted so that they will polymerize only if they are in contact with a metal. Only put in the position where you want them to glue, will they start action. That's really beautiful chemistry.

Now we are trying to shift to *cellular adhesion*—adhesion between living cells. This is a very different world because these are extremely fragile and the tools of measurement are different. Even the concepts turn out to be somewhat different. In standard adhesion the basic concept is the energy required to separate one surface from another—the energy per net area. However in these new systems, very often what is measured is a force—how much you have to use force to extract this protein from its receptor protein. I've been struggling for the last few months to reconcile the two views. Sometimes the situation needs one, sometimes the other, and of course, as usual in science, you need to improvise. It's just at the beginning but I've found it amusing.

Another example happened on a visit to Allied Chemicals in New Jersey. They said to us, "We have a little problem about polymers. We want to put polymers in solution. It's hard, it takes time. We know that if we start from a fine powder it works a little better, but how much grinding should we do?" I'm a typical Latin and I say, "This goes back to 'obvious' principles. It's a diffusion problem of a solvent in a polymer, etc." The Americans are very polite, they answer, "Sir, it is not exactly as simple as you think—there is this experiment, and that experiment, and it can't be described simply in these terms.". We go back home very humbly, we talk together and come back six months later with a model which is much more interesting, where you superpose the effects of solvent diffusion with the effects of polymers which *disentangle* at the same time. In naive terms you have the two things happening. Then you come up with what we have called the 'magic length', and you conclude that if you have a finer and finer powder there is a magic size at which you should stop, that nothing is gained by going below this size. But at the start this was a very humble industrial problem—how best do we dissolve this material?

I like this example because the starting point is really modest, but afterwards the whole theory of coupling between mechanical stress and concentration fluctuations in polymer solutions was started and has been helpful for many things.

For some time you have favoured a style of group works (on superconductivity, liquid crystals, polymers, etc.) even sometimes publications where there were no individual names. Would you recommend this approach today with all the emphasis on individual research assessment?

It was easier in the days when we worked on superconductivity, or on liquid crystals, because the career problems were very easily solved. We could publish major papers as a group, without names, but we would still maintain the short paper, the letter, showing a new effect with the name of the person who invented it. We could still defend careers but we could have major review papers signed by the group as a whole, which I really liked. It would be harder now because the competition is harder and people are tense.

France is not the worst for this. I find the situation in the U.S. is not brilliant in this respect: you have these young assistant professors and they want tenure. What is the result? They take too many students because they want too many things; they publish too much, too hastily; and they fight each other like mad. This is a weakness in the American system. The French system at least has this little channel—the CNRS—where you can give permanent positions to very good young people and this avoids the tension. Also it allows them to risk an experiment which has a strong probability of failing, but if it works it will be a great experiment—you do it better when you are not anxious. So in this particular respect I think our French system is sound. However, there are many other weaknesses in the French system!

What about the work you have been doing to promote the young people in these groups?

That came very naturally. When we started on superconductivity with Etienne Guyon, for something like 18 months I couldn't sleep very well. There I was, a theorist, knowing nothing about experiments. I had these 4 or 5 young boys, and I had the impression that they would never get a PhD.... nothing worked! Fortunately, because Etienne had also done some theory, he went to Cambridge, gave a good talk, and in return got a recipe to make tunnel junctions. Suddenly we could make them too—and our programme started! Little things like that! But there were really tense moments.

Images are known to be very important in your work and, listening to you, you are continually using images in the way you describe things. How would one encourage this? Is it important just for a theoretician, or for a physicist in general?

I think it's important for a physicist in general because it's a way of conveying messages. I mentioned how I learned about making rapid detailed drawings—that was a good education. I still like to sketch, as you can see from the pictures on my office walls.

Some fifteen years ago we were interested in polymer adsorption. This we described for many years by formal theories leading to scaling laws, etc., but we didn't have a simple image to give to the students. After many years we came up with *one drawing* which summarised adsorption, and from that, not only could we explain things to the students in a very few words, we could invent new problems! This is a case where I really saw the power of an image. But the image came ten years after the formal theory!

When I worked with Charles Kittel, in Berkeley as a post doc, he was amazingly good at images like this, and he taught me a lot. He had a beautiful way of explaining things in one sketch.

I've had a very recent experience. Two weeks ago in St. Petersburg at a polymer meeting, an old friend talked to me about a tricky problem of chains that have a random sequence of A or B, and A hates B. There is 50% A and 50% B, so what do they do? My friend described a clever thing which he had done with only two chains in contact—in theory—where by sliding them along each other, he had found regions of 'happiness' and others not. Then he asked "How would we transform this into a vision in the real three-dimensional case?" First I played it down and I said, "This is probably a case where you can use the random phase approximation together with replica techniques..."—the typical armory of a theorist, and I departed.

Fortunately, sitting on a bench in a beautiful St. Petersburg avenue I had time to think. Suddenly it dawned on me that I can essentially do this in one sketch. Having done this I found what I now call 'weak segregation', a completely unusual form of segregation in polymers which can be described very simply.

Travelling back, I write it up on the plane, I arrive back and visit my troops, Ludwik Leibler in this case. Ludwik says "Ha! This is amusing. We worked on this in 1992 and here is the formal answer." He had a beautiful formal paper that contained important results, but it was impossible from it to really guess what would be this form of weak segregation, although all the artillery was there. So I'm constantly insisting: you need the artillery, but you also need to withdraw from it and look again.

Moving on to the funding of research, do you think it should be concentrated on areas of strength or should areas be considered on their merit?

I'm worried about the notion of areas of strength because usually these are decided by people in ministries who have a very schematic view and often just repeat what they've heard. I'm fully in favour of nano-sciences but the 'nano-excitation' goes beyond limits because there is an echo through the French administration.

I am a very strong defender of *small science* as opposed to large science. For instance, I have been fighting against the new French Synchrotron. I have been in favour of a High Flux reactor and a Synchrotron in Grenoble but I was not tempted to have a second source in France. One of the reasons I can explain simply. In the early days I found these reactors were useful not only for the direct science produced but also for their cultural influence. At that time, France was very uninstructed in physics; people would come from their remote universities and spend up to a year at the reactor and learn all the contemporary physics very efficiently. Now that important cultural role has disappeared. Even in the smallest French university you can have a decent education in the physics of our days so there is not the same motivation.

So why were you not in favour of the new synchrotron?

I see little groups striving for little funds and if we build huge laboratories we will kill a large number of these. I also see the industrial aspect. I'm much more interested in helping young people who build start-up companies than in building a big machine. Last month, three brilliant inventors came to me for advice on ideas for new products. One was microlenses where you can modulate the focal length by an electronic field on a droplet of liquid. This could have an enormous market with the next generation of mobile phones which have a little camera transmitting images. Another, which I like very much, was having a can of beer where you press a button and it cools in three minutes. There are a number of competing teams—this particular team started with a man from Saclay, who had left to build his own little company and is now associated with Heineken. I really enjoyed talking to him. When I see that sort of imagination I'm much more tempted to stimulate that than to subsidise the Synchrotron.

From the examples you give, it doesn't seem that you're concerned with possible short-termism in the funding of science.

I am concerned with short-termism in industry: we have had this big change in financial matters some 10-15 years ago when suddenly shareholders took power over the large industries. Now the power is really in the hands of these major shareholders who are only interested in three-year research, nothing longer than that. That means that there are large sectors where we cannot use the inventiveness that is present. I think it is very bad not only for science but for the companies also. In this short-term operation they essentially only work on improving their products according to the demands of their customers rather than thinking of the future. This defensive attitude is dangerous.

How important do you consider is the European dimension in Science?

In our field we have always exchanged freely with the Western world. At one time we didn't exchange so much with Russian groups (certainly in my case, because I refused to go to the Soviet Union as long as it was the Soviet Union). It is now improving, but there are still a lot of things to do. One of my dreams, I don't know whether I will have time to achieve it, is to establish a strong summer school for the Balkan countries because there is excellent fertile ground there. The high school education is not bad, the people are very eager to work but they are often faced with science that is a little 'dusty'—a bit too classical. If we had a one month summer school where we could attract some good students and put them in front of active lecturers we could do a lot for these countries at a very low price.

On the narrower question of where one publishes, should European publications be under the responsibility of their learned societies, in an attempt to balance the dominant position in publishing of the APS and the AIP?

I had one personal experience 3-4 years ago. I became conscious of the fact that there should be a European journal on soft matter. But if we didn't do something fast, some commercial editor in the U.S. would, and we would lose the opportunity. I worked on various possibilities and ultimately we established a European journal of soft matter with some physics and some chemistry. We wanted to have it as a joint action of the chemical and the physical societies. This didn't work for stupid reasons because the chemical society (at least in France) was connected to one commercial editor and the physical society to another. The Americans show us that you can have a thriving publishing industry that is entirely public. So I'm not too happy to see this soft matter journal operated by a private company, but it's better than nothing. I'm just happy that the journal exists, presenting a good view of soft matter physics in Europe.

It's a specific response.

I like to start off with examples.

Can we return to the problem of the general suspicion of science and scientists by the public? As you know, in Britain they attempt to address this with the so-called Public Understanding of Science (PUS) initiative. Do you have ideas on how to improve the situation?

We have a lecture series planned at the *Espace des Sciences* at ESPCI and this serves several functions. One function is copied from the British Royal Institution with the lecturers speaking in the evening. Our specificity, compared with the other sites here in Paris, will be to have *real experiments with each talk*, the same as at the Royal Institution. Function two will be to show some spectacular experiments to the public using our students here as the presenters of the experiments. There is a little architectural trick that I like too. The *Espace des Sciences* has some low windows which open onto the street, and people walking in the street will be able to see the experiments. I think that's a clever move towards the public. Last but not least is the important initiative of Charpak directed towards improving the state of physics in elementary schools and among school teachers. The *Espace des Sciences* will provide a meeting place for teachers and scientists.

I would also like to raise the fluency of our students in English. When I arrived here I imposed a rule that if the students did not attain a certain level of English at the end of their studies, even if they had excellent marks in all the sciences, they would not get their degrees. The first year the students laughed and said, "Impossible! I'm so good in, for example, chemistry that they won't kick me out." Okay, the first year we had to enforce it, painfully in some cases, and after the second year they understood. My dream is to have students who are able to present one year's work with maybe two transparencies, in 10 minutes, in English, to a broad public. If I can achieve that I will be happy.

The last few years have witnessed an upsurge of concern for the under-representation of women in physics culminating in the IUPAP conference: 'Women in Physics' that was held in Paris in March last year [EPN 33/3]. How do you view this concern?

In soft matter we are very happy because the contrast is much less striking than in other disciplines. For instance, in our laboratory in the *Collège de France* we have roughly a 50:50 balance of males and females, and the two directors that we have had over the past 15 years have both been women.

I have also been working on a project that is difficult to operate, but nice. This is a collaborative project of UNESCO and L'Oreal (the large French cosmetic company) in which they have decided to establish a Prize for Women, one woman in each continent (Africa, Asia, etc.). They started it in biology 2-3 years ago, and now they are extending it to condensed matter physics plus chemistry. I accepted to launch the thing as the president of the jury. I've found it very hard work but it is now underway. In the biology sector, as well as giving prizes, UNESCO and L'Oreal also give *grants*. I think the grant system is much more powerful. But probably we need both because prizes give an image. I hope we can contribute in a small way to this. It is not easy to collect the right candidates.

Perhaps if one does see more women going into the sciences it could help to address the problem of the general public's suspicion of science and scientists.

Yes, I agree.

How do you view the role of physics in the development of the life sciences?

Firstly, we have to be very modest. I have seen premature attempts that were failures. I've seen many examples where physical scientists were too pompous, claiming that they came with the truth, and the others just had to sit and listen. Then there was a backlash!

My attitude here is very much the opposite. If you get into a biological problem, you have to become a student again and study it for three years. After which you have reached a graduate student level and you can begin to participate in seminars and possibly propose ideas. But you need this long, humble training before you can do anything. With people who accept that, I am happy.

Secondly, we should carefully distinguish between physics and applied physics. For instance, in studying protein structures there is very useful applied physics, where you look at the structures either by diffraction or by nuclear resonance. But it's not real physical research, it's applying techniques to an interesting problem. This requires a very special type of mind, a very different type of mind from the physicist whom we are used to educating.

Globally indeed biology is interesting and it's moving fast, and there are thousands of problems to be tackled.

You have thought for a long time that physics and chemistry could be taught together, but it has not been the case for physics and biology.

I have fought for 12 years here with my administration (the City Council of Paris) to get biology into this school. And I got it, ultimately. I don't claim that my students have a very broad view of biology but they have been introduced to it and they have more snappy reactions, even if they do not work in biology. An example which I often quote is: suppose we suddenly discover a particular metal in the periodic table, that we may call X, which has not been exploited. Now, the chemist will look at the periodic table and say "X looks very much like Y. Let's look at the mining for Y, and maybe in these ores we'll find X." That's a good reaction—but that's not enough. In our time, a good chemistry student will say "not only will we look at the ores but we'll look also at the bacterial colonies on the site, and maybe some bacterial colonies for some mysterious reason will have decided to select X and not Y. If so we can use that." It is a trivial example, but I think we need such a reaction.

I was quite surprised on checking back, that it was as long ago as 1991 that you were awarded your Nobel Prize. And listening and talking to you, it's quite clear that you have taken it in your stride without it changing you much. But it would also be interesting to know, if one may ask, what it has meant personally for you?

Two comments here. I was lucky to get the Nobel Prize at a rather ripe old age. I didn't get giddy about it, whereas I have seen some brilliant individuals who were so entranced by the glory that they got lost to science.

In everyday life the prize brings more work—one or two hours more per day. This is because one gets an enormous number of requests for advice. Sometimes these requests are very technical, like the 'cool beer can', but sometimes they are not technical at all, just requests from people who want to have you on their side in a cause. Very often you don't know enough about the cause, you are hesitant and it takes time to form an opinion. I've seen friends and colleagues who were too willing to become involved in every cause. That is a danger too. You have to do a lot of filtering and you have to do it yourself. You have to perceive each human case separately.

You also get a number of 'crackpot cases'. The difficult cases are those that are just at the limit of being inventive and being completely 'crackpot'! These are often hard to respond to and sometimes take a lot of time—you have to give a long answer. The prize takes up a lot of time. That's my general conclusion.

I am afraid that we too have given you two hours of additional work! We can only thank you for what has been a most interesting and thought-provoking experience.

The secrets of Framework 6 proposals

Sean McCarthy, Hyperion Ltd., Co-Cork, Ireland

All over Europe researchers are preparing proposals for the European Union's Research and Development programme (known as Framework 6). Researchers start by studying the workprogrammes (scientific priorities) and then they study the documentation on CORDIS (www.cordis.lu) needed to submit the proposals. This documentation is very comprehensive. After 20 years of designing and implementing these programmes the European Commission has prepared a very complete set of guidelines and websites to support proposal writers. Some researchers seem to master these guidelines and procedures and other researchers have difficulty understanding what is expected in the proposals. This article presents some of the secrets of the European Union Framework programmes. It is based on the author's involvement in European Union R&D programmes since 1980 (and his involvement in over 150 proposals and 60 contracts).

The Players in European Union R&D Programmes

Before discussing the secrets of Framework 6 proposals it is first necessary to understand the background to these programmes and the main players involved. The Member States of the European Union first come together and they prepare a **Treaty**. This describes the areas where they wish to cooperate. These topics include Energy, Agriculture, Transport etc. Article 163 of the Treaty describes how the Member States will work together in Research and Development. Following this the Institutions of the European Union prepare **Policies**. Examples include Agricultural Policy, Enterprise Policy, Regional Policy and Social Policy. To implement these policies the European Union has two 'instruments'—**Legislation and Funding** Programmes.

Figure 1: The Players in the Framework 6 Programme

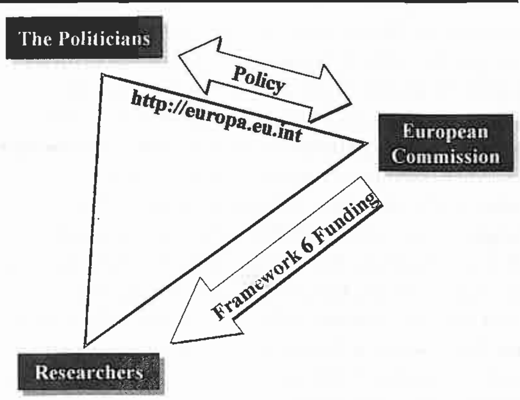


Figure 1 shows the relationship between the different players in Framework 6. Research Policy is first prepared between the Political Institutions (Council of Ministers and the European Parliament) and the European Commission (civil servants). When the policy is agreed the European Commission implements its Research Policy through the Framework 6 Programme. The important point here is that the topics in Framework 6 are political priorities. It is essential that researchers are familiar with these background documents before they start writing proposals. Examples of the background policies for the priorities in Framework 6 can be found on www.hyperion.ie/fp6websites.htm

Secret 1: You never go to Brussels looking for money for your research. You only go there to help the Europan Commission solve a problem that THEY have identified.

Your proposed research must be designed to solve European problems identified in European Union policies. For example the aim of the EU Information Technology Policy is to establish Europe as the world leader in Information Technologies by 2010. The European Commission has published an action plan titled the eEurope Action Plan. This is the background policy document for the Information Society Programme in Framework 6. In the Programme on Food Safety the background policy document is the White Paper on Food Safety.

Secret 2: Educate the Evaluator (with facts and figures)

Researchers must understand the difference between a Framework 6 proposal and a scientific paper. When a scientific paper is submitted to a journal the content of the document is scientific *only* and it is reviewed by scientific experts in the field. In the case of Framework 6 proposals the content is scientific, political, economic, social and it also has a comprehensive management section. The different evaluators will have scientific, economic and political backgrounds. It is essential that you educate all of the evaluators (with fact and figures) by answering very important questions (that are not in the proposal!).

1. Why bother? (i.e. what European problem are you trying to solve?)
2. Is it important at a European Level?
3. Why do you have to develop this? Is there a product or service already on the market?
4. Why now ? (Why did it have to wait until now?)
5. Could you transfer the technologies from another sector e.g. space
6. What background do you have that shows you have the skills to do this?

The following table is an example from a proposal that received 5/5 for economic relevance.

▼ **Table 1:** Improved Performance of Plastics with 3.5% Nano-additive Loading

Performance Properties	Improvement
Tensile Strength	100-700%
Flexural Modulus	50-300%
Thermal Stability	30-80%
Gas Permeability Reduction	10-40%
Heat Release Rate Reduction	60-80%

One of the best training courses on Proposal Writing is to become an evaluator of Framework 6 proposals. To do this you first have to put your name and details of your expertise in the expert database on http://emmfp6.cordis.lu

Secret 3: Lobbying or Briefing?

Lobbying is an American concept. In Brussels it is better to describe the process as 'Briefing'. To understand the Lobbying (or briefing) process we refer to Figure 1. First someone must 'brief' the politicians on the importance of the research topic e.g. Food Safety. Someone must then 'brief' the European Commission to ensure that the specific research topics are included in the work-programme of Framework 6. Eventually the scientists must be briefed on the political background to the priorities of Framework 6. This briefing process is done through Conferences /Evaluations /Assessments /Studies /High Level Groups / etc. The process is extremely transparent and the European Commission continuously advertises these activities on its Cordis News services (www.cordis.lu).

It is important that researchers are involved in these activities as it gives them a thorough understanding of the background to the different topics in the programmes. It also means that when you are setting up a consortium it is important to have partners who have been active in this 'briefing' process. Examples of the 'Expert Groups' can be found on:
www.hyperion.ie/framework6websites.htm

Secret 4: From Framework 4 to Framework 5 to Framework 6

Framework 4 concentrated on the development of advanced science and technologies. e.g. *The Development of a Sensor to Monitor Hydrocarbons in Water.*

Framework 5 focussed on developing scientific and technology solutions to important EU problems. e.g. *The Development of a Hydrocarbon Monitoring Sensor to assist water companies in meeting the requirements of the EU Water Framework Directive.*

Framework 6 involves bringing together the best scientists in Europe to solve big problems with technology. *The Development of Technical Platforms and Standards to improve the Quality of Drinking Water in Europe (in accordance with Water Framework Directive).*

In Framework 6 the single most important task in preparing a proposal is selecting the best possible partners. These would include scientists already active in EU R&D contracts, members of standards committees, members of EU 'expert panels'. The relevant websites can be found on:
www.hyperion.ie/framework6websites.htm

Secret 5: European Documentation for Research Proposals

Every question in the proposal has a history. The Framework 6 guidelines are very good at telling you what they want. They are not good at telling you why they want the information.

Background to the questions in the proposal. Again refer to figure 1. The European Commission is obliged by legislation to regularly report the progress of the Framework Programmes to the European Parliament. They do this through Annual Monitoring Reports (http://www.cordis.lu/fp5/monitoring/), 5-Year Assessment Reports (http://www.cordis.lu/fp5/panels.htm) and External Advisory Group Reports (http://europa.eu.int/comm/research/fp5/eag.html). In addition to this the European Commission has established a high level advisory group called EURAB (European Research Advisory Board) (http://europa.eu.int/comm/research/eurab/index_en.html) The recommendations of these 'Expert Groups' have to be implemented. This is why the rules change so often.
Examples:

- *The next Framework Programme must be firmly based on the twin pillars of scientific excellence and economic and social relevance.* 5-Year Assessment (1997)
- *Relevance can be derived from forward-looking analysis of technologies (foresight studies). The role of the JRC IPTS (www.jrc.es) is worth examining in this connection.* 5-Year Assessment (1997)
- *Impact assessment should become one of the most important elements of evaluation.* 5-Year Assessment (2000)

The above websites are essential reading for all proposal writers (and advisors) in Framework 6.

Secret 6: Focus on Deliverables, Users and Routes for Exploitation

Excellent science is the most important part of any Framework 6 proposal. However, this on its own is not enough. During the preparation of Framework 6 Elly Plooij-Van Gorsel Member of the European Parliament said in an interview in European Parliament Magazine (February 2002) "Europe is very good at transferring euros into research, but not in transferring research into euros."

In addition to excellent science the writer must address the following key issues:

- What exactly will come out of the proposed work i.e. the deliverables (prototypes, software, data, documents, databases, media...)?
- Who will use these—or to be more specific who is the NEXT USER?
- How will you deliver the results to these users—i.e. routes of exploitation (publications, licences, spin off company, education..)?

This in fact is how proposals for Framework 6 should be started. When this is defined then you can start designing the science.

Summary

The European Union provides funding for research to "*strengthen the scientific and technological bases of Community industry and encourage it to become more competitive at international level, while promoting all the research activities deemed necessary by other Chapters of the Treaty.*" (Article 163 EU Treaty). The funds provide by the European Commission are public funds and there is a legal requirement on the European Commission to continuously monitor how these funds are used. They must also regularly adapt the work-programmes and rules to reflect changes in new political, economic and social challenges. Researchers who rely on public funding for their research (National and EU) MUST become more aware of these issues and they must be able to address these non-scientific issues in the proposals. On a positive note researchers who are aware of the political, economic and social background to the Framework 6 Programme claim that it makes their research more interesting AND they get more contracts.

About the author

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WYP2005 Kicks Off

Representatives of 4 continents and 22 countries met in Graz, Austria for a three day conference to discuss strategies and ideas for implementing WYP2005. Specific ideas and plans were presented in plenary and poster sessions by all participants. Seven working groups also discussed physics in education, international physics competitions, promoting science among young people, events and exhibitions, popularising physics, physics in the media and physics in different cultures. The role of women physics was an integral part of each of the working groups.

The conference was organised under the auspices of the Austrian Physical societywith the talent and energy of Max Lippitsch, Gero Vogl and Sonja Draxler. The University of Graz and the State of Styria were also instrumental in the organiosation.

M. Ducloy, EPS past president made the opening presentation. He outlined the history of the initiative and EPS plans for 2005. Through the involvement of EPS member countries, a resolution is currently being discussed at UNESCO to obtain its support for the declaration of 2005 as the World Year of Physics.

Mme Tania Friederichs represented the EU research Commissioner P. Busquin. Her message to the delegates stressed that science and society issues, including the WYP2005 initiative were a priority within FP6. The successful implementation of the European Research Area not only requires structured coherent research, but an adequate supply of trained scientists and a broad general culture of science.

The last day was devoted to project development sessions. The participants of the conference laid the ground work and aims for the following specific actions: architecture and science education; couldn't be without it follow up activities; science story writing; a travelling exhibit showing the impact of physics in history, politics, society and culture; light around the world; physics talent search; and a physics calendar.

International Steering Committee

3rd meeting, 7 July 2003, Graz (A)

The meeting was held as part of the plenary session of the 1st WYP2005 Preparatory Conference.

A draft resolution for UNESCO support for the declaration of 1005 as the World Year of Physics was prepared and widely distributed for presentation to UNESCO delegations around the world. The Brazilan UNESCO delegation, supported by France and Portugal presented the draft resolution to the Executive Board of UNESCO at its meeting in April 2003. The resolution was well received, and will be formally place on the Executive Board's agenda for the September 2003 meeting, and transmission to the UNESCO General Assembly. If the resolution is passed by the UNESCO General Assembly, it may then be transmitted to the UN General Assembly for eventual discussion and adoption.

The draft resolution was presented to the participants at the 1st WYP2005 Preparatory Conference. After some discussion and clarification of the language, the resolution was unanimously supported by the participants at the conference.

All participants were urged to contact their UNESCO delegations and request support for the resolution.

The wyp2005.org website is online. An electronic form is available to sign up to join the WYP2005 International Advisory Committee. The IAC is open to national committees for WYP2005 activities, and to interested groups of physicists that wish to organise activities. Information about activities will be sent to those who sign up.

Once submissions for planned activities are received, an events calendar will be generated. All participants were urged to sign up and place their activities on the site.

As the status of the activities in the countries participating in the conference was part of the regular agenda of the conference, no reports were given.

The place and date of the next ISC meeting should coincide with the 2nd WYP2005 Preparatory Conference. If such a conference is held, it was felt that it should be piggy backed onto a large physics conference outside of Europe, perhaps in Latin America in early 2004, or the APS March meeting in Montreal.

"Science is physics, everything else is stamp collecting" Rutherford

M. Ducloy and D. Lee met with Professor José Israel Vargas, Brazil's Ambassador to UNESCO to discuss the progress made in obtaining UNESCO support for the declaration of 2005 as the World year of Physics. Below is a summary of

Professor Vargas, an intelligent, charming and entertaining person was very positive with regards to UNESCO support. He will step down as Brazil's Ambassador, but will nonetheless continue to represent Brazil on UNESCO's Executive Board.

The next step in the process is the formal decision by the Executive board in September 2003 to present the resolution declaring 2005 as the World year of Physics to the UNESCO General Assembly this autumn. If adopted by the UNESCO General Assembly, then direct action by UNESCO is possible, such as organising conferences, direct appeal to UNESCO member states to take action in 2005 to promote physics, prepare publications, and use UNESCO's media contacts. UNESCO could also organise a large kick-off event early in 2005 at its headquarters in Paris.

It is generally accepted that science is important for economic and cultural development. However, governments tend to favour applied science. According to Professor Vargas, a good motto for WYP2005 might be "there is no applied science without science".

One important element to gather support for the initiative could be to show the economic impact of Einstein's theories and discoveries in modern life, from lasers to GPS. This would be elegant proof that profound theories about the nature of the universe have an impact on everyday life.

Contact **Susan Mackie** • EDP Sciences • 250, rue Saint Jacques • F-75005 Paris • France
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hmi

TU berlin

The Hahn-Meitner-Institut Berlin (HMI)
Member of the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren e.V.
and the
Technische Universität Berlin
invite applications for a joint appointment in the field

„Technologies in Photovoltaics"

as

Head of Department "Technology"

in the Division of Solar Energy Research of the HMI
and

University Professor (Bes.Gr.C3)

at the Faculty IV "Elektrotechnik und Informatik" of the Technische Universität Berlin.

The Hahn-Meitner-Institut (HMI) is a scientific research centre with about 800 employees located at Berlin-Wannsee and Berlin-Adlershof. The main research activities are structural research using neutrons, ions and synchrotron radiation and, in solar energy research, thin-film photovoltaics. Solar energy research covers the entire range from basic research on materials and concepts to the development of prototype solar cells and modules.

The department "Technology" is designed to link the research on solar cell development at a laboratory scale with the requirements of industrial production. Investigations cover structuring, alternative deposition processes and reliability control for solar cells and modules. At present, work is concentrated on chalcopyrite solar cells based on sulphur, currently the most advanced HMI concept.

We are looking for an **Engineer/Physicist** experienced in at least one of the following fields:

- industrial production of solar cells,
- development of thin-film solar cells,
- industrial quality control of devices.

Candidates holding a PhD in engineering/physics with an outstanding international reputation for research in the fields of technology and preparation of thin-film solar cells are invited to apply. We are looking for a candidate capable to motivating her/his department and who is prepared to accept management tasks within the HMI.

We expect the successful applicant to be committed to the general programme of teaching and training of students at the Technische Universität and to foster collaborations both internally and externally. Within the main course, "Electrical Engineering", at the Technische Universität, she/he is expected to teach the basics of photovoltaic energy conversion and the fabrication of solar cells.

Both HMI and Technische Universität Berlin are seeking to increase the number of female scientists in their institutions. Therefore, women are especially encouraged to apply. Handicapped applicants will be given preference over others of equal qualification. The legal requirements of § 100 BerlHG for entry into public service as a university proffessor (a leaflet will be sent upon request, for a German version see http://www.iv.tu-berlin.de/iv/fv/rundschreiben/prof-einst-vor.html) must be satisfied.

Applications should be received within 4 weeks from the date of publication and should be addressed to **Prof. Dr. Michael Steiner, Scientific Director, HMI, Glienicker Straße 100, 14109 Berlin, Germany**, who also may be approached for further information by phone (+(49) (0) 30 8062 2762) or e-mail (steiner@hmi.de).

Faculty Position in the Condensed Matter Warsaw University

The Dean of the Faculty of Physics, Warsaw University invites applications for the Associate Professor position at the Institute of Theoretical Physics.

The successful candidate will be expected to carry out a high level research program in the field of theoretical condensed matter physics, and will contribute to teaching on both undergraduate and graduate level. The Faculty may provide an opportunity to employ a co-worker on the level of assistant professor.

Qualifications of candidates include doctoral degree and habilitation or equivalent.

The candidates should have an exceptional scientific record in condensed matter theory, ability to initiate and conduct scientific programs and demonstrate experience in teaching.

Detailed information: ***dziekfiz@fuw.edu.pl***

The applications should be submitted to the Dean Office of the Faculty of Physics, Warsaw University, ul. Hoza 69, 00-681 Warszawa, Poland before October 3, 2003.

The final decision is taken by the Faculty Selection Committee by December 31, 2003. The Committee may ask the candidates for additional informations and invite them to give a seminar at the Institute of Theoretical Physics.

UNIVERSITÉ DE GENÈVE

The **Faculty of Sciences**, University of Geneva, Switzerland, has an opening for a position as

FULL PROFESSOR
OR ASSOCIATE PROFESSOR

Responsibilities: This is a full time appointment including 6 hours of lectures per week and research activities in the area of Applied Physics. Teaching will be given in French. The successful candidate is expected to conduct a vigorous research program in the field of living matter physics in collaboration with the other research groups of (optical and materials science/superconductivity) and local scientific infrastructures. Administrative charges.

Degree of requirements: Ph.D. or equivalent with advanced training in physics.

Starting date: October 1st, 2004 or as agreed.

Applications, including curriculum vitae, list of publications, list of references and a short research plan are to be sent to the Dean of the Faculty of Sciences, 30, Quai Ernest-Ansermet, CH-1211 Geneva 4, Switzerland.

Closing date for applications: November 30, 2003.

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

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Details on projects and application procedures can be found by e-mail reclutamento@infm.it or at http://www.infm.it/Uk/Job/Training/Mcurie/index.html

Closing date for applications is 23 August 2003

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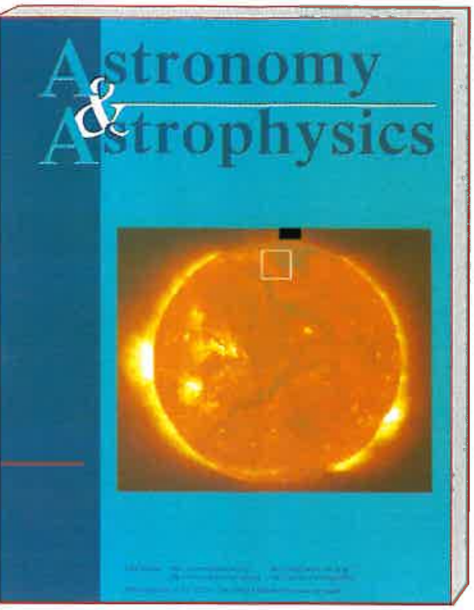

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