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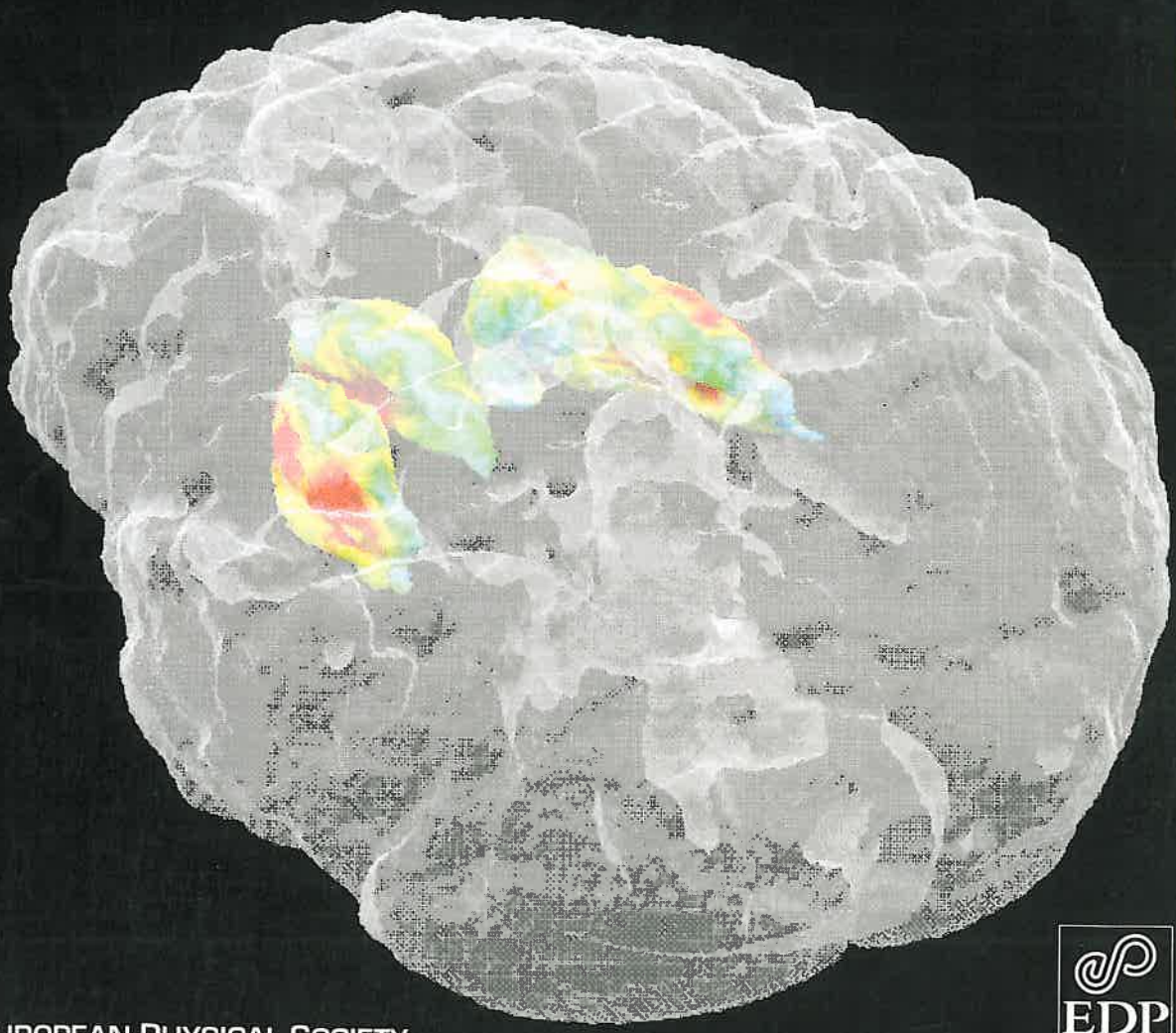

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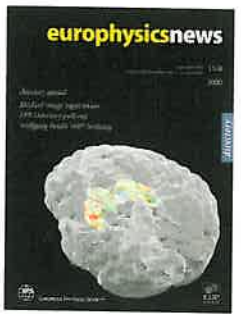

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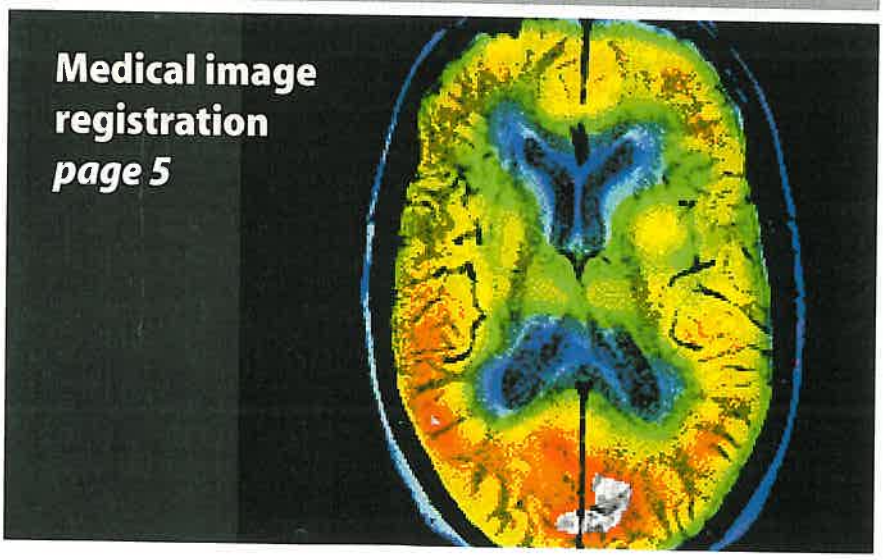

Dedication of the Synchrotron Radiation source at the Kurchatov science center

from our Russian correspondent

In spite of all the difficulties now facing Russian science we are happy to report the opening of the 2.5 GeV dedicated electron storage ring synchrotron at the Kurchatov science center. This event brought to Moscow the leaders of most of the SR sources in Europe and provided for a appraisal of this rapidly expanding area of research. Initially SR, that accompanied the operation of synchrotrons and storage rings, was seen first as a nuisance and factor limiting the possibilities of these machines. But very soon it was recognized that SR, spanning the spectrum of radiation from the infrared to hard X-rays is a remarkable in its potential instrument of research. At present, in the world more than 50 dedicated SR sources have been built and the whole area is expanding at a remarkable rate. With SR from a modem source the spectral brilliance of radiation, the parameter that in practical terms determines the potential for experiments is by many orders of magnitude greater than of any other source. This has led to a formidable revolution in experimental physics and spectroscopy of all kinds. Finally, SR is now becoming a versatile tool for producing advanced microelectronic chips and has led to its use for making minute devices and gadgets of all kind, now known as nanotechnology.

For a physicist a SR source compliments in its properties in studies of matter neutron sources and it is no accident that the first Russian source is built at the Kurchatov science center, that has a long standing tradition in neutron scattering. In fact, another SR source is to be built at the Joint Institute for nuclear research in Dubna. This symbiosis of SR and neutrons is practiced in Grenoble and Brookhaven, and the new Swiss SR facility is also to be built at the site of a powerful pulsed neutron spallation source at the Paul Scherer Institute.

Up to the present, SR radiation was mainly incoherent, but now the first uses of spatial coherence with X-rays have been demonstrated, showing the potential of these new methods. The extension of truly coherent radiation at these energies with free electron lasers are now to be developed. In this case the next revolution in SR research will happen, similar to the transformation in optics, that came with the invention of lasers.
SR sources is really the use of what is arrogantly called Big Science instruments for solving the problems of 'little science'. But the significance and sheer scale of the output show how short sighted this attitude is. Finally, SR research and facilities are not only multidisciplinary, but also draw together scientists from different countries and intellectual traditions. One can be sure, as it was indicated by the Minister for science and technology M.P. Kirpichnikov that the modern and high power facility built at the Kurchatov center, incorporating all the technical excellence of accelerator physics of the Budker Institute for nuclear physics in Novosibirsk, will now serve both Russia and Europe, and be a fine partner in the flourishing international community of SR research and technology.

S.P. Kapitza

Errata

Our apologies to Prof. Debu. The equation published on page 7, second column of Europhysics News 31/3 should read:

$$\mathrm{NA48}: \epsilon'/\epsilon = (14.0 \pm 4.3)\ 10^{-4} \quad \text{and not} \quad \mathrm{NA48}: \epsilon'/\epsilon = (14.0 \pm 74.3)\ 10^{-4}$$

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Printer Rotofrance

Schedule
Six issues will be published in 2000. The magazine is distributed in the second week of January, March, May, July, September, November. Meetings issues are published every six months (in March and September) and a directory issue with listings of all EPS officials is published once a year (in July).

Subscriptions
Individual Ordinary Members of the European Physical Society receive *europhysics news* free of charge. Members of EPS National Member Societies receive *europhysics news* through their society, except members of the Institute of Physics in the United Kingdom and the German Physical Society who receive a bimonthly bulletin. The following are subscription prices available through EDP Sciences. **Institutions** 600 French francs or 91 euros (VAT included, European Union countries); 600 French francs or 91 euros (the rest of the world). **Individuals** 380 French francs or 58 euros (VAT included, European Union countries); 380 French francs or 58 euros (the rest of the world). Contact subscribers@edpsciences.com or visit www.epdsciences.com.

ISSN 0531-7479
ISSN 1432-1092 (electronic edition)

Medical image registration

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Functional imaging using single photon emission computed tomography (SPECT) and positron emission tomography (PET) is extremely valuable in the diagnosis of various disorders. Uncertainty in the anatomic definition on SPECT and PET images, however, sometimes limits their usefulness. To overcome this problem, a combination of magnetic resonance images (MRI) and X-ray computed tomography (CT) images with functional SPECT or PET images of the same sections of the body, is used. This provides complementary anatomic (MRI or CT) and physiological (SPECT or PET) information that is of great importance to research, diagnosis, and treatment.

Two basic types of medical images are made: functional body images (such as SPECT or PET scans), which provide physiological information, and structural images (such as CT or MRI), which provide an anatomic map of the body. Different medical imaging techniques may provide scans with complementary and occasionally conflicting information. The combination of images can often lead to additional clinical information not apparent in the separate images. The goal of image fusion is to impose a structural anatomic framework on functional images. Often in a functional image, there simply isn't enough anatomic detail to determine the position of a tumor or other lesion.

Although, the construction of a composite, overlapping medical image – described in the field as medical image registration has been primarily used in the fusion of functional and anatomical images, it has also been applied to a series of the same modality images. Examples of this are registration of SPECT images of the same subject in follow-up studies or in a comparison of an image with normal uptake properties to an image with suspected abnormalities. In addition, image registration of SPECT and PET images and the registration of SPECT and PET images with anatomic atlases, provide an important means to evaluate comparative uptake properties of SPECT and PET radiopharmaceuticals, and to correlate uptake properties with anatomy.

Medical image registration has been applied to the diagnosis of breast cancer, colon cancer, cardiac studies, wrist and other injuries, inflammatory diseases and different neurological disorders including brain tumors, Alzheimer's disease and schizophrenia. This method has also been utilized in radiotherapy, mostly for brain tumors, and by cranio-facial surgeons to prepare for and simulate complex surgical procedures.

One area where image registration plays an important role is in medical imaging in the early detection of cancers. Radiologists often have difficulty locating and accurately identifying cancer tissue, even with the aid of structural information such as CT and MRI because of the low contrast between the cancer and the surrounding tissues in CT and MRI images. Using SPECT and radioactively labeled monoclonal antibodies it is possible to obtain high contrast images of the concentration of antibodies in tumors. However, sometimes it is difficult to determine the precise location of the high concentration of the radioactive isotope in SPECT or PET images in relation to anatomic structures, such as vital organs and surrounding healthy tissue. Image registration is a visualization tool that can significantly aid in the early detection of tumors and other diseases, and aid in improving the accuracy of diagnosis.

The problems related to multimodality imaging can be separated into three groups; a) problems related to file structures, transfer and networking, b) registration, and c) visualization of the composite images.

Problems related to file structures, transfer and networking

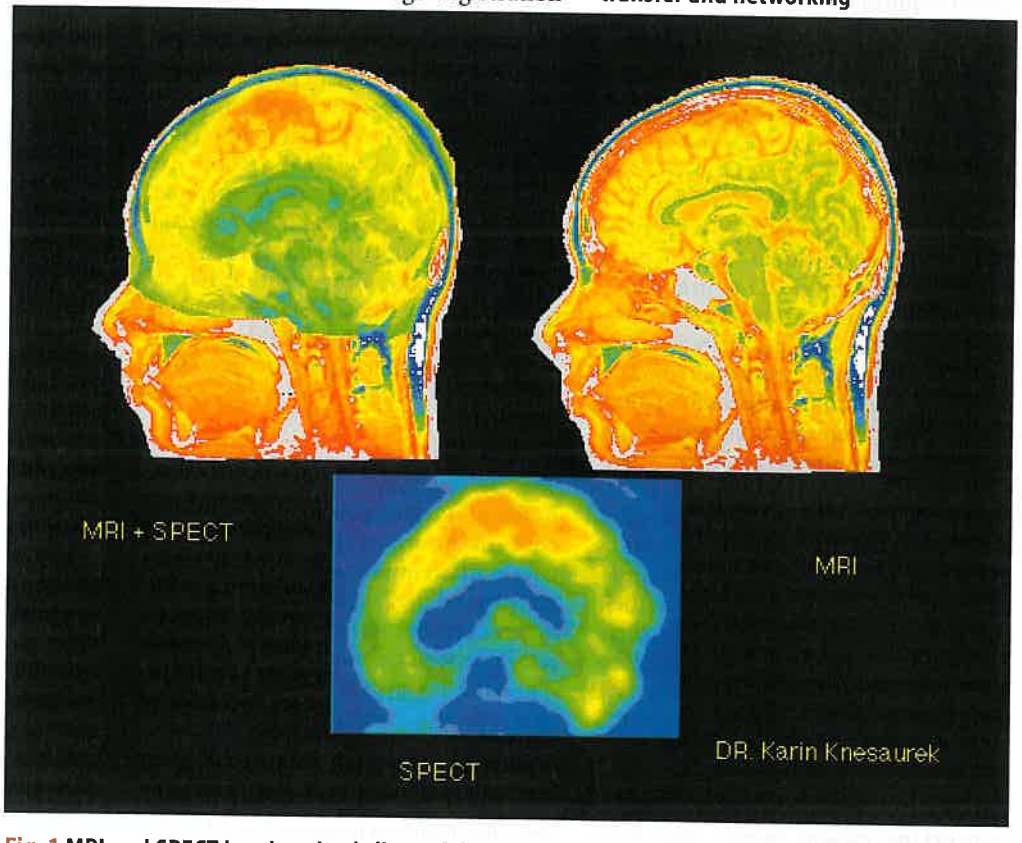

Fig. 1 MRI and SPECT head sagittal slices of the same patient and the coregistrated (MRI + SPECT) image. The lesion on the top of the skull is more prominent in the composite image, although it can be visualized in both modalities.

The main problem in networking of diagnostic images from different modalities is the need to merge unknown or unlike image file structures. To illustrate the problem, suppose you wanted to find out whether a man has grown a bigger mustache by inspecting two pictures taken at different times. One is a photograph, and the other on a video camera. And you want to do it precisely. Imagine the problems in composing the pictures in the two media, the size of the pictures, their quality, different viewing angles, etc. The problems with medical images are much more severe. Different vendors use different ways of writing patient data on the hard disk. Usually patient data are split into two parts; header and binary image data. The two parts can be one file or two separate files. The header contains general information such as patient name, age, matrix size used in imaging, number of images acquired, depth of each image, i.e. 8 or 16 bit deep images, diagnostic comments and the date of examination. The binary image or images are usually one file. However, on some computers the way of writing the data can be different, e.g., the order of high and low bytes can be reversed. The worse case is facing an unknown format of patient data, e.g., the compressed data. Handling the different patient file structures may be the most difficult issue in applying medical imaging registration but it obviously is not the only one. There is now a big effort in the medical imaging community to define certain standards for patient imaging files. There are several proposals, although still in the development stage, such as the DICOM standard being developed in the USA and the Interfile standard being developed in Europe. But in spite of the general approach and standards, individual manufacturers still maintain their own patient file formats. Therefore, there remains a need for software to transfer information from one format to another. We hope that medical equipment companies will provide basic information on their patient formats and allow direct access to the raw and uncompressed patient images. Networking patient images and their physical transfer to the common processing system is also an obstacle facing many clinical institutions. The main problem is the transfer of huge amounts of data at a reasonable speed using affordable hardware and software. There is a concern about the transferring of confidential patient data using the main hospital Ethernet backbone, which is accessible to the general public. The optimal solution is to run a local network which is connected to the outside world by a bridge or router, providing on-line transfer of patient data. The router or bridge should also serve as a gatekeeper, and protect unauthorized access to sensitive patient data. As a backup, it is advisable to use tape cartridges or other common media (optical, floppy disk, etc.).

Fig. 2 Coregistrated SPECT-MRI image. The SPECT image was pasted in "opaque" mode on the top of the black-and-white MRI image, which provided an anatomical template.

Registration

The first step in correlating images of the different modalities is to address differences in the acquisition parameters between different modalities. Those parameters are different pixel† or voxel†† size, different matrix size and different orientation in acquired images. For example, one of the first steps in registration SPECT with MRI or CT images is to expand the 64x64 SPECT image to the 256x256 or even to 512x512 matrix, the usual size of the MRI or CT images. In order to preserve the quality of images enlarged to this extent, certain interpolation has to be used. Mostly bilinear and B-spline interpolations have been used in medical image registration

The process of registration, which is also referred to as image fusion, superimposition, matching or merge, is based on the definition of the transformation that transforms an image of one modality to the image of the another modality. Image registration should map each point in one image onto the corresponding point in the second image.

Mostly it is assumed that transformation between the images of the different modalities is isotropic. It is assumed that neither image is skewed and that pin cushion or barrel distortion for each modality is negligible. Thus, linear transformations can been used, such as rotation, scaling, reflection and translation. In addition to the linear transformation, affine transformations that include uniform and nonuniform scaling and shearing in addition to linear transformations have been used. When there is variability in geometric structures between images, e.g. distortion in the MRI image because of the variable magnetic field, curved transformations, referred as warping, may be applied.

There are four general approaches to the registration problem; control-point based registration, moment-based registration, edge-based registration, and optimization of a similarity measurement.

Control-point based registration methods

Defining control-points consists of choosing some characteristic points in images. Usually features and/or geometric properties that are unique to a set of images define these points or landmarks. Control-points must lead to an accurate description of the image transformation. These landmarks can be used as extrinsic, intrinsic or combination of both. They can be internal anatomic landmarks (rib cage, ventricles, bone surfaces, etc.) or external point sources attached to the patient, or external fiducial markers in stereotactic studies.

The registration step consists of defining the transformation, which maps the control-points of the first image onto the ones in the second image (an MSE, mean

square error). Preprocessing performed using control-points is not always an easy operation. Using internal anatomic landmarks requires considerable operator expertise. However, user provided control-points usually lead to satisfactory and fast registration. Also, a priori information from the user's knowledge is straightforwardly introduced in the process.

The process of registration can be accomplished manually, semiautomatically or automatically. The most common approach is semiautomatical, although the degree of interaction can vary considerably among different applications.

Moment-based registration

The basic idea here is to extract common information from images without or with minimal participation of the user.

Gray-level and geometric properties of images are characterized by the center of gravity, principal axis and more complex moments. Parameters (translation, rotation, scaling, etc.) of the transform leading to "standard" images are computed by normalizing moments in each image. The main property of the normalized moments is that they are invariant features of images.

For moment-based registration techniques noise tolerance is rather weak since noise can lead to imperfect moment estimates and large errors in parameter determination. Also, moments do not involve enough knowledge about a priori information that is present only through the registration model. These techniques usually do not permit robust registration and field of use is restricted to the matching of simple objects in image pairs.

Edge-based registration methods

This class of methods has usually been performed to register images where neat contours exist. The preprocessing stage consists of discarding all information except edges in each image.

The edge extraction step can be solved in many different ways: template matching, zero-crossing, etc. Nevertheless, contours are not easily extracted from noisy images. Resulting contours must be characterized properly for the associated matching algorithm.

Minimizing MSE and comparing intensity values of edge pixels is frequently used to match edges. Available information about edges is incompletely used since only the appearance of edges is involved in this method and the optimization criterion often presents a very sharp minimum. Because of noise in contour images, this minimum can be missed and a local minimum selected instead, leading to a totally meaningless registration. In order to overcome this failure, and to ensure high reliability, contour-based methods must in-

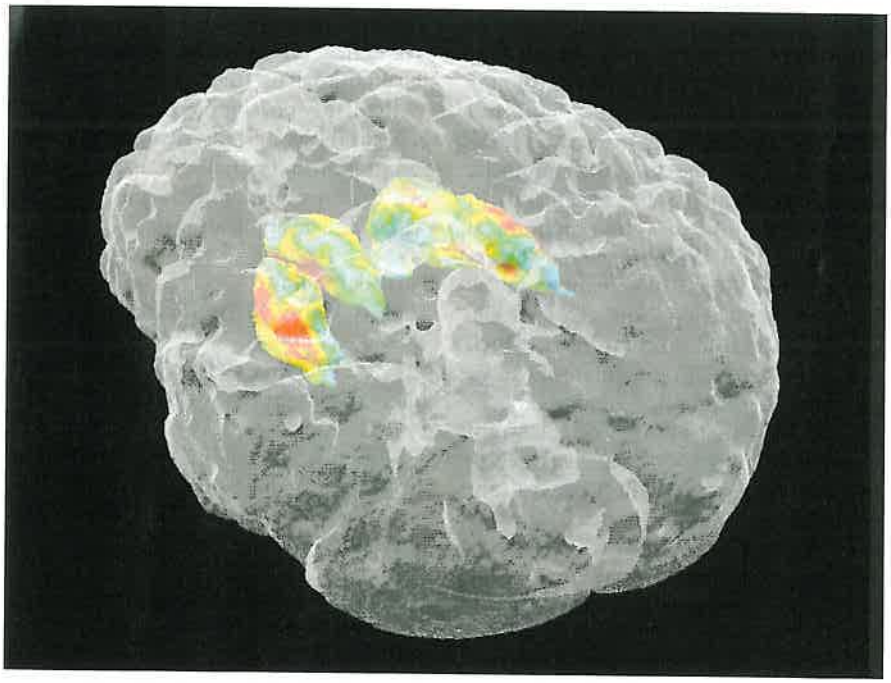

Fig. 3 Coregistrated 3D image of the brain and basal ganglia. The brain image was obtained from the MRI study, while basal ganglia image was created as a result of the PET study of the metabolic rate using F-18 FDG (Courtesy of PET Laboratory at Mount Sinai Medical Center, New York).

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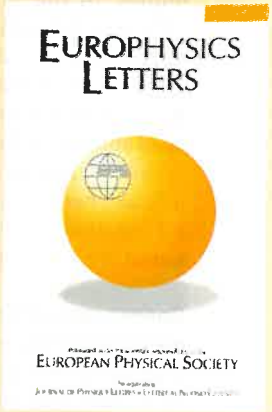

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volve systematic search, symbolic representation or global optimization techniques. In the three-dimensional case (3D), edge detection techniques match the images by minimizing the MSE distance between the surfaces of an anatomical structure visible on both modalities (e.g., head and hat method).

Potential use in medical imaging is significant, because in most instances edge information is the only common feature found in each image.

Optimization of a similarity measurement as a registration method

The goal here is not the extraction of features but rather transforming one of the images and measuring the similarity between images until, the best fit is achieved.

Registration is usually performed by optimizing a similarity criterion, such as a correlation coefficient, a correlation function, or a sum of absolute differences. However, in some situations using these similarity measurements for the registration of images may lead to misregistration. The reason for this is that criterion values may not take into account variations in the amount of contrast medium during angiography or the presence of a tumor in only one image. This class of method usually works well with the images from the same modality, but it is not as useful for registering the images from different modalities because the pixel intensity values are usually not related in different modalities.

The above methods have been implemented on X-rays, radionuclide (SPECT and PET) scans, CT scans, ultrasound, and MRI images. Registration parameters used have usually been translation, rotation, gray-scale and spatial scaling; in some cases, it is necessary to include more parameters such as shear and warping. A priori information, usually as landmarks, has been used in almost every instance to extract information relevant to registration. Only in simple cases, for which images are very similar, has the preprocessing been of little importance. The choice of the applied method usually depends on the existence of features in medical images, such as neat contours.

In clinical practice the methods are usually combined. In Fig. 1 are shown the sagittal MRI, SPECT, and the combined head sagittal slice of the same patient. The lesion on the top of the scull is visible in both modalities, but is much more enhanced on the composite image. The MRI and SPECT images were centered and oriented by using center of gravity and principal axis. This was followed by extracting the edges that are used to size the images. The final stage was to use the control-points in fine-tuning in the matching process. The point sources were made by filling capillary tubes with a drop of concentrated solution of Tc-99m and copper sulfide. The markers were about 1x1x1 mm. These point sources were on the patient's head. The activity was strong enough to be visible in the SPECT image, but weak enough not to contaminate the SPECT brain image. For MRI imaging, copper sulfide is a contrast medium. The point sources were visible in both modalities, and matching the control points was performed manually.

Most errors, which propagate through the matching process, are due to sample size, imperfection of the acquisition system, noise and interpolations used. Accuracy of the registration process tested in the phantom studies has shown that is better, or at worse, equal to 2 mm.

Visualization

After matching, a problem of visualization of the composite image occurs. It is not clear how to create the composite image, i.e. how to combine images of the different modalities in the process of creation of a single composite image. More precisely, the question is what should be the value in each image location, i.e. in each pixel in the composite image. The main problem in creating a composite image is how to retain information from both individual images in addition to giving correlation information of the functional (SPECT and PET) and anatomical (MRI and CT) features. The way of creating the composite image depends on the clinical demands. In certain situations retaining anatomical structures in the MRI image may be essential, while SPECT information may be barely visible. The opposite may be desirable in some other situations in which functional (SPECT) information can be pasted on barely visible anatomic background provided by MRI or CT study. Usually, MRI (or CT) image is scaled to one color range and a SPECT image to another. A very attractive approach is to keep the MRI (or CT) image black-and-white as an anatomic template, while making the SPECT image transparent and colored (Fig. 2). The new techniques of 3D presentations using different shadings and transparencies can also be utilized in the visualization (Fig. 3).

Future work involves producing better markers that would be visible in both modalities, i.e. SPECT-MRI and SPECT-CT studies. The next problem is placing the markers on the patients. They can be attached directly to the patients skin, as we did, or face masks and holders can be designed and used. Such masks and holders are usually part of the patient immobilization system, which allows reproducible positioning. There are several companies making facial masks and plastic holders, but some additional engineering may be necessary for modification for a particular application. These masks and holders should also be transparent to the image modalities used, which is obviously not an easy task to achieve.

In addition to the use of different scales of chromacity and intensity, as well as hue and saturation in the creation of a composite image, some other approaches seem to be worth trying. One promising method consists in creating a composite 512x512 image from two 256x256 images. In the composite image each second pixel can contain information from the MRI image and the rest can be filled with SPECT image values. It will be interesting to investigate other combinations in creating combined images from the value of each pixel in individual modality images.

In conclusion, image registration has been used in many clinical situations; radiotherapy, tumor, stroke, blood flow and other diagnostic procedures, as well as in plastic and cranio-planar surgery. Mostly, image registration was applied in merging the functional SPECT or PET data with anatomical CT and MRI images, providing additional useful clinical information. With further development of the computer technology and physical methods for registration and visualization, medical image fusion will definitely find an even wider clinical application.

Further reading

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'Recent developments in both experimental and computational techniques are leading to a greater understanding of the liquid state at the microscopic molecular level. The following three articles, in describing some of these advances, extend and update the coverage of activities in the area of liquids that was presented in the Liquids Special Issue, EPN 30/3.'

Reactive liquids from first principles

Michiel Sprik[1] and Michele Parrinello[2]
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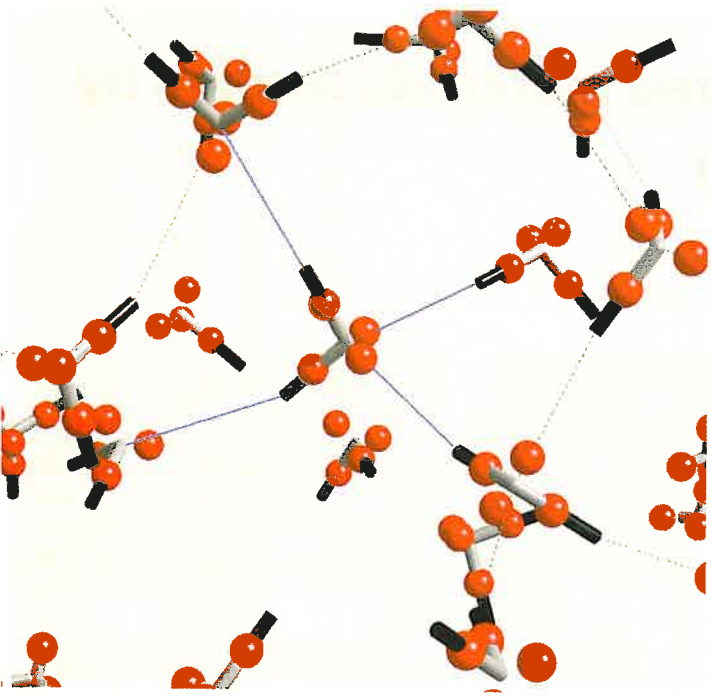
[2] Max-Planck-Institut für Festkörperforschung, Germany

Modelling and computer simulation have played a vital role in our understanding of liquids. The use of numerical methods has enabled us to characterize and quantify the finite temperature fluctuations which stabilize the liquid phase and distinguish it from the solid state. Dynamical disorder is also the decisive factor that makes liquids a suitable medium for chemical reactions. Diffusive and reorientational motion gives solvent molecules the freedom to make way for solvated reactive species allowing them to assume the often highly specific configurations required for a successful reactive encounter. Polar solvents have the further crucial function of assisting in the separation of charged products. An all important example of a polar solvent is, of course, water. What is unique for this most famous among solvents is the ability of water molecules to form strong hydrogen bonds to ionic or polar solutes and at same time maintain hydrogen bonding to fellow water molecules in the surrounding solvent. Multiple hydrogen bonding is the explanation why water is capable of stabilizing ionic species that hardly exist anywhere else. However, the tendency of water to directly participate in a reaction, either as reactant or catalyst, makes aqueous reactions complex and difficult to control. This is the reason that water, in fact, is one of the less popular solvents in organic chemistry laboratories. Living organisms, on the other hand, have learned to exploit these properties and water is the preferred solvent in biochemistry.



›shot of an initio MD simulation of liquid water. The H_2O geometry is :ated by wire frames with black for H and gray for O atoms. The blue ; are hydrogen bonds. The red balls are a representation of the ıntaneous (adiabatic) electronic ground state. They are the centres of lized (Wannier) wavefunctions[3] with an occupation of two electrons ;tate. Each molecular frame has four of these centres attached to it, esponding to the valence states of that particular molecule. This esentation was employed by Silvestrelli and Parrinello[2] to compute nolecular dipole moment in the liquid(3.1D).

Computer modelling has already made essential contributions to unravelling the complexity of aqueous solutions. In particular it has helped us rationalizing the activity of biomolecules. Numerical simulation is certain to play a similar role in the study of reactive solutions, such as water at non-neutral pH. However, owing to the lack of reliable force fields, aqueous chemistry has eluded treatment by atomistic modelling so far. This situation is rapidly changing now as a result of advances in *ab initio* Molecular Dynamics (MD) methods. This new technique in computational chemistry combines the Density Functional Theory (DFT) approach to electronic structure calculation with simulation of finite temperature dynamics, thus avoiding parametrized force fields altogether.

A first priority in the application to liquids was verifying that the accuracy of DFT is adequate to describe the comparatively weak intermolecular interactions determining the physics and chemistry of these systems. For aprotic solvents, dominated by VanderWaals forces, the technical difficulties have not been fully resolved yet. For hydrogen bonded liquids, on the other hand, a class of electronic energy functionals developed by chemists specifically for the application to molecules, such as BLYP, was found to be able to stabilize liquid conditions at ambient temperature yielding structural and dynamical properties in excellent agreement with experiment[1, 2]. Using this approach Silvestrelli and Parrinello determined the effective molecular dipole moment in liquid water[2]. The value they obtained is 3.1D, almost the double of the 1.85D in vacuum. This result is a good illustration of how *ab initio* MD can be used to obtain data that cannot be directly deduced from experiment. Also from a more technical point of view this computation represents a major step forward. It required overcoming the difficulty of identifying molecular entities in the collective extended DFT electronic ground state which makes no such distinctions. Thus, by using a localization

scheme[3] Silvestrelli and coworkers succeeded in recovering the molecular description of the liquid.

The encouraging results for pure water gave the green light for a series of *ab initio* MD applications to simple acidic and basic solutions. A milestone here was the detailed examination of the excess proton in water by Tuckerman et al.[4] which contributed to resolving the old controversy about the role of the $H_5O_2^+$ (Zundel) and $H_9O_4^+$ (Eigen) cation. When these ions are viewed embedded in the hydrogen bonded network of the surrounding liquid, they turn out to be two phases of the same fluctuating complex. The simulation showed that the dynamical rearrangements in the pattern of hydrogen bonds driving the interconversion of these two structures are also the key to the explanation of the structural (Grotthuss) diffusion of the solvated proton. Subsequent investigations of two prototypical strong aqueous acids, sulphuric and hydrochloric acid (Laasonen et al.) are extensions of the excess proton work and confirmed that DFT estimates for the pH of these solutions are in the correct range of values. Recent path integral *ab initio* MD calculations by Marx et al., addressing the role of proton quantum effects, have validated and refined this picture[5]. Weak acids pose more of a technical problem, because of the highly activated nature of proton release. A first attempt to a determination of the pK of water resulted in a value of 13 (Trout et al.).

Ab initio MD is ready to be employed in investigations of reaction mechanisms in aqueous solution. Examples of studies that have been recently completed, or are currently under way, concern acid catalyzed addition of water to a carbonyl group (Meijer et al.), ligand substitution of a cisplatin complex (Carloni et al.) and the conformation of peroxynitrous acid (Doclo et al.). In all of these cases the *ab initio* MD clearly exposed the concerted nature of the processes in aqueous chemistry. Looking ahead, an important task for the near future will be the quantitative characterization of reactivity in water and other protic solvents. In particular the first principle computation of pK, redox potentials, activation energies and, ultimately, reaction rates is a major challenge. A further topic which is already the subject of intensive ongoing research is the development of methods for the evaluation of the response functions determining optical and NMR spectra of liquids with as a first result a fully DFT based computation of the infrared absorption spectrum of liquid water[6]. *Ab initio* molecular dynamics may very well the only way to deal with the level of complexity prevailing in liquids in which the electronic states are strongly coupled to thermal disorder.

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The dynamics of disordered materials studied by inelastic x–ray scattering

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A present challenge in condensed matter physics is the understanding of the microscopic dynamics of liquids, dense fluids and glasses. The collective dynamical properties at wavelengths approaching inter-particle distances, d, are intimately related to the determination of many macroscopic quantities as, for example, thermal expansion, thermal conductivity, specific heat and viscosity. In particular, it is of great interest to study the collective dynamics in the transition region bridging the long wavelength and long time hydrodynamic behavior, where a density fluctuation in the system can be described as a small perturbation of an isotropic continuum in thermodynamic equilibrium, and the single particle regime, where the dynamics is considered at very short length- and time-scales and can be pictured as that of a free particle among successive collisions. This intermediate region is particularly relevant because it reflects the properties of the particle-particle correlation function at distances approaching the inter-particle distances and at times typical of density fluctuations at the inter-particle level, i.e. in the pico-second range. This dynamics can be investigated by the experimental determination of the dynamic structure factor S(Q,E) - the time and space Fourier transform of the particle-particle correlation function - in the momentum (Q)-energy (E) regions of 0.1 to 20 meV and 0.01 to 10 nm-1.

In crystalline systems, this is one of the most successful applications of inelastic neutron scattering (INS) [1]. In disordered systems, the neutron technique has been successfully used to investigate the dynamics at momentum transfers typically larger than 10 nm-1 [2]. At wavelengths longer and comparable to d, due to the kinematics conditions of available neutron spectrometers, serious difficulties are found to probe acoustic excitations with speeds of sound, v, larger than v@1500 m/s. The typical values of v in liquids and glasses are either comparable or considerably larger than 1500 m/s, and this is the main reason why, in disordered systems, a comprehensive experimental picture of the high frequency collective dynamics is still missing.

Inelastic x-rays scattering (IXS) with 10π20 keV incident energy is, in principle, a complementary method to INS for studying acoustic modes at small momentum transfers. In fact, providing sufficient energy resolution and incident beam intensity, one can access the desired phase space.

The IXS technique is a recent development, made possible by the high spectral flux density of the new synchrotron radiation sources, and by new ideas in x-ray

optics using Bragg diffraction from perfect crystals. This combination has allowed the construction of a unique IXS spectrometer, now in routine operation at the European Synchrotron Radiation Facility in Grenoble. Its main success lies in its capability to measure S(Q,E) at momentum transfers, Q= 0.5π30 nm-1, with basically unlimited energy transfer, and with an energy resolution of 1.5±0.2 meV.

Thanks to the new instrument, it has been possible to begin to address issues on the high frequency dynamics of disordered materials as the following ones [3]:

1. Collective excitations have been discovered in all the investigated liquids and glasses at wavelengths approaching d. The Q-dependence of their energy values testify that they are the short wavelength evolution of the hydrodynamic sound mode. Important deviations are observed, however, from phonons in crystals. In particular, their Q-dependent broadening suggests that these modes deviate from the plane waves found in crystals. At present one is trying to relate these deviations to the behavior of the sound excitations observed in the long wavelength limit, and, in glasses, to the anomalous specific heat and thermal conductivity found at low temperatures. In this respect, one would like to understand, when compared to the Debye behavior of the corresponding crystal, the origin of the excess specific heat at low temperature and the excess density of vibrational states found in glasses.

2. The interference between density fluctuations and microscopic structural relaxation processes have been clearly identified in glass-forming liquids as glycerol, ortho-terphenyl and in hydrogen bonded liquids as water. These studies have allowed determining experimentally, as a function of temperature and Q-transfer, important parameters as the infinte-frequency sound velocities. These parameters enters in the modeling of the S(Q,E) of a liquid, and in the current efforts to relate the liquid-glass transition to a change in the ergodicity of the system [4].

The possibility to contribute with an experimental method to the understanding of such problems is creating a worldwide interest towards the IXS technique, and important results have been already documented [3]. In this respect, in fact, it is quite reasonable to expect important contributions not only on the high frequency dynamics of liquid systems, but also on glassy materials, on supercritical fluids, on complex chemical aggregates, on systems of biological interest, and more generally, to understand better the collective dynamics of disordered materials.

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Metastability and Nucleation

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One of the "grand challenges" in liquid state physics is to gain insight into activated processes on a molecular level. Why is this such a challenge? First of all: activated processes are ubiquitous and important. They include homogeneous and heterogeneous nucleation of liquids and crystals, cavitation, and conformational changes of flexible molecules. In addition, activated processes often control the rate of transport in condensed phases, e.g. diffusion of polymers in porous media or transport of defects in solids. However, in order to qualify as a challenge, a physical phenomenon should not only be important, it should also be difficult to study. In this respect, nucleation scores high. The formation of a novel phase from the metastable parent phase proceeds through the formation of a "critical nucleus". Clusters of the novel phase that are smaller than this critical size tend to disappear spontaneously - clusters that are larger than critical can continue to grow into a macroscopic domain of the novel phase. The rate of nucleation depends strongly on the free energy of the critical nucleus, while its structure and composition determine the nucleation pathway. Classical Nucleation Theory makes the assumption that nuclei of the novel phase are small spherical "droplets" that have the same properties (density, surface tension etc.) as the bulk phase.

Unfortunately, direct knowledge of the critical nucleus is limited. The problem is precisely that the formation of a critical nucleus is a fleeting event. Experiments can probe the rate at which crystallites form in a supersaturated solution, but by the time these crystallites are observed, the critical nucleus stage is long past. It is possible to estimate the size of the critical nucleus from experiment but, to my knowledge there are, at this stage, no experiments that can directly image the critical nucleus in any nucleation process

At first sight, it would seem that the problems for simulation are even worse: events that are rare in a system of 1023 particles are much rarer still in a system of only a few thousand, or even a few million, particles. Fortunately, in simulations we are not forced to wait for a rare event to happen. Using the techniques pioneered by Charles Bennett and David Chandler [1], we can make them happen and still get an accurate estimate for the nucleation rate in an unperturbed system. Using this approach, it is now possible to simulate the early stages of homogeneous (or heterogeneous) nucleation. The simulations that now start appearing [2,3] reveal that the structure and free energy of the critical nucleus often deviate significantly from the predictions of Classical Nucleation Theory. It seems likely that further study, both numerical and experimental, will help us to understand how to control (enhance/suppress) nucleation of specific phases or, more generally, how to steer activated processes.

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Wolfgang Pauli's 100th birthday

A personal view by Prof. C. P. Enz, W. Pauli's last assistant

According to a recent inquiry by Physics World concerning the ten most important physicists ever, Wolfgang Pauli does not belong to them. For those of an older generation for whom Pauli was "the conscience of physics" this comes as a surprise. But it shows perhaps that both his exclusion principle and his neutrino idea – which at first were hard to swallow – have since become household words, while his proverbial wit is lost to a generation communicating by e-mail.

So who was this man? Pauli was born just 100 years ago on 25 April 1900 in Vienna. His father Wolf Pascheles came from a well-known Jewish family in Prague where he studied medicine with one of Ernst Mach's sons and took physics classes from Mach himself. As a young medical doctor Wolf Pascheles settled in Vienna in 1893, took the name of Pauli, was baptized Catholic and married in 1899. Mach, who accepted a chair of philosophy at the University of Vienna in 1895 accepted to be godfather for Pauli's son Wolfgang.

At age 13 Wolfgang read Mach's famous Mechanics that the latter had given him with a dedication. At 18, before becoming a student of Arnold Sommerfeld in Munich, Pauli published his first paper on general relativity. Sommerfeld, who saw that this young man could not learn much more from him, let Pauli write a review on relativity in the Encyklopädie der Mathematischen Wissenchaften. This almost perfect work published in 1921 (still a standard reference today) made Pauli famous. Pauli's biting wit was already well-known. When in 1922 Paul Ehrenfest – who had also written an Encyklopädie article – met Pauli, he said to him : "Pauli, I like your Encyklopädie article better than yourself", to which Pauli answered : "How strange, with me it is just the opposite!". In Copenhagen where Pauli spent the year 1922/23 at Bohr's institute he became a good friend of Bohr's assistant Hans Kramers who remarked : "Pauli, your heart is better than your wit!".

The following six years Pauli spent in Hamburg where three fundamental ideas were born. First, Pauli introduced the fourth quantum number of the electron that later was recognized as the spin. Then, making use of this fourth quantum number, he formulated the exculsion principle which could explain the periodic system of the elements and later was recognized to be responsible, quite generally, for the stability of matter. But even before that he had postulated the existence of a nuclear spin in order to explain the hyperfine anomalies in the spectra. Hamburg also was the scene of Pauli's discussions with Otto Stern. But in spite of this friendship Stern would not let Pauli enter his laboratory – because of the Pauli effect. For, it was said that every time Pauli entered a laboratory something went wrong. Pauli believed in it and was amused.

In 1928 Pauli became the successor of Peter Debye at ETH, the Swiss Federal Institute of Technology in Zurich. He asked for only one condition, namely to have a research assistant. Pauli stayed in this position to the end of his life, and at the same time the assistantship was occupied 12 times. The first of Pauli's assistants was Ralf Kronig. With him and with his experimental colleague Paul Scherrer, Pauli explored the night life of Zurich. The second assistant, Felix Bloch, later received the Nobel Prize. Of the third, Rudolf Peierls from Berlin, Pauli said : "Peierls, he speaks so fast, when one understands what he has said he already claims the contrary". Hendrik Casimir, the fourth assistant, later became a director with Philips at Eindhoven. When Pauli then heard that one was going to Holland he would say : "when you see Casimir, call him 'Herr Director', for, that vexes him!". His fifth assistant, Victor Weisskopf had the misfortune to publish the result for the self-energy of the electron with the wrong sign, whereupon Pauli mused : "I should have taken Bethe!" For, Hans Bethe was an accomplished calculator, but he worked on the solid state which displeased Pauli. Apparently, later assistants came away with milder jugements – until the last, myself, who at the beginning ignored that organizing tickets for classical concerts for Pauli and collaborators was one of the assistant's tasks. One day I had in my mail a card from a bar in downtown Zurich, on which Pauli complained that he had missed a concert with Isaac Stern and which closed "with the hope of better times".

There was also a more hidden side to Pauli's personality. At the beginning of his professorship at ETH he developed a neurosis which manifested itself in the fact that, as he told his friend and colleague at the University of Zurich, Gregor Wentzel, "with the women things don't go at all". In fact, a first marriage failed after less than a year. It was during this period, however, that Pauli had the idea of the neutrino as the only way out of the problem of an energy deficit in the beta-decay. – In 1932 Pauli met the famous psychiatrist Carl Gustav Jung in Zurich which resulted in a psychoanalysis during three years. Shortly afterwards Pauli remarried, this time durably. Jung had immediatly seen that Pauli had frequent dreams containing a wealth of archaic material that caught Jung's keen interest. From this time on Pauli wrote up his dreams, and a fascinating exchange of ideas developed between Pauli and Jung which lasted almost to the end of Pauli's life.

The war years, from 1940 to 1946 Pauli spent in the United States at the Institute for Advanced Study in Princeton. There he published the famous spin-statistics theorem which probably constitutes his most brilliant paper. It was in Princeton that in November 1945 the news of his Nobel Prize for the exclusion principle reached him. But Pauli went to Stockholm only in 1946, on the way back to ETH in Zurich. Instead there was a great celebration in Princeton where Einstein unexpectedly rose for a toast, in which he designated Pauli his spiritual son and successor at the Insitute for Advanced Study.

Back in Zurich Pauli's institute became a world centre of quantum field theory. Moreover Pauli, influenced by his dreams, also devoted much time to the archetypal background of physical ideas. This he first exemplified with Johannes Kepler, on whom he wrote an important essay, and went on to physical notions in general. In the mid-fifties, again guided by dreams, he turned his attention to symmetries and wrote the important paper on the CPT-theorem This was like a presentiment of the sensational news in January 1957 of parity violation in weak decays. The last year of his life Pauli let himself be carried away by the "world formula", a non-linear Dirac equation, of his life-long friend Werner Heisenberg who had succeded in building into it an internal symmetry. But realizing the shortcomings of this approach, Pauli soon withdrew again in disappointment. And after a short struggle with cancer he died in Zurich on 15 December 1958.

Pauli

Wolfgang Pauli and Modern Physics

On the occasion of the centenary of the birth of Wolfgang Pauli, the ETH Zürich is paying tribute to one of the most outstanding physicists of the 20th century with a very interesting exhibition. It presents the most important stages in the life of the scientist along a chronological chart and explains his most significant contributions to theoretical physics.
This exhibition was first presented in April 2000 at the ETH and it will be on display at CERN from 17 August to 26 September 2000.
The mobile exhibition can be rented for display by interested organisations at very advantageous conditions. For more information on its availability, please contact:

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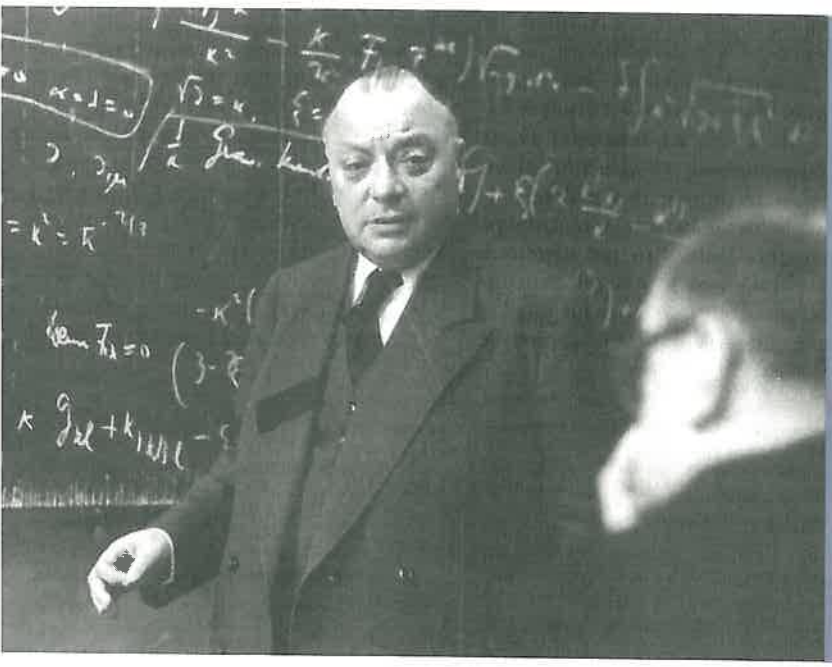

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Determination of the gravitational constant G by means of a beam balance

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At the end of 1999, an international committee (the CODATA) decided to increase the uncertainty of the accepted value for the gravitational constant from 128 ppm to 1500 ppm. This remarkable step of increasing the uncertainty instead of decreasing was made to reflect the discrepancies between recent experiments. These experiments were originally performed with the aim to improve the accuracy of G, since even before increasing its uncertainty the gravitational constant had a very large uncertainty compared to that of other fundamental constants. The confusion started in 1995 when three groups published their results, which span a wide range of 0.7% (see Figure 1) – for reasons which remain unknown. The device most often used for measuring G is the torsion balance of Cavendish in one of its various forms, and 1998 was the 200 anniversary of the publication of his paper entitled "Experiments to determine the density of the Earth".

In the present experiment, a completely different and conceptually very simple approach is chosen. Using one of the world's most precise beam balances, the weight difference of two test masses is changed by the gravitational force of two movable tanks filled with a liquid of known density and measured with a sensitivity of 10^{-11}. From the measured change in weight difference, G is computed. Test measurements with one ton of water have been made, and measurements with 13.5 tons of mercury are currently in progress. The idea for this experiment arose from our earlier gravitation experiment at the Gigerwald storage lake, in which the stored water was used to measure G at an effective distance of approximately 100m. This experiment set more stringent constraints on the strength and range of a conjectured fifth force.

General Principles

For the new experiment, the "lake" is brought into the laboratory. As shown in Figure 2, two test masses are suspended on separate wires such that they occupy different levels on the same vertical axis. The test masses are alternately hung on the beam balance, and their weight difference is determined. Effects that are equal for both test masses cancel, such as tidal forces and zero-point drifts of the balance. The weight difference is modulated by the gravitational force of two field masses, which are moved between two positions. In the first position, the field masses are located between the test masses, while in the second, the test masses are between the field masses. These positions are alternated many times, and the averaged change in the weight difference is the gravitational signal from which G is computed. In this way, all disturbing effects which are independent of the field mass position cancel out.

Each field mass is a cylinder with a central hole, implying that its gravitational force has extrema close to each end of the hole. Since the field masses are moved such that the test masses are at an extremum, the gravitational force acting on a test mass is to first order independent of the test mass position, reducing the required accuracy of the distances between the field and test masses. In order to achieve a 10ppm relative uncertainty in G, the distances must be known with an accuracy of 0.1mm. This is contrast to the accuracy of approximately 0.001 mm required without this extremum. To take full advantage of the extremum effect, the dimension of the field masses, mainly the inner diameter, must be measured very accurately. But the diameter of a hole in a solid object is easy to measure compared to the distance between two bodies, one of which is hanging on a thin wire.

A liquid is employed for the field masses, since for large volumes the density of liquids is more homogeneous than that of typical solids, and mercury is used because of its high and well-known density. Measurements made with water allow an important consistency check, and the effect of the tanks can be measured with empty tanks.

Experimental Setup

The experiment is located in a 4.5m deep pit inside an experimental building at the Paul-Scherrer-Institute in Villigen, Switzerland. This pit has thick concrete

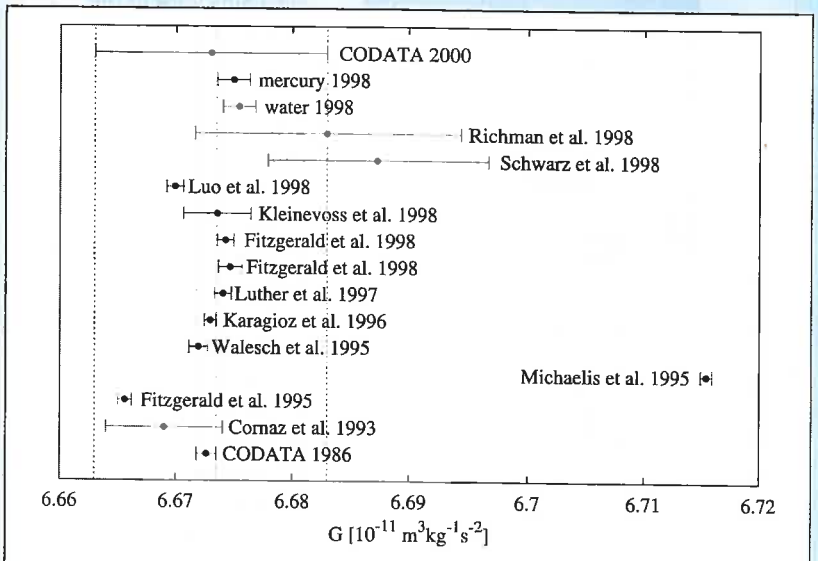

Fig 1 Recent measurements of the gravitational constant. The data points labelled "mercury" and "water" are the preliminary results from our experiment. The measurement made by Cornaz et al. is a result from our previous experiment at the Gigerwald storage lake, and the point labelled "CODATA 2000" is the presently accepted value.

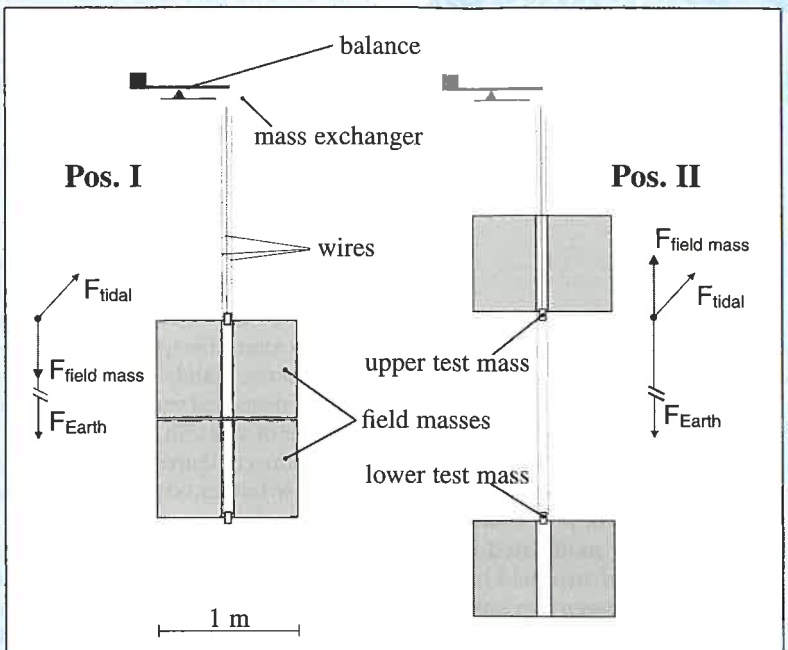

Fig 2 Schematic view of the mass arrangement. The test masses are alternately connected to the balance by means of the "mass exchanger" and their weight difference is determined. The field masses are moved between the two positions I and II. The forces on the upper test mass due to the Earth, the field masses and tidal forces are plotted for the two field-mass positions on the left and right of the figure.

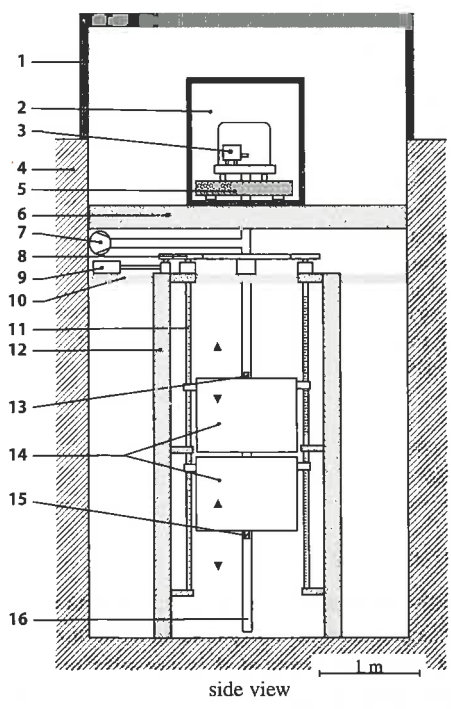

Fig 3 Side view of the experimental set-up.
Legend:
1: enclosure
2: thermally insulated chamber
3: balance inside the vacuum chamber
4: concrete walls of the pit
5: granite plate
6: steel girders supporting the balance
7: vacuum pumps
8: gearbox
9: motor
10: working platform,
11: spindle
12: steel pillar
13: upper test mass
14: field masses
15: lower test mass
16: vacuum tube

walls and good mechanical and thermal stability. A schematic view of the experiment is shown in Figure 3. The experiment extends over two rooms, separated by an insulating working platform. The upper room contains the beam balance, the electronics and the auxiliary equipment, and the lower part houses the field masses. Both parts are thermally and mechanically insulated from each other. Special care is taken to maintain a high temperature stability, each room having its own temperature stabilization system.

The balance is situated on a granite plate, which in turn is supported by two steel girders fixed to the walls of the pit. In order to avoid errors due to convection and buoyancy, the balance is operated in vacuum at a pressure of 10^{-4} Pa. At atmospheric pressure, the temperature stability would have to be in the mK-range in order to reduce to a tolerable level an apparent mass change due to thermally driven convection currents. The vacuum system consists of a 0.5m diameter chamber housing the balance and a long tube enclosing the test masses. In order to minimize magnetic forces, the 1kg test masses are made of copper.

The tanks employed for the field masses are made of stainless steel, each one 700mm high with a volume of 500 liters. The corresponding 6.8 tons of mercury result in a gravitational signal of approximately 0.8mg. To obtain the same signal with water instead of mercury, more than 2000 tons of water would be necessary. For the movements of the tanks, a robust tower was built, with the tanks supported by ball-bearing nuts on three spindles with left- and right-hand threads. The spindles are coupled by a gearbox and driven by a synchronous motor. With this construction, a positioning precision of better than 0.01mm is achieved.

The balance is a modified version of a commercial product of Mettler-Toledo (AT1006 Comparator), specifically designed for the high precision comparison of 1kg standard masses. Such balances are needed by the bureaus of standards, since the kilogram is still defined relative to a standard object. For the puposes of the experiment, the resolution of the balance was improved from 1μg to 0.1μg. Of considerable importance for the high-precision comparison of weights are a temperature stability in the mK-range and a careful exchange of the masses.

Measurements and Results

The measuring procedure is fully automated and computer-controlled. A mea-

suring cycle consists of a determination of the weight difference in both field-mass positions and takes about 8 hours. The balance is calibrated every four hours using a 1g standard mass.

Initial tests of the experimental setup were made with empty tanks and with each tank filled with 500kg water. After a measuring time with water of 20 days, a gravitational signal of approximately 110μg was measured with a statistical uncertainty of 9 ng (one standard deviation). To determine G, the gravitational force from the field masses on the test masses was computed by numerical integration. The results with full and empty tanks were found to be consistent to within the statistical uncertainty. The result of this test is

$$G_{water} = (6.6754 \pm 0.0005_{stat} \pm 0.0014_{sys}) \times 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$$

The first error is the statistical uncertainty and the second the systematic uncertainty.

During winter of 1997/1998 the tanks were filled with mercury. The mercury was purchased in 400 flasks, and the total mass of mercury in the tanks was determined, by weighing the full and the empty flasks, to be 13 520.635(27)kg. The amplitude of the gravitational signal is now 785μg, and a portion of the data for the modulated weight difference is plotted in Figure 4. During the measurements, a variation in the value of G of approximately (80 ppm was found, which is at present not satisfactorily understood. This variation appeared on a time scale of weeks, but so far no systematic behind it as been found. A preliminary result is plotted in Figure 1, in comparison with recent published measurements. The measurements made with water- and with mercury-filled tanks are consistent within their assigned uncertainties of 220 ppm, which are believed to be dominated by a nonlinearity of the balance. So far, only an upper limit for this nonlinearity has been estimated, but a precise experiment to investigate the linearity of the balance is in preparation. It should be mentioned that a nonlinearity would affect both of the G-values and their uncertainties in the same way. This is the reason why the measurement made with mercury has not yet resulted in a smaller uncertainty than the water measurement. This result, which differs from the presently accepted value by approximately two of our standard deviations, represents the current state of our experiment. Additional improvements and investigations will be made, and we are optimistic of reaching the design accuracy of the experiment of 10 ppm.

On the occasion of the 200th anniversary of the Cavendish experiment, a meeting was held in November, 1998, in London. At this meeting the preliminary results of several experiments, with uncertainties between 2000 and 100 ppm, were presented (see further readings). They are all in rough agreement, and their mean tended to exceed the at this time accepted value (see CODATA 1986 in Figure 1). Due to the variety of measurement techniques used, each with its own particular systematic effects, it is clear that progress in the accuracy and the confidence in the value of G is possible.

Acknowledgments

We thank the Paul-Scherrer-Institute for helpful support. We wish to thank Mettler-Toledo, especially M. Baumeler, for providing the balance and for mass determinations. We gratefully acknowledge the excellent work of the machine shop of our institute. We also thank E. Holzschuh for helpful discussions. Further, we want to thank all the metrological institutes that have helped us. This experiment is supported by the Swiss National Science Foundation, the Dr. Tomalla Foundation and the Scientific Research Foundation of the University of Zurich.

Further Reading

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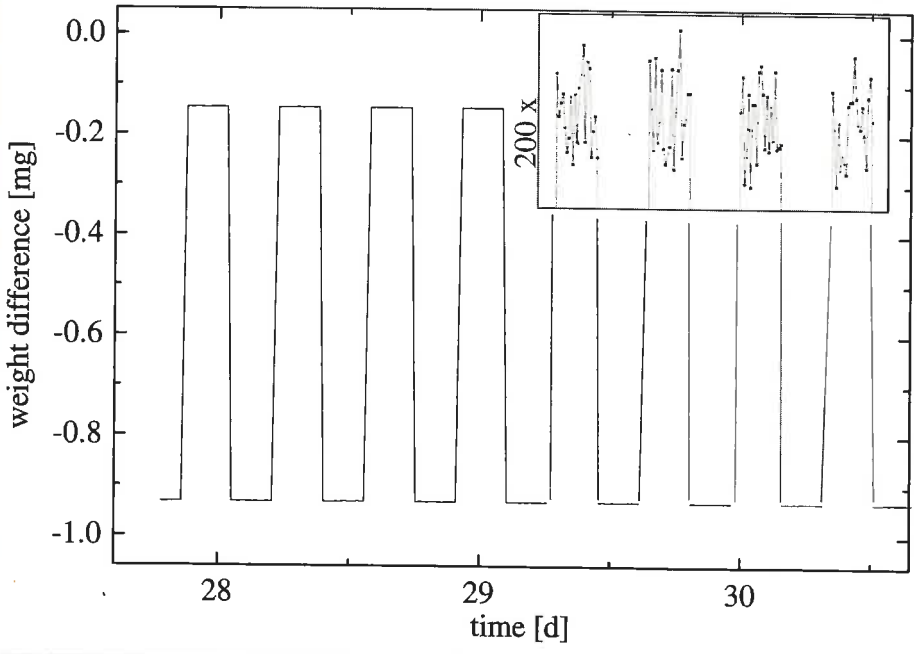

Fig 4 Modulation of the weight difference due to the gravitational force of the mercury-filled tanks. The inset shows the weight difference enlarged 200-fold for the field masses in position I (tanks together).

Highlights of Molecular Photodynamics

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The recent workshop "Photodynamics from isolated molecules to condensed phases" (La Havana, February 13-20, 2000) masterfully organized in La Habana (Cuba) by Prof. Jesus Rubayo-Soneira and his colleagues from the Instituto Nacional de Ciencias y Tecnologias Nucleares, was a unique encounter between South and North American scentists and European scientists working in the fields of molecular and chemical physics. In addition to excellent presentations, the workshop also strengthened and broadened the links and communication between physicists from South America on one side and Europe and North America on the other side. It was sponsored by the EPS (through the Group of Physics for Development and the Division of Atomic and Molecular Physics, section of Chemical Physics) and by the International Center for Theoretical Phyics (Trieste). About 70 participants from 14 countries attended, including a large number of local students for whom it was a unique opportunity to make contact with foreign scientists.

The meeting organized in sessions spanning from isolated molecules and building up in complexity all the way to biological systems and condensed phases, was not only tutorial but also stressed the relationships that exist between conceptual approaches in treating different systems, as well as reflecting the modern trend to treat increasingly complex systems while still referring back to simple systems. The results presented during the workshop also reflected how fundamental approaches provide answers to problems of current practical interest. The meeting opened with fundamental problems of relevance to combustion, atmospheric chemical physics, and astrophysics, both theoretical and experimental point of view. The theory aspect stressed the input of high-quality quantum chemical calculations in combination with the use of advanced computational tools to simulate dynamics.

In aggregating more atoms to a molecular species, such as in the case of van der Waals clusters, both the energetics and dynamics gradually evolve. The energetics change because generally, the solvation properties of the ground and excited states shift their position with respect to the free species. This has an effect on the threshold for chemical transformation as shown during the meeting in the case of metal atoms in neutral and ionic clusters. However, the increase in the number of degrees of freedom opens new channels for energy flow and intramolecular vibrational redistribution (IVR), sometimes accompanied by vibrational predissociation and/or reactivity, becomes important. As such, studies on simple van der Waals molecular complexes help understand similar effects encountered in the condensed phases. The different presentations on this topic showed the fine details of the IVR process, particularly the role of quantum effects.

The debates on clusters also pointed to the importance of studies of the dynamics in real time using ultrafast laser spectroscopy. Examples were given of how both conventional and femtosecond spectroscopy, quantum-chemical calculations, molecular dynamics and wave packet simulations can deliver the full picture in the case of the more complex metal clusters.

Molecules on surfaces provide another elegant extension of the gas phase studies in terms of increased complexity. The need to clearly interpret the data from surface diagnostic experiments necessitates the development of new models as shown in the case of the vibrational spectroscopy of adsorbates on surfaces using inelastic electron scattering and helium atom scattering.

Dynamics of biological systems is currently a very hot topic. We now realise that (static) structure alone is not sufficient to understand. It is essential to "see" the structure as it evolves in time, if possible in the corresponding physiological medium. Light is an essential ingredient to drive a large number of biological functions. It can also be used to deposit a well defined amount of energy in specific coordinates and to observe the evolution of the system. To reach this aim, one needs the energetics of the system and simulations of the dynamics. In the first case, we saw beautiful results on biomolecules in the gas phase which help pinpoint the details of the energy level structure of the different isomers in an unprecedented way by freeing the experimentalist from the complexity of environment effects. In the second case, a Cuban colleague gave a remarkable lecture on how simulations and molecular mechanics studies can be combined to gain insight to different substrate-specificities on enzymes.

The meeting ended with talks on the condensed phase stressing the role of the environment, in dissipating energy and modifying the outcome of a chemical reaction as compared to the gas phase. High quality calculations of the role of non-adiabatic effects.in condensed phase photochemical reactions were reported at the meeting.

The meeting stressed the importance of cross-fertilizing the approaches developed for a given class of system or phenomena to other systems or phenomena as shown by the theoretical approaches. No doubt that the photodynamics of molecular systems is a lively field and the Havana workshop fully reflected this in embracing the various domains (reactivity, surfaces, biological systems, condensed phases) it touches.

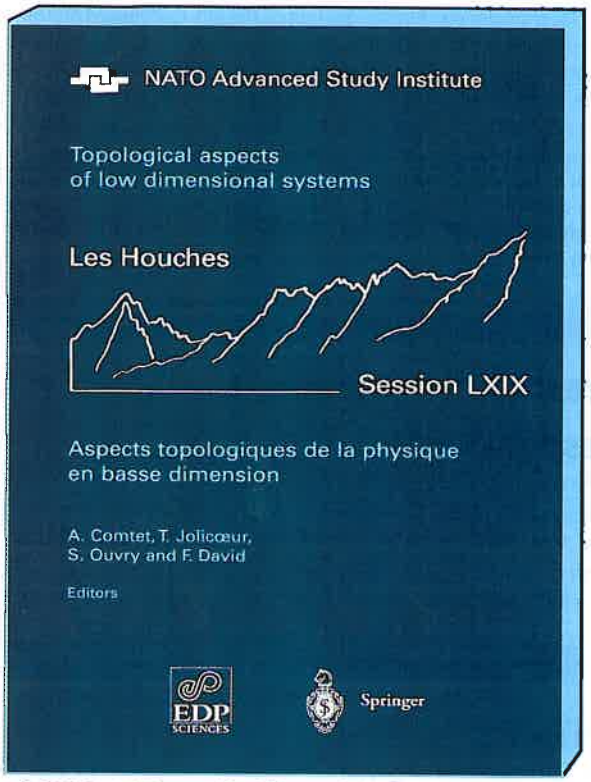
Last, to most of the participants, this workshop was a discovery, if not a revelation. On the human side, the warm welcome of our Cuban colleagues, their modesty and the perfect organization were a moving experience. The meeting took place in the marvellous XVIth century Convent of San Francisco de Asis in the heart of the old city of La Havana, now used as a primary school, reminding us that we were also here to learn. The remarkable science, the beauty of the city, the hospitality of our Cuban colleagues and the sound of the Cuban music, all magically merged to make the Workshop an unforgettable event. Many of us left with the feeling that collaborations should be initiated or strengthened with Cuban colleagues whose means for research are limited, which makes their achievements all the more impressive.

We were however saddened by the absence of our US colleagues (except one) who were refused visas to visit Cuba by the US Department of Treasury. We hope that this type of interference of politics, which is contrary to the spirit of scientific exchange, will soon disappear and that scientists will be able to meet independently of their origin.

Topological aspects of low dimensional systems

Les Houches summer school - Session LXIX

Scientific Editors: A. Comtet, F. David, T. Jolicœur and F. Ouvry



Hardbound
ISBN: 2-86883-424-8
590 pages
Prices: **860 FF**
131,10 Eur.

The notions of fractional charge as well as fractional statistics can be interpreted by a topological interaction of infinite range. So it is natural to find in Les Houches series a school devoted to quantum Hall physics, intermediate statistics and Chern-Simons theory. This session also included some one-dimensional physics topics like the Calogero-Sutherland model and Luttinger-liquid physics.

Polymer physics is also related to topology. In this field, topological constraints may be described by concepts from knot theory and statistical physics. Hence this session also included Brownian motion theory related to knot theory.

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noticeboard

IGA Election Results

The following persons have been elected to the Board of the EPS Interdivisional Group on Accelerators.

J.M. LAGNIEL (CEA, Saclay)
S.P. MOLLER (ISA, Aarhus)
A. MOSNIER (CEA, Saclay)
C. PAGANI (INFN, Milan)
F. RUGGIERO (CERN)
A.F. WRULICH (PSI, Villigen)

Nominations to the Board of the Macromolecular Physics Section of the CMD

The Macromolecular Physics Section of the EPS Condensed Matter Division will organize elections to replace three outgoing members, whose terms expire on 31 December, 2000. Nominations are invited from members of the section. Nominations including a 1/2 page cv, as well as a statement from the candidate should be should be addressed to David Lee, EPS, B.P. 2136 34, rue Marc Seguin F - 68060 Mulhouse, France. The deadline for receipt of nominations is 31 August 2000. The resulting list of candidates and ballot papers will be mailed to Section Members who will be invited to vote by the deadline of 31 October 2000.

Solar Physics Section of the JAD Election Results

At the last General Assembly of the Solar Physics Section of the Joint Astrophysics Division, Prof. Jan Kuipjers was elected as chairman, and Dr. Nicole Vilmer as secretary. Elections were also held to replace outgoing members. Elected for a 3 year are:

B. Fleck (ESA, ESTEC)
G. Poletto (Firenze, Italy)
A. Hoffman (Potsdam, Germany)
M. Carlsson (Oslo, Norway)
J. Sylwester (Wroclow, Poland)
M. Karlicky (Ondrejoc, Czech Republic)

Interested in becoming a correspondent?

Europhysics News is always looking for willing physicists to supply us with short news items covering what is happening in your field of physics or in your country.
For more information, please contact: David Lee d.lee@univ-mulhouse.fr

INTAS

INTAS has launched its call for proposals for 2000 and 2001 for collaborative research projects between INTAS members and the New Independent States of the FSU. The deadline for proposals in 2000 is 29 September 2000. For more information, please see http://www.intas.be.

In memoriam

H. B. G. Casimir 1909-2000

The EPS was saddened by the announcement of the death of Prof. H. B.. G. Casimir. Born in the Netherlands in 1909, he studied theoretical physics at Leyden with Ehrenfest, at Copenhagen with N. Bohr, and at Zurich with W. Pauli. Before joining the Philips Research Laboratories in 1942, he held research positions at Leyden. He became director of the Research Laboratories in 1946, and a member of the Philips Board of Directors in 1957. Prof Casimir became president of the EPS in 1972, and served four consectuive terms, until 1976.

L. Rinderer 1927-1999

The EPS was saddened by the announcement of the death of L. Rinderer, honorary Professor at the University of Lausanne. Director of the Institute of Experimental Physics at the University of Lausanne from 1968 to 1991, Prof. Rinderer was instrumental in designing the solid state cirriculum, organizing student laboratories, and initiating a laboratory for microanalysis. Very active as an international ambassador for physics, he headed the first delegation of Swiss scientists to China in 1980, and received, shortly before his death, the prestigious Japanese Order of the Sacred Treasure.

Secretary General's Report

IOM Benefits

Did you know that as an IOM of the EPS you can order publications from the American Physical Society at APS member rates? For an order form, and a list of journals, please see http://www.aps.org/memb/guide/prbook-recip.shtml. Other benefits include participating at APS conferences at their member rates.

IMU Collaboration

The Executive Committee has approved an agreement with the International Mathematical Union relating to Electronic Information and Communication Systems to enhance the free flow of information in their scientific fields. The EPS and the IMU will work to coherently synchronise all world-wide high quality information in Mathematics and Physics through the creation of interdisciplinary services, joint standards, e.g. in the field of metadata, and technical solutions to insure user-friendly access to information and communication in both.

Education Site and FAQ

The latest feature on the Physnet (http://www.physik.uni-oldenburg.de/PhysNet/education.html) which provides online educational resources for physics. The structure of the site allows resources to be chosen by the type of information required (for example Lecture Notes, Seminar Talks, Visualization and Demonstration Applets). After the Introductory Material the resources are listed as far as possible in broad subject areas. FAQ is a related service on the same site (http://www.physik.uni-oldenburg.de/PhysNet/physicsfaq/) provides answers to questions about physics for the public at large. We are desperately seeking volunteers to review the links provided on the Education site, and answer the questions asked on the FAQ site. If you are interested, please send your e-mail co-ordinates to David LEE d.lee@univ-mulhouse.fr

New Honorary Editor of EPJ

Dr. Allistair Rae has been appointed as the new honorary editor of the European Journal of Physics. Dr. Rae is a professor at the School of Physics and Astronomy, University of Birmingham. The EPS would like to welcome Dr. Rae. Many thanks to Prof. Lennart Samuelsson, outgoing honorary editor for his hard work and dedication.

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

For those of you willing to help with the FAQs on the EPS Education site, here is a sample of what you will be up against. (If you don't know the answer, take a look at the site.)

- What is the Quantum Mechanics aiming at?
- What is Momentum in Physics?
- Are the following points true? Is there any research going-on to disprove these things? Is there an unanimity over these things?
  1. No particle matter can ever achieve speed of the light
  2. Heisenberg's uncertainity principle
  3. Total entropy in a closed system always increases and needs external intervention to decrease the entropy in a system
- Where can I find a mathematical and narrative description of the sequence of events that generates a photon from the collision of two electrons - what are its characteristics as a photon (energy level charge etc.) and what happens to its morphology as it travels. In other words, the life of a photon.
- What is the energy transfer involved with the absorption of sound into a brick wall?
- What is Action in Physics?
- I am a French student and I am just looking for information about the physics of "Sun pool" for a school project.
- Where can I find various theories on Quantum Physics?
- What is projectile motion and what equations do i use to solve problems involving it?
- Can we use E=kq/r^2 when the charge causing the electric field is accelerating or does this law only apply for static charges, or does it apply also to charges moving at constant velocities?
- Can you please tell me why a very hot body in a vacuum cool at a faster rate than the same body at a lower temperature? And could you please distinguish between the mechanism of thermal conduction in metals and in non-metallic crystals.
- Why is friction higher in ultrahigh vacuum than under ambient conditions?

Peter Reineker

EPS Activities Strategy Plan

The purpose of the EPS according to the Constitution is to contribute to and promote the advancement of physics, in Europe and neighbouring countries by all suitable means. Highlighting the relevance of physics for the development of all sciences, and as the basis of innovative technologies contributing to world wide prosperity is part of this goal, and at the same time must serve the interests of its members.

In 1996, the Council accepted a strategy paper prepared by H. Schopper which provides the basis of the Activities Strategy Plan (ASP) currently being prepared by the Executive Committee. The ASP will define the areas of strategic importance to achieving the EPS' overall goals. Programmes and projects will be devolped accounting for the priorities of the EPS, and resources will be allocated to implement them. Committees, Divisions and Groups will be responsible for the programmes and projects and monitor their success. The strategic areas are: Scientific Issues of Physics; Professional Issues in Physics; Pre-University, University, and Continuing Education; Public Awareness, Information and Publication; East-West Co-operation and Physics for Development; and the Financial Situation of the Society.

The Executive Committee is responsible for all activities of the EPS. Each of the areas will be the specific responsibility of one or more of its members. The activities in each of the areas will be split into core business, programmes, and projects. Core business comprises normal operations and activities for which there might be no possibility of outside funding. Programmes are ongoing activities of the EPS and are normally be run by a committee, supported by and reporting to a member of the Executive Committee. Projects describe specific actions to attain a defined goal within a given time and will end once they have achieved their goal, or reached their allotted time. For programmes and projects, attempts should be made to obtain outside funding.

The ASP is currently circulating among the members of the Executive Committee. One their comments are in, the plan will be sent to the Chairmen of the Committees, Divisions, Interdivisional Groups, and to the National Societies. All comments received will be discussed at the next meeting of the Executive Committee. Then the ASP will be correlated with and adapted to the financial possibilities of the Society. This version will be sent to the members of the Council. It will be discussed and hopefully put into action during the next Council meeting in Mulhouse in spring 2001.

Hannes Alfvén Prize to R. Balescu

"I have been in love with the statistical physics of plasmas over my whole scientific life."

In agreement with the family of Hannes Alfvén, the Plasma Physics Division of the EPS has created The Hannes Alfvén Prize of the European Physical Society for Outstanding Contributions to Plasma Physics. The prize was awarded for the first time in the year 2000 to Prof. Radu Balescu of the Université Libre de Bruxelles for his outstanding scientific work in the field of statistical physics of charged particles and of controlled fusion.

A system of charged particles has a very peculiar behaviour as compared to neutral fluids. The reason is the long-range of the Coulomb interactions, which introduces a strongly collective character. The usual methods of statistical mechanics, in particular of non-equilibrium states, lead to mathematical divergences in all expressions of the physical quantities. In 1960, Prof. Balescu derived a new kinetic equation by identifying an approximation scheme different from the usual Boltzmann or Landau schemes. The collective, many-body character of the collision processes in a plasma is thus explicitly accounted for, and the divergences disappear. It thus becomes possible to construct a consistent theory of transport processes in fully ionised high temperature plasma. This equation carries his name and has entered the literature as Balescu - Lenard equation.

Prof. Balescu has worked with the many-body dynamics of an ensemble of charged particles in all aspects: statistical mechanics of classical and quantum mechanical plasmas, non-equilibrium properties, the description in the framework of special relativity. The latter topic was a difficult problem for a long time, and the previous answers were ambiguous. In their formulation, inspired by a very elegant work of Dirac, Prof. Balescu and his coworkers achieved a unification of classical (and later, quantum) Hamiltionian dynamics and special relativity. The key is the construction of the generators of the Poincaré group of canonical transformations. The result is a set of ten generalised Liouville equations acting on the phase space distribution function for a plasma and the electromagnetic field. These equations tell us how to describe time translation, spatial translation, rotation and Lorentz transformation in terms of canonical transformations, which automatically ensure the relativistic covariance of the theory. As a natural extension and application of the work on relativistic statistical mechanics of plasma-radiation interaction, Prof. Balescu became interested in the physics of laser fusion and inertial confinement. He published several papers on anomalous transport in laser-created turbulent plasmas and on parametric instabilities.

Prof. Balescu still leads an active scientific life. He has written many books with a wide circulation and enduring importance, which have been translated in many languages. His two volumes on CLASSICAL and NEOCLASSICAL theory of transport in plasmas generally and particularly in toroidally confined fusion plasmas are standard textbooks both for graduates and scientists in the field of plasma physics and fusion research. The books represent a comprehensive review and a fully consistent and unified presentation of the theory. This series is not yet complete. A concise description and representation of turbulent transport in fusion plasmas is still missing. Prof. Balescu was and is active in this field and he has provided dynamical and probabilistic concepts for the motion of charged particles in stochastic magnetic fields. His academic position and his (partly) fusion oriented research field made Prof. Balescu a valuable and esteemed counsellor and judge in all matters of sciences and fusion science development in Belgium and an advisor in the development of European fusion research.

Prof. Radu Balescu was born in 1932 in Bucarest, Romania, and acquired Belgian nationality in 1959. He studied at the Université Libre de Bruxelles and was the assistant of Prof. Prigogine from 1957 until 1961. He received the title Professor Emeritus in 1997. He is Member of the Académie Royale de Belgique, a member of the Belgian Royal Academy Council of Applied Sciences, of the Comité National de Physique, of the former Groupe de Liaison Euratom (Fusion), of the former Euratom Programme Committee, chairman of the European Study Group on Intertial Confinement. Prof. Balescu is also an Honorary member of the Romanian Academy, a member of the Academia Scientiarium et Artium Europaea. He is the recipient of many prestigious prizes including the prix THEOPHILE DE DONDER the FRANCQUI prize, and the VON ENGEL prize.

Hannes Alfvén

Hannes Alfvén won the 1970 Nobel Prize in physics for "his contributions and fundamental discoveries in magneto-hydrodynamics and their fruitful applications in different areas of plasma physics." Hannes Alfvén was born in 1908 in Norrkorping, Sweden, and he died in 1995.

Hannes Alfvén pioneered work in the field of cosmic physics, magnetospheric plasma physics, and laboratory plasmas. He developed the concept of gyro-centre-approximation and frozen-in magnetic field lines and introduced the notion of a universe filled with plasmas and not a vacuum. The consequences were the flow of currents which give rise to extended magnetic fields. Hannes Alfvén pointed out mechanisms which could lead to energetic cosmic particles, identified the synchrotron mechanism for non-thermal radiation from astrophysical objects, discovered that a special form of electro-magnetic wave - the Alfvén wave - could propagate in a conducting medium. His work contributes to many areas of physics including the origin of the universe, the physics between galaxies, the formation of the solar system, sun-spots, the Van Allen belt, currents in the magnetosphere, electric fields along the magnetic field lines, auroras and wave propagation in plasmas. His findings still play a major role in fusion research, in astro-plasma physics and in areas like accelerator development.

Hannes Alfvén wrote many popular books on natural science and won many awards in addition to the Nobel Prize. For several years, he was president of the Pugwash movement.

European Community - Access to Research Infrastructures action of the Improving Human Potential Programme (HPRI)

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Please submit your application together with a curriculum vitae and a list of publications to **the President of ETH Zürich, Prof. Dr. O. Kübler, ETH Zentrum, CH-8092 Zürich, no later than September 30, 2000.** The ETHZ specifically encourages female candidates to apply with a view towards increasing the proportion of female professors.

Laboratori Nazionali di Frascati dell'INFN

European Community

Access to Research Infrastructures action of the Improving Potentiel Programme

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LNF Director, TARI, INFN, Lab. Naz. di Frascati
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More information can be obtained visiting our website at http://www.lnf.infn.it/cee/, or from the TARI secretariat, e-mail: tari@lnf.infn.it - fax: ++39-06-9403-2582.

CALL FOR PROPOSALS

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1 March 2001 - 31 August 2001, with **deadline 1 December 2000**, and
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Beam time will be allocated on the basis of a review of the submitted research proposals by a programme advisory committee.

Access is **free of charge** for all non-proprietary research. Researchers from EU-countries and Associated States other than the Netherlands are eligible for support under the Access to Research Infrastructures action of the Improving Human Potential Programme of the European Community.

Further information on the characteristics of FELIX and on ancillary equipment, as well as guidelines for the submission of proposals, are available via the internet:

http://www.rijnh.nl/felix