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Near Eastern ancient bronze objects from Tell Beydar

38/5
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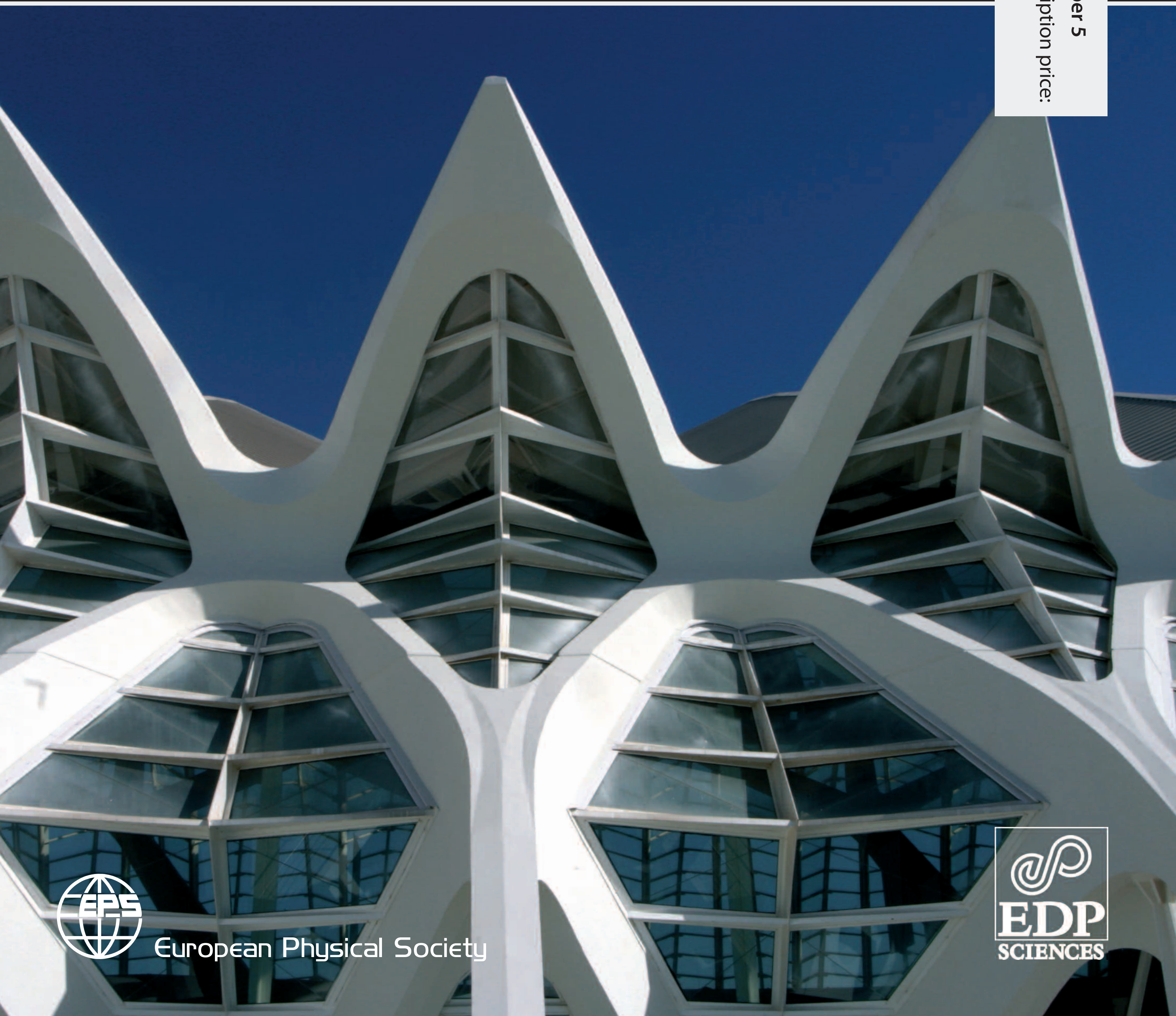

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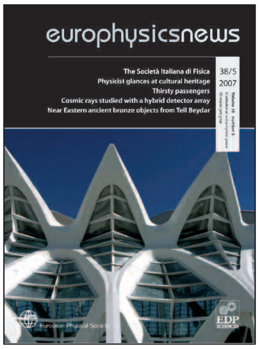

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Cover picture: Outside view of the Science Museum Príncipe Felipe in Valencia, Spain.

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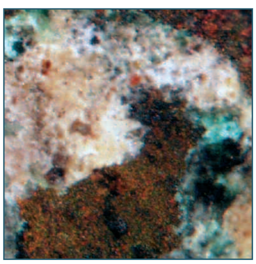
Cosmic rays studied with a hybrid detector



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Near Eastern ancient bronze

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The Science Museum Príncipe Felice

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Is truth still of value? [EDITORIAL]

In 1633, when Galileo was sentenced to life-long arrest, the heliocentric world model of Copernicus was in conflict with the Ptolemaic one and the literal interpretation of the Bible, which described the earth resting on a firmament and the stars and planets orbiting around it. Indeed Psalm 19, verse 6 says " It (the sun) rises at one end of heavens and makes its circuit to the other..." The Ptolemaic system was already shaken in 1610 by Galileo's observation that the planet Venus, located closer to the Sun than the Earth, has phases like the moon. The conjecture of Tycho Brahe, that the Sun moves around the Earth just as the Moon does and that all the other planets move around the sun was still compatible with the Bible. The Clergy was ready to accept the view that the Copernican model was a hypothesis, a possibly useful mathematical description but not the final truth. At the time it was guided by the view that science can never deliver final proof because God has the power to change and modify the evidence. About 100 years later, the Copernican model was no longer a theory but became fact.

The trial proceedings against Galileo happened in the aftermath of the Reformation where the restoration of Catholic authority strengthened orthodox positions, specifically the strict exegesis of the Bible and the Aristotelian concepts and schools. But there was no unanimous condemnation of Galileo on the part of the Clergy. Galileo was rehabilitated in two steps - first in 1741, when his " Complete Works " were taken from the Index of the Roman Catholic Church and then in 1992 in a process guided by Pope John Paul II.

In the same year the Catechism of the Catholic Church was approved which starts with the words: "In the beginning, God created heaven and earth." That the universe has a beginning is an inspiring agreement between modern cosmology and Biblical Genesis. Truth and faith are different categories which both remain of eminent importance for human beings independently of each other and which are complementary and not alternatives, neither needing compromise nor reconciliation. Knowledge in natural sciences does not unavoidably lead to atheism. Science deals with knowledge, religion with human existence, dignity and the sense of life.

To a large degree disconnected from organised religions is the creationist movement which challenges scientific procedures and methodologies and attacks the theory of evolution as the potentially weakest element of the natural sciences. Though the long-term goal of this movement may be the implementation of dramatic changes in western social and political structures, it is an immediate threat to the fundament roots and principles of scientific work. Placing the theory of evolution and Intelligent Design (ID) on an equal footing implies the abandonment of the requirement that scientific conclusions and progress are based on empirical data, that they must be confirmed by experiment in a reproducible form, that a mathematical description must be possible, that they must be free of internal contradictions, and that they must allow predictions with the potential of new discoveries. The ID movement is not restricted only to the USA (Kansas); it also has supporters in Europe. The claim of the creationists that ID must be included in the biology curricula and taught at schools as a conceptual alternative to the theory of evolution also finds supporters both in the European Parliament and in national governments. A member of the Council of Europe, Guy Lengagne, wrote a report on "The dangers of Creationism", which was not approved immediately by the Council. He commented on this refusal by saying: "We witness how the return to mediaeval times is initiated"...

There are strong forces wishing to discredit science (and often technology also) that involve for this purpose the public which often does not have the necessary information or awareness. A frequent form that this takes is the misuse of the role of falsification. Instead of seeing it as an important element of the scientific method and a basic requirement that a scientific result or statement has to meet - un-falsifiable concepts are un-scientific - it is often used as a general acknowledgement that science leads to arguable results only. As a consequence, so their argument goes, any other hypothesis not gained by scientific methodology can co-exist and has to be equally well accepted. →

In spite of all the enlightenment in the Western societies, the value of truth is of declining importance. It is replaced by what could be called fabricated truth, a commodity which is defined, for example, by the form of its presentation, by the backing it obtains from the media or the resonance it has with the public but which has not been gained by scientific methodology. The case made by the creationists is to put scientific results on the same footing as the literal understanding of the bible. This method is, however, not restricted to the issues of Genesis. Fabricated truth might have a larger appeal and be less complex (boring), less contradictory and more plausible than scientific truth, and might offer a more simplistic view of the world. Fabricated truth therefore has a strategic value or it can be manipulated to obtain one. Fabricated truth can be used to defend or justify doctrines; its potential can be exploited for political, social or other goals. Scientists must remain vigilant and should not refrain from confronting fabricated truth, should challenge it with scientific truth and defend its results and the principles and methods used in gaining them. ■

Friedrich Wagner,
President of the EPS

Kai Siegbahn (1918 – 2007) [OBITUARY]

Professor Kai Siegbahn, Uppsala University, Sweden, died on the 20th of July 2007 at the age of 89. He was staying at his beloved summer home in Ängelholm, not far from the town of his birth, Lund, and he was in the midst of the planning for next semester's work, inspired and committed as always, despite health problems.

Kai Siegbahn was born into physics. His father was Manne Siegbahn, who received the Nobel Prize in Physics in 1925 for his achievements in the field of x-ray spectroscopy. Kai, who was then only seven years old, soon shared his father's interest in physics and natural sciences in general. He received his Ph.D. in Stockholm, where in 1951 he took up his first academic position as a Professor. In 1954 he moved with his family to Uppsala, where he held the chair as Professor of Physics until his retirement in 1984. He initiated an amazing number of research programmes in many fields of physics, partly reflected in the major monograph "α-, β-, and γ-ray spectroscopy", of which he was both editor and contributing author. He was for fifty years the Editor of Nuclear Instruments and Methods, the leading journal in the field.

Gradually, Kai Siegbahn's interest turned towards spectroscopic studies of matter using electrons as information carriers, and not long after his move to Uppsala the first photoelectron spectra were recorded using the new methods he developed together with his research group. Electronic states in matter were found to be reflected in the spectra as very sharp lines extremely sensitive to the detailed chemical composition of the samples. On this basis, a new formidable scientific method was invented, named ESCA (Electron Spectroscopy for Chemical Analysis). At the end of the 1960s, Kai Siegbahn and his research group wrote two comprehensive books on the ESCA method, which still form a basis for the worldwide research in this field. In 1981 Kai Siegbahn was awarded the Nobel Prize in physics "for his contribution to the development of high-resolution electron spectroscopy".

The research field diversified and deepened successively, and the research group in Uppsala grew. More than 180 research students received their Ph.D. under Siegbahn's leadership, most of them later reaching high academic, industrial or social positions. He took a great responsibility for students at the undergraduate level by inviting them to do their exam or diploma works in his teams. Many guest researchers visited his institution for longer or shorter periods. The international contribution was always large and often lifelong. His retirement in 1984 was not a retirement from the research vocation. On top of the continued daily research, he invented a new generation of electron spectrometers and, in addition, another research method that combined ESCA instruments with powerful lasers and modern mass spectrometers in a truly impressive programme.

Kai Siegbahn was honorary doctor at many universities and had numerous international scientific activities. He was guest researcher at Berkeley for extended periods of time. A Humboldt Scholarship allowed him and his wife Anna-Brita to spend a happy year of research in Germany. He served as president for IUPAP, the International Union for Pure and Applied Physics, during one period. He was also a member of the Comité International des Poids et Mesures, the steering committee of the International Bureau for Weights and Measures, in Paris. In his own country he was a very active member of the leading scientific societies as well as of the Nobel committee for a number of years and he was president of the Swedish Physical Society.

Kai Siegbahn was a dynamic and inspiring research leader with a contagious curiosity and enthusiasm in doing research and in supervising students. Friends and colleagues in Sweden and around the world will regret his demise. ■

Leif Karlsson and **Carl Nordling**,
Uppsala University

The International Physics Olympiad 2007 [LETTER]

This year the International Physics Olympiad (IPhO) was held from 13 to 22 July in Isfahan, a historic city and former capital of Iran, known as the pearl of Persia. There were 326 competing secondary school students coming from 69 countries, including almost all European Union countries, China, India, USA, Russia and Japan. Two new participants were Montenegro and Nepal. The competition was in the modern premises of the Isfahan University of Technology located on a large piece of land some 20 km outside the city.

The first theoretical problem proposed to the contestants dealt with the properties of a binary star system to be elucidated from spectroscopic data. In the second problem students had to examine a model of an accelerometer designed to activate air bags for protection of passengers in colliding vehicles. The last theoretical question was related to black holes and Hawking radiation. In the experimental problem the aim was to measure by a spectroscopic method the energy band gap of a semiconductor thin film, using a different sample for each contestant. Formulation of the problems, their solutions, results of the competition and other details can be found at the following website www.ipho2007.ir.

A total of 214 distinctions were awarded. Among them were 37 gold medals for students originating from 22 countries, with the largest number (4) going to Chinese and 3 to Russian students. The best individual score was achieved by Young Juon Choi from the Republic of Korea. The best female student, Russian Kseniya Salavyova, ranked tenth.

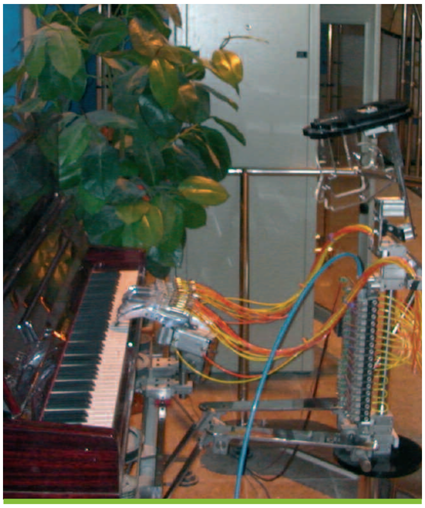
During the Olympiad, on the day of the theoretical competition, July 15, the long time President of the IPhO, Dr Waldemar Gorzkowski, suddenly passed away (See insert). Besides the IPhO, he initiated the establishment of the international competition for high school students "First Step to Nobel Prize in Physics" and was running it successfully since its beginning in 1993. The International Board of IPhO unanimously appointed Prof. Maija Ahtee, from the University of Jyväskylä in Finland, as Acting President until next year's election of a new president.

In the free time, students and leaders visited many interesting sites, among them the shaking minarets, which illustrate coupled oscillators, beautiful tiling patterns some of them found to possess non-periodic fivefold symmetry, and broken absorbing surfaces on the walls in the musical chamber of the Royal palace. Visits were organized to several laboratories: for computational solid state physics, high-temperature superconductivity and hydraulic studies. The Royan Institute dedicated to genetic and stem cell research proudly exhibits a cloned sheep, the Iranian Dolly named Royana. The Science Park under construction has a pianist robot, a harp with laser beams instead of strings and many other exciting displays. The hosts of the IPhO have proven their great hospitality in this first International Science Olympiad held in Iran.

For the competing students, a one-page multiple-choice questionnaire prepared by myself, with up to ten proposed answers, was kindly distributed by the organizers to the students in order to obtain information on their attitudes and intentions. From the 114 answers received, the largest group of 43 students intends to continue studying physics at a university level, followed by smaller groups interested in engineering (28), medicine (9) and other subjects. The most influential factor inspiring the interest of students towards physics are their teachers, while second in importance at approximately the same level are books, demonstrations of experiments and observations of nature. Questioned on an essential factor influencing their choice of future profession, more than 70% of students indicated that they want to select an interesting profession. More than 50% of all students aspire to become researchers and the second largest group, comprising roughly 10% of respondents, expressed their interest toward education. Only 10% of students perceive the opportunities for physicists in their own country as very good. It would seem worthwhile to pursue these enquiries with some modifications in similar events in the future.

The next Olympiad will be organized in the Vietnamese capital Hanoi, from 20 to 29 July 2008. ■

Viktor Urumov,
MK Skopje, Macedonia



▲ The pianist robot presented at the IPhO 2007 in Isfahan

W. Gorzkowski (1939-2007)

On July 15, 2007, the President of the International Physics Olympiad Dr Waldemar Gorzkowski passed away in Isfahan, Iran (see above). He died suddenly in the middle of the activity he loved most – presiding over the International Physics Olympiad (IPhO). It was just too early to see his proposal for a European Physics Olympiad, published in the previous issue of Europhysics News (EPN 38/4, p.6-7). He had been for 23 years the active promoter and leader of the IPhO, which grew from 10 participating countries from the so-called Eastern Bloc to over 90 countries from all over the world.

W. Gorzkowski was a research scientist at the Institute of Physics of the Polish Academy of Sciences in Warsaw throughout his career. His colleagues in Poland and the Physics Olympiad Movements have lost a great and enthusiastic personage of a high level of physics education.

Statement of the EPS, Computational Physics Group

"On the need for research in basic physics to have access to high-performance computing resources at European Supercomputing Facilities".

Statement

High-performance computing with supercomputer systems is a very important tool in computational science and engineering. In computational physics, fields such as elementary particle physics, physics of hadrons and nuclei, plasma physics, solid state physics, soft matter physics, biophysics, hydrodynamics, atmospheric physics, geophysics, astrophysics, etc. all have very distinct needs to access high-performance computing facilities; in each of these fields the need for sustained supercomputer performance has been estimated to be at least of the order of 100 Tflops in the year 2010 [1,2].

The same is true for neighbouring disciplines and/or interdisciplinary fields such as material science and nanoscience, theoretical chemistry, computational fluid dynamics for engineering applications, climate and weather prediction, biological sciences and bio-informatics, *etc*.

In all these branches of computational physics, European scientists work at the forefront of research, and in a number of subfields European science defines the frontier. To keep this distinctive position in science and possibly strengthen it, continued access to very powerful high- performance computing resources is mandatory. We strongly believe that this access should be granted solely on the criterion of scientific merit, judged by peer review.

The Computational Physics Group of the European Physical Society feels among others [3-8] that creation of a European Supercomputer Infrastructure, as a joint endeavour of many European countries, should be a very useful step to satisfy these needs. In this way it should be possible to stay competitive with the rapid development of high- performance computing facilities taking place in the US and Japan. It is doubtful whether such competitiveness could in the long run be maintained by purely national initiatives of European countries alone (such national supercomputer centres ··· ··· will still be necessary, since only the very largest projects of the very best European scientists should be admitted to European Supercomputer Centres, in the interest of the most efficient use of this resource).

High-performance computing is also indispensable for applied research, engineering and last but not least, for industry. However, the Computational Physics Group of the European Physical Society explicitly emphasizes and endorses the use of European supercomputer centres as joint European facilities of basic research, similar to the large European accelerator facilities, or facilities for neutron and synchrotron radiation scattering, large telescopes, etc. Modern technologies (*e.g.* information technology based on semiconductors, the internet, laser technologies, *etc.*) all are "spin-offs" from basic research carried out in the second half of the last century.

It is foreseen that current basic research will be similarly fruitful for future technologies. Thus, it is an important task to create and maintain conditions favourable for forefront research in the European Research Area. European supercomputer centres operating along such guidelines will serve this purpose. ■

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[3] http://cordis.europa.eu/fp7/capacities.htm

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[5] www.e-irg.org

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[7] www.gauss-centre.eu

[8] www.bmbf.de/press/2021.php , www.fz-juelich.de/portal/index.php ?index= 721&cmd=show&mid=475

The EPS Executive Committee

The EPS Directory [EPN 38/2, 31-32 (2007)] gives the names, addresses and EPS function of the members of the Executive Committee of our Society. Since this Committee, elected by the Council of the EPS and chaired by its President, is the actual governing body of the Society, it has been decided that Europhysics News should give a brief background profile of the nine Committee members, other than the President, Friedrich Wagner [see EPN 38/3,5-7 (2007)] and the Vice-President Ove Poulsen (see many past issues of EPN).

These have been prepared by the members themselves and are presented in alphabetic order, five in the present issue and four in the next one, with the name as title, immediately followed by the birth year and the home city and country.

> John L. Beeby (1937, Leicester, UK)

My career began with a PhD at Cambridge and from 1965 to 1972 a post at the Atomic Energy Research Establishment, Harwell.

My research has been primarily concerned with theoretical studies of the properties of disordered systems and surfaces. From 1972 to 2002 I was Professor of Theoretical Physics at the University of Leicester, during which period I also held various administrative posts including Pro-Vice-Chancellor. Also, from 1984-1988 I was Coordinator of the Science and Engineering Council's Low Dimensional Structures and Devices Programme. I was an Editorial Board Member of Journal of Physics F: Metal Physics (later Editor) and of Semiconductor Science and Technology. In the Institute of Physics I was previously Chairman of the Condensed Matter and Materials Physics Division, a Member of Council, was awarded the Glazebrook Medal and Prize (1995) and since 2003 have been Honorary Secretary. I served earlier on the EPS Condensed Matter Division Board, on the Conference Committee and as an IM Representative on Council and have been Honorary Treasurer since 2006.

I strongly believe in the importance of the EPS for European Physics and, indeed, for Europe. It is widely appreciated that a strong, cohesive and well-resourced physics research community is required if Europe is to compete effectively with other parts of the world and that, at the same time, physics education must provide a good supply of well-trained graduates and researchers. I welcome the opportunity to play a small part in support of the EPS. ■

> Angela D. Di Virgilio (1956, Pisa, Italy)

After higher education in Physics at the University of Pisa (Italy) and 3 postdoctoral years at Purdue University (1983-86, mostly at the Fermi Laboratory on the CDF experiment),

I became a staff researcher of the Pisa INFN section in 1986, working from the beginning on the Virgo gravitational wave antenna. From 1998 to 2006, I have been leader of the experiment LFF of the Virgo project (qualification of the Virgo suspension around 10 Hz, first observation of the "Optical spring" effect, thermal noise power spectrum around 10 Hz). Since 1998 I have been on the INFN senior research staff and am now leader of the experiment "G-Pisa", a fundamental approach, which uses a gyro laser to improve the performance of the antennae in the low frequency region. It implies international collaboration and the construction of much equipment requiring a deep knowledge of Fabry-Perot cavities, lasers, control and data analysis. Gravitational wave research is one of the most difficult experimental enterprises, and so far my main interest has been in the construction of very difficult and unique experimental apparatus and making it work.

EPS gives me the opportunity to see the world of physics from a broader perspective: the exchange and dissemination of information, the training of the younger generation and the keeping and enlarging of an interest in physics. The exchange between physicists of different backgrounds and attitude, coming from all over Europe, is the key to developing all of the above. As a woman I really care about the next generation, and I am very interested in keeping the world of physics in good health for the next generation. I believe that exchange between different fields of physics is one of the ways to keep the international community healthy. ■

> Berndt P. Feuerbacher (1940, Köln, Germany)

I started my career in 1968 as Research Scientist at the European Space Laboratory (ESLAB) of the European Space Research Organisation (ESRO, now ESA) and became Deputy head…

… of the Astronomy Division at the Space Science Department of ESA in 1973. Then, I have been Director of the Institute of Space Simulation, German Aerospace Centre (DLR), Köln, and Chair of Experimental Physics (Space Physics) at the Ruhr-University in Bochum, Germany, until 2006. I am now Founding Director of the new Institute of Space Systems, German Aero-space Centre (DLR), in Bremen.

My original scientific roots are in surface physics, where I worked in photoelectric spectroscopy of intrinsic surfaces and adsorbed layers, and in atom-surface scattering. From early photoelectric measurements on lunar material from Apollo-Missions I developed activities in space materials science and astrophysics. One major achievement is the design and construction of the comet lander "Philae" presently on its way to comet Churyumov-Gerasimenko with the European Rosetta-Mission.

At the EPS, before becoming Secretary of the Executive Committee, I have been a member of the Council (1984-1987) as a Delegate of the Individual Members and (1998-2002) as Delegate of the Associate members, long after being Chairman of the Surfaces and Interfaces Section (Condensed Matter Division) from 1978 to 1984. So, being active in EPS since 1977 I have followed the development of the society through the years. EPS has been a forerunner of European cooperation, which is becoming increasingly important as scientific research is achieved in teams beyond national borders. EPS has established itself as a valuable and recognised entity in the international environment.

Future emphasis of the EPS work I see in the areas of a stronger integration of eastern European countries, an improvement in the balance of task sharing with national societies, and a strengthening of the public awareness of physics in Europe. ■

> Keijo Hämäläinen (1963, Vantaa, Finland)

After completing my higher education in Physics at the University of Helsinki (PhD in 1990), I spent 2 post-doctoral years at the Brookhaven National Laboratory (USA)

before becoming Junior (1993) then Senior (1997) Research Fellow of the Academy of Finland and, at the same time, Senior Assistant at the Department of Physics of the University of Helsinki. Since 2002, I am physics Professor and Division Head at the Department of Physical Sciences at the University of Helsinki. My field is experimental solid state physics and I carry out most of my research utilizing synchrotron radiation, mainly for various inelastic X-ray scattering techniques. I am mostly interested in fundamental electronic properties of different kind of materials varying from water to high-temperature superconductors.

Due to my scientific background I am very much interested and involved in science policy related to large scale research infrastructures. These multidisciplinary research facilities play an important role in keeping Europe in the forefront of science. EPS shares many common goals with them and should have close and active collaborative relations with them. Representing the somewhat younger generation in our society I also believe that one of the most important and also challenging tasks for EPS is to integrate especially the younger scientists within their national physical societies and to encourage them to maintain their scientific identity in the present, sometimes overwhelmingly, multidisciplinary research environment. ■

> Maciej Kolwas (1949, Grojec, Poland)

After completing my higher education in Physics at the Warsaw University in 1972 (Atomic Physics) I gained my Ph.D. in 1975 and Doctor of Sciences in 1983, I have been a Professor at the Institute of Physics…

… of the Polish Academy of Sciences in Warsaw since 1992. (see: www.ifpan.edu.pl/ON-2/on22/staff/kolwas.html). There, I have been head of the Department of Physics of Radiation & Spectroscopy (1985-1997) and deputy director of the Institute (1997-2000). At present I am head of Postgraduate Studies (since 1997), president of International Study of the Polish Academy of Sciences (2000), and head of the Laser Spectroscopy group (1991). My scientific activity began with quantum optics and now concerns light scattering studies of the properties of small objects.

I have organised together with Prof. L. Woeste (Berlin) three Polish – German Conferences in Modern Optics (1996, 98, 2000) and co-organised the three first Quantum Optics Conferences (1985, 89, 2003) as well as five Congresses of Polish Physicists. I have participated in and stimulated the production of several TV programmes about physics.

I have been Secretary General (1998-2002) then President of the Polish Physical Society (2002-05) in particular during WYP2005, so successful also in Poland.

My other interest, which I plan to continue, is the international cooperation between societies, institutions and people involved in the development of physics, physics promotion and education. I participate in the International Young Physicists' Tournament as representative of Poland and as an international jury member, as well as being a jury member in the International Conference of Young Scientist and Physics on Stage (Polish edition).

Participation in the newly-formed EPS Forum Physics and Society will be one of my main activities in the future. ■

Max Born Award 2007 for optics to L. Lugiato

Luigi Lugiato of INFM-CNR, now professor at Università dell'Insubria in Como (Italy), is the winner of 2007 Max Born Award. The honour was established in 1982 by the Optical Society of America and is awarded every year for outstanding contributions to physical optics. Prof. Lugiato received the Max Born Award on June 12th during the Rochester Conference '*Coherence and Quantum Optics 9*'.

Prof. Lugiato has previously won the Michelson Medal of the Franklin Institute of Philadelphia, the Lamb Medal and the Quantum Electronics Prize of the European Physical Society. Now he has received the Max Born Award "for pioneering theoretical contributions to the fields of optical bistability and instabilities, optical pattern formation, cavity solitons, squeezing and quantum imaging".

Born in Milan in 1944, Prof. Lugiato is a Fellow of the American Physical Society, the European Physical Society and the Optical Society of America. During his research activity – over more than thirty years – he has been interested in non-linear optics, statistical mechanics and non-linear system dynamics. He has published over three hundred papers in refereed journals and has been a member of many Italian and international committees. ■

Giuditta Parolini,
INFM-CNR, Italy.

IBA-Europhysics Prize 2007

>>> for « Applied Nuclear Science and Nuclear Methods in Medicine »

The Executive Committee of the EPS has approved the recommendation of the Nuclear Physics Board according to the proposal of the IBA-EPS prize selection Committee to award the IBA-Europhysics Prize 2007 to **Dr. Dieter Schardt** (Biophysics Division, GSI Darmstadt, Germany) and **Prof. Dr. Wolfgang Enghardt** (Technische Universität Dresden, Dresden,Germany). The prize is attributed with the citation:

"For their outstanding contributions to the development of tumour therapy with heavy ions, providing detailed information on the interaction of ions with biological tissues and novel techniques for treatment quality assurance"

Dr. Dieter Schardt uses his large experience in experimental nuclear physics to treat questions of uppermost importance in heavy ion therapy: measurement of depth-dose curves, measurement of fragmentation cross sections to study biological effects with carbon or heavy-ion irradiation at high energy, investigation of the interaction of ionizing radiation with nerve cells, high accuracy measurement of neutron emission in the treatment of tumours, neutrons being able to induce secondary tumours. Dr. Dieter Schardt is at present the technical leader of the tumour therapy project at GSI. His work is influencing the quality of ion therapy facilities under construction and the reliability of ion therapy as a new modality for cancer therapy.

Prof. Dr. Wolfgang Enghardt has worked out a sophisticated but still very useful method to check the tracks of ions via their production of radioactive nuclides decaying by positron emission. PET detection hardware and software has been developed for their "in beam" use during radiation cancer therapy. The PET system was put into operation and it is currently in use at the GSI Facility for hadron therapy.

▲ Dr D. Schardt
▼ Prof. Dr. W. Enghardt

Since the 90's a stable and fruitful collaboration has been established between the Institüt für Kern and Hadronen Physik at Rossendorf and GSI - Darmstadt. The physics basis of "in beam" PET at therapeutic ion beam stations has been investigated and an "in beam" scanner has been developed, constructed and integrated into the experimental C ion therapy facility of GSI. The device has been in clinical routine use now for 10 years and the method has been steadily improved on the basis of experiments at the GSI accelerators.

The IBA-Europhysics prize is sponsored by the IBA (Ion Beam Applications) Executive Committee, Chemin du Cyclotron, 1348 Louvain-la-Neuve, Belgium.

The award ceremony has taken place during the 9th ECAART (European Conference on Accelerators in Applied Research and Technology) in Firenze (Italy), September 3-7, 2007. ■

Ch. Leclercq-Willain,
President IBA-EPS Selection Committee
Université Libre de Bruxelles, Belgium.

The Società Italiana di Fisica:

>>> 110 years of service Promoting physics, supporting physicists

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The year 2007 marks the 110th anniversary of the birth of the Italian Physical Society (Società Italiana di Fisica, SIF), the non-profit, scientific association devoted to promoting and favouring the progress of physics in Italy, increasing its understanding and application, and to supporting physicists.

SIF represents the Italian scientific community in the research, and the educational and professional fields, both private and public, relevant to all areas of physics and its applications. It has an extensive national membership and is a leading communicator of physics with all audiences, from specialists through government to the general public.

The history

The Italian physical Society was founded in 1897. From the beginning its history has been tightly bound to the history of the monthly journal of physics *Il Nuovo Cimento*, which became a part of SIF constitutional heritage when Riccardo Felici, the owner of the journal, transferred it to the Society. The same year on the January issue of the journal the subtitle "Organ of the Italian Physical Society" appeared for the first time. The journal had been founded in 1855 and its title recalls the ancient *Accademia del Cimento*, the association founded in 1657 by Prince Leopoldo de Medici and the disciples of Galileo Galilei.

SIF adopted also the association logo, in which are reproduced a burner, three crucibles full of melted metals, and a flying scroll with the motto "*Provando e Riprovando*" (trying and trying again), which refers to the experimental method. The motto can also be interpreted as "*proving and reproving*", which is also very appropriate.[1]

In the early decades of the 20th century SIF lived and grew, steadily faithful to the spirit of its founders (R. Felici, A. Battelli, P. Blaserna, G. Ferraris, A. Pacinotti, A. Righi, A. Ròiti and V. Volterra), keeping international relations through its most eminent fellows. In the Thirties, under the stimulus of a few distinguished masters (such as O.M. Corbino and A. Garbasso) and of the new generation of prominent Italian physicists (such as E. Fermi, E. Segrè, E. Amaldi, G. Bernardini[2], U. Fano, E. Majorana, E. Persico, B. Pontecorvo, G. Occhialini, G. Racah, F. Rasetti, B. Rossi, G.C. Wick, G. Wataghin), the development of physics in Italy accelerated and SIF increased its international recognition. From 1947 onward, SIF showed an impressive quantitative and qualitative growth: the number of members increased from about 250 to about 2000, important initiatives were set up, like the International School of Physics "Enrico Fermi", and the Society became an influential national institution for the development of physics and validly participated in the world-wide framework of national physical Societies

Today SIF continues its work to advance science, teach the next generation the basis of physics, disseminate research results to industry and fight attacks on science from people led by prejudices. It provides a national forum to discuss science and policy issues of interest to its individual members, who come from academic and research institutes, industry, and education.

Social activities

SIF is run and operated by the President and the Executive Council, which establishes the strategic orientation of the society, and provides advice in areas important to physics.

Every year SIF organizes the National Congress in a different Italian city. The Congress gathers more than 700 physicists working in different fields, and represents an important opportunity for discussions, keeping abreast of the most relevant results in research, application and physics education, and for discussions upon activities promoted by the Society.

During the inaugural ceremony, prizes and awards are given to members of the Italian scientific community (mostly to young people), in recognition of outstanding achievements in research and education, and service to the Society. The nomination and selection procedure, involving SIF-appointed selection committees, guarantees high standards and prestigious choices. Among these prizes it is worth mentioning the prestigious *Enrico Fermi Prize* for a prominent member of the Society who has honoured Italian Physics with his/her discoveries, and the very new *Giuseppe Occhialini Medal*, that will be jointly awarded by SIF and IOP to a distinguished Italian or British physicist for relevant results in physics research.

Every three years during the annual Congress, memberships elect, by secret ballot, the President and seven Councilors of the Executive Council.

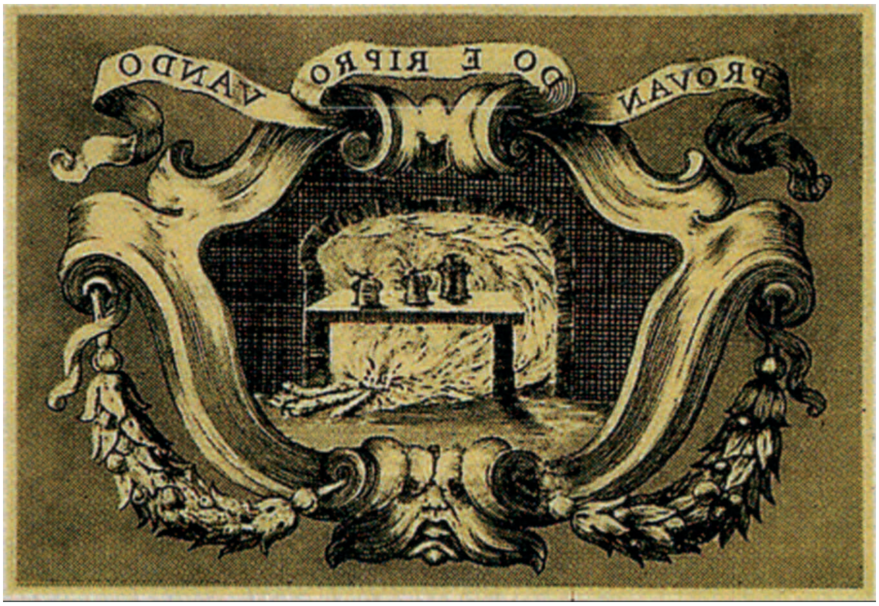
SIF takes also initiatives to provide an insight into "hard science" and policy issues in physics to the general public. Today's challenges include finding ways in which science can help improve human welfare worldwide in such areas as energy, climate change, and health care. In this respect and following a recommendation of EPS President F. Wagner, recently SIF has established an "Energy Group" to deal with all aspects of energy, by developing a good profile within the national debate, contributing to it and educating the public. SIF had produced in the past several studies about energy related issues that were well received by the scientific community but did not reach the general public. In order to ···

[1] It is worth mentioning that "provando e riprovando" is found, with this latter meaning, in the first tercet of the third "canto" of the Paradise in the Divine Comedy poem by Dante Alighieri:

"That Sun, which erst with love my bosom warmed,
Of beauteous truth had unto me discovered,
By proving and reproving, the sweet aspect."

(translation by Henry Wadsworth Longfellow). Here the beauteous truth, which Dante refers to, concerns the lunar spots and the influence of stars.

[2] We recall that Gilberto Bernardini has served as President of EPS from 1968 to 1970



▲ "Cimento in its pregnant meaning is at the same time the trial, the test, the effort, the risk, the peril, the experiment, the comparison, the thirst for knowledge, the extent to which the metal refines in the crucible. The crucible then is the mind, and the two words (provando e riprovando) of the enterprise, mirroring each other, show the route to attain, by trying and trying again, the 'beauteous truth'. It is the essence of the Galilei's method." - **G. Polvani** (SIF President 1947-1961)

••• overcome this drawback, SIF has named in the new "Energy Group", besides experts in various energy technologies, two politicians and one science journalist.

Publications, the International School of Physics "Enrico Fermi", and education are the keystones in all SIF activities.

Publications

SIF is a world leader in scientific publishing and the electronic dissemination of physics.

Il Nuovo Cimento has been published continuously since 1855 up to the present time. It was for long time the only physics academic journal published in Italy. It has attained its international character after the Second World War, with an astonishing increase of the number of published papers and with the adoption of English as its main language. This growth induced in 1965 the publishing of two and subsequently four different sections of the journal covering more specialized fields [specifically, *Il Nuovo Cimento A*: Nuclei, Particles and Fields; *Il Nuovo Cimento B*: General Physics, Relativity, Astronomy, Mathematical Physics and Methods; *Il Nuovo Cimento C*: Geophysics and Space Physics; *Il Nuovo Cimento D*: Condensed Matter, Atomic Molecular and Chemical physics, Fluids, Plasmas, Biophysics] and, in 1969, the start of issuing the *Lettere al Nuovo Cimento*, for rapid scientific information.

In recent years, SIF began collaborations in partnership with other European publishers and distributors in order to support efforts to construct a European platform in physics publishing. *Europhysics Letters* (EPL) was launched in 1986 under the scientific auspices of EPS as a merger of *Lettere al Nuovo Cimento* and *Journal de Physique Lettres* of the Société Française de Physique, with the sponsorship of the Institute of Physics (IOP). In 1998-2000 *The European Physical Journal* (EPJ) was launched as a merger of *Il Nuovo Cimento* (Sections A and D), *Journal de Physique* and *Zeitschrift für Physik*. For the first time, a truly European physical journal appeared, jointly published by the *EDPS*-French Physical Society, the Italian Physical Society and the German Springer-Verlag academic Publisher.

SIF also publishes: (i) *Il Giornale di Fisica*, a quarterly journal, mainly in Italian, especially meant for physics teachers in secondary schools. It contains peer-reviewed papers on educational methods and new educational techniques; a forum for discussions, a selection of problems and experiments suitable for physics lessons; reprints of archival papers of up-to-date interest; a glossary of fundamental concepts and terms in physics. (ii) *Quaderni di Storia della Fisica*, a journal, mainly in Italian, with contributions on various aspects of the history of physics. (iii) *Il Nuovo Saggiatore*, which is the bulletin of the Society, published every two months, mainly in Italian. Besides general information for the members of the Society, the journal keeps its readers informed about science and its place in the world with authoritative feature articles, news stories, and analyses, as well as by providing a lively forum for the exchange of ideas.

Moreover, the Italian Physical Society publishes the proceedings of the Courses of the International School of Physics "Enrico Fermi" and of other conferences and workshops, and books in commemoration of prominent Italian physicists or on the occasion of special events. Recent examples of these books are:

1) The two books "Ettore Majorana-Scientific papers" and "The scientific legacy of Beppo Occhialini" published, in collaboration with Spinger, on the centenary of the birth of the two prominent Italian scientists. The first book collects the ten published works of Majorana, his communication to the SIF 1928-Congress and his notes for the "*lectio magistralis*". For the first time all Majorana's articles are published both in Italian and English and are commented by experts in the specific field. The second book covers Beppo's scientific life and collects reminiscences by his friends and colleagues.
2) The book "Il Nuovo Cimento, Scritti Scelti 1855-1944", a collection of articles published on the journal by outstanding physicists from 1855 to 1944. The book has been printed on the occasion of the *World Year of Physics* (WYP 2005) and of the 150th anniversary of the foundation of *Il Nuovo Cimento.*

The International Summer School of Physics "E. Fermi"

Since 1953, the SIF organizes in Varenna, on the Como Lake, the International Summer School of Physics "Enrico Fermi", in the beautiful scenario of Villa Monastero.

A number of advanced courses have been held in topical fields of physics in the past 54 years. Considerable attention is paid to the cultural impact and the up-to-date scientific content of the discussed themes, as well as to a fair distribution among the different fields of contemporary physics. Each course is attended by about fifty post-graduate researchers from all Countries. All courses have been directed and attended by famous and outstanding physicists, from all over the world, including 45 Nobel laureates. Enrico Fermi gave a memorable series of lectures on "Pions and nucleons" in the summer of 1954, shortly before his death.

Varenna is undoubtedly one of the most beautiful and characteristic villages in the eastern bank of Como Lake. The mild climate and the picturesque surroundings guarantee a relaxing and peaceful stay. Villa Monastero, once a monastery, is one of the most ancient and beautiful villas of the region with its impressive botanic garden.

The proceedings of all Courses have been published by SIF, since the foundation of the school. Clearly, besides the pedagogic value, this book series has also a relevant interest as historic archive.

Education

SIF studies issues of concern relating to physics education, not only at the university level, but also at the primary and secondary school level.

For the latter, SIF has a special relationship to the Italian Association of Physics Teachers (Associazione per l'Insegnamento della Fisica, AIF), providing scientific and technical support. In 2005, in order to improve the teaching of science in the schools, two projects have been deployed: the *Virtual Classroom* and the *Natural Radioactivity* projects. The first project aims to offer all schools the opportunity of introducing the "experiment" in the teaching of physics. The net is used for the transmission of all information necessary to make a specific experiment: it allows a bi-directional connection, both in video and audio, between the teacher, who makes the experiment in his/her own class, and the classes interested in that experiment, which can be located in any part of Italy. This makes possible: the live illustration of the performed experiment, with provision of all instructions to replicate it; the discussion of the results; answering questions lively arisen by students from whatever class.

The *Natural Radioactivity* project aims to arise the curiosity and the attention of young people about the scientific method and to induce them to use a correct approach to the observation of a natural phenomenon. For this purpose SIF provides secondary school students with a kit of instruments (a Geiger-counter, a personal computer and a GPS) for the measurement of the natural radioactivity. Natural radioactive phenomena have been chosen because they are present everywhere and can be easily detected.

Very recently some attention has been given to the multimedia sector, with participation in the distribution to the secondary schools of the DVD collection of the Physical Science Study Committee (PSSC) project, and with the production of the DVD collection "*Raccontare la Fisica: Esperimenti e personaggi esemplari*", a collection of significant experiments and of films on the life of prominent Italian physicists.

At the university level, SIF, in collaboration with the Ministry for the University and Research and the Italian Chemical and Mathematical Associations, has implemented the "Progetto Lauree Scientifiche" ("Hard Science Diploma Project"), a project which aims to counteract the decline of interest among the young generations in studying hard sciences, and to enhance the access of hard science graduates to the labour market. To this purpose grants are awarded to good students enrolling in mathematics, physics and chemistry, and *summer schools* are organized to promote an integrated vision of the scientific culture among science students, to stimulate and strengthen the interest for science and to guide students in the selection of their future research or professional job.

On June 2005, SIF, in association with the Italian Science-Faculty Deans, has organized in Varenna the Workshop on "Physics: from School to the Job Market" to discuss the marketplace opportunities for physicists in Italy and Europe. The workshop explored the opportunities and the actual paths taken by physics students from their encounters with the field of physics to their later professional life.

Other recent SIF activities comprise: (i) proposals and implementation of physics programmes and curricula in the high schools; (ii) contribution to the analysis of the European Bologna process and of the impact of different national actions as compared to the Italian situation; (iii) analysis and follow up of the new two-main-cycles system (3+2 years), recently adopted in the Italian university, following the Bologna process recommendation; (iii) topical conferences and meetings for the continuing education of school and university professors; (iv) fostering the birth of the Italian Association of Physics Students; (vi) a draft bill for the creation of a professional association of physicists, the *Albo Professionale* (Physicist Register), to support physicists active in the workplace.

Looking into the future, it is clear from the past achievements that SIF shall continue to effectively contribute to the advancement and diffusion of knowledge of the science of physics and its application to human welfare. ■

About the author

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▼ The Villa Monastero on Lake Como, home of the International Summer School of Physics "Enrico Fermi".

Highlights from european journals

Nano-mechanical resonators for computing applications

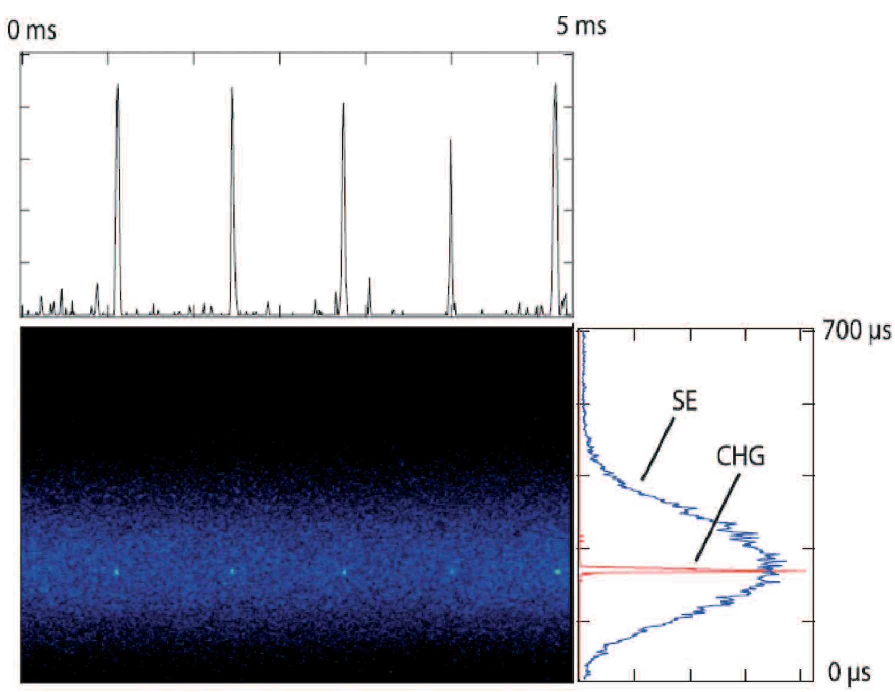
Conventional integrated circuits, like complementary metal–oxide–semiconductor (CMOS) circuits, allow large numbers of transistors to be combined into electronic boolean logic gates such as NAND gates or NOR gates. These gates in turn may be interconnected within the integrated circuit to create more complex logical devices such as arrays or computers. Conventional circuits using transistors have some significant limitations. They can be disrupted by radiation (common in space shuttle applications), have limited operating temperatures and may have difficulty operating at extremely low voltages. The nano-mechanical computer (NMC) as proposed in a recent article in *New Journal of Physics* is a robust alternative to conventional transistors, since it is based on so-called nano-electro-mechanical single electron transistors (NEMSET). These nano-scale switching elements may be readily constructed using standard integrated circuit techniques, and can operate at temperatures far exceeding conventional transistors (up to 500°C). They are inherently radiation insensitive, and the design holds promise for extremely low power dissipation. NMC have operating speeds on the order of 1 GHz. While this speed is not competitive with traditional complementary metal-oxide-semiconductor (CMOS) technology, it is sufficient for applications like cell phones, calculators and other micro-controllers that require robustness and low power consumption. ■

Robert H. Blick, **Hua Qin**, **Hyun-Seok Kim** and **Robert Marsland**,
'A nano-mechanical computer - exploring new avenues of computing', *New J. Phys.* **9**, 241 (2007)

Coherent harmonic generation on UVSOR-II storage ring

Future light sources aim at reaching sub nm wavelengths with fs pulse duration, preserving highest degree of coherence. In particular, accelerator-based light sources provide unique possibilities of tunability in a wide spectral range, brilliance, coherence, and adjustable polarization. In a Free Electron Laser, the interaction between an external laser and a relativistic electron beam leads to an improved longitudinal coherence and shorter sub ps pulses. In this article, we present one possible FEL configuration, so-called Coherent Harmonic Generation, operated on UVSOR-II storage ring. A commercial fs laser is injected inside a first undulator located on a straight section of the ring. The interaction between the photons and electrons allows delivery of coherent radiation in a second undulator, with harmonic content. The intensive investigations performed since 2005 on the third coherent harmonic radiation properties are reported. In addition to being of high interest for users' experimental studies, Coherent Harmonic Generation experiments provide significant insight for the future Linac based HGHG FEL sources, which should reach x-ray domain, with short pulse duration and high peak power. ■

M. Labat, **M. Hosaka**, **A. Mochihashi**, **M. Shimada**, **M. Katoh**, **G. Lambert**, **T. Hara**, **Y. Takashima**, **M.E. Couprie**,
'Coherent Harmonic Generation on UVSOR-II Storage Ring', *Eur. Phys. J. D* **44**, 187 (2007)



◄ Streak Camera snap shot in CHG operation at UVSOR-II storage ring. A streak camera is positioned at the output of the optical klystron, to collect the radiation, which consist in the undulators spontaneous emission (SE) and in the coherent radiation (CHG) generated thanks to the seeding laser injection. The bright blue spots on the image correspond to CHG on the third harmonic of the undulators fundamental (at 1 kHz), while the dark blue background corresponds to SE (at 5.6 MHz). The vertical axis provides the longitudinal distribution of the radiation (CHG pulses are found much shorter than SE). The horizontal axis provides the evolution in time of the radiation (during 5 ms in this case).

Model for ionization rate in He* collisions

Triplet metastable helium, He*, is long-lived with an excitation energy of ~ 20eV. When two He* atoms interact they can follow $^1\Sigma_g^+$, $^3\Sigma_g^+$ or $^5\Sigma_g^+$ molecular potentials. Only on the $^5\Sigma_g^+$ potential is Penning ionization forbidden, (hence spin polarization is needed for a BEC). Measurements have been made of ionization at mK temperatures in an unpolarized gas. How can theory describe these collisions?

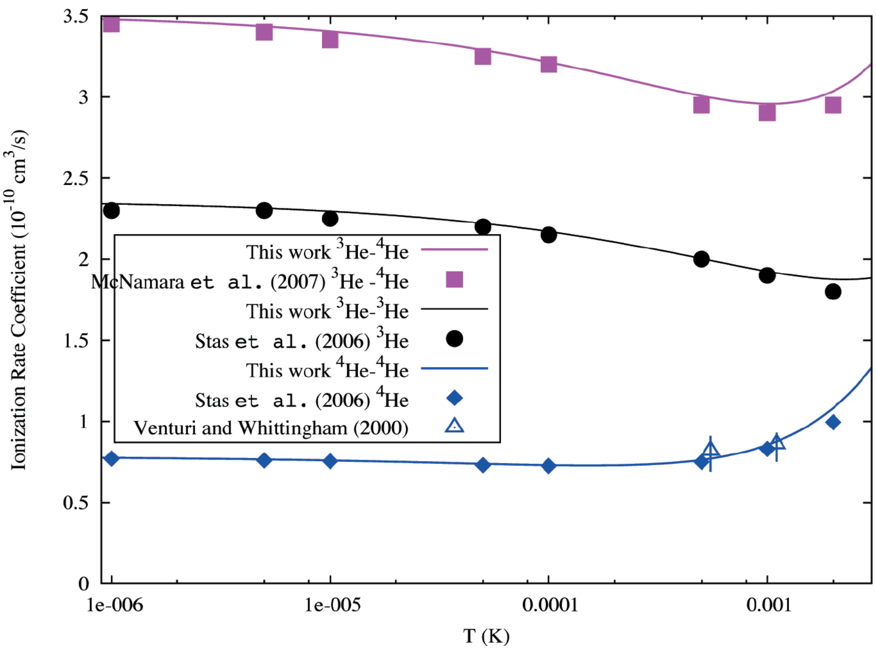
Following earlier work on ionization of metastable Xe, a key factor was identified by Wassen and colleagues - quantum reflection. For He* atoms at mK temperatures the typical de Broglie wavelength is » 1000 a_0, while in the $^1\Sigma_g^+$ or $^3\Sigma_u^+$ potential well the wavelength is ~ 0.5 a_0. Wassen's group solved for the transmission coefficient to short distances, where ionization was assumed to occur on *all* collisions. With this model they found good agreement with their measurements of ionization in ^{4}He* – ^{4}He*, ^{3}He* –^{3}He* and ^{3}He* –^{4}He*.

This model can be simplified further by using analytic results for near-threshold transmission on inverse-power potentials. Using just the C_6 coefficient and the assumption of 100% ionization on transmission, the complete process can be modelled in closed form.

In the figure this approximation is compared with Wassen's group's results and those from Whittingham's group, who used complex potentials. Similar agreement (not shown) has been obtained with the detailed calculations for Xe.

This model allows an easy estimate of the ionization rate coefficient and should also be applicable to other cold metastable rare gases. ■

A. S. Dickinson,
'Quantum reflection model for ionization rate coefficients in cold metastable helium collisions', *J. Phys. B: At. Mol. Opt. Phys.*, **40**, 237 (2007)



► Ionization rate coefficients for cold He* collisions. Note that the results of Venturi and Whittingham are shown, for clarity, at a temperature 10% higher than their calculations. The vertical line indicates the range of their values obtained with varying imaginary potentials. (References to be found in the article)

Improved calculations for the fine structure levels of Cl I

An extensive configuration-interaction (CI) calculation is made to obtain the oscillator strengths for all optically allowed and inter-combination E1 in Cl I between the fine structure levels of the odd-parity configurations $3s^23p^5$, $3p^4(^1D)4p$, $3p^4(3P)np$ ($4 \le n \le 5$) and the even-parity configurations $3s3p^6$, $3p^4(^3P,^1D,^1S)ns$ ($4 \le n \le 5$), $3p^4(^3P)6s$, $3p^4(^3P,^1D)3d$, $3p^4(^3P)4d$, within the Breit-Pauli approximation. A remarkable agreement is observed in the length and velocity forms of the oscillator strengths, demonstrating a marked improvement over previous theoretical work. The present results also conform with the majority of the experimental data. Alternative energy level classifications are proposed for a number of heavily mixed J = 5/2 and J = 3/2 levels based on the present calculations, which are supported by experimental measurements (see the table). ■

P. Oliver and A. Hibbert,
'Breit-Pauli Oscillator strengths for transitions among the fine structure levels of Cl I', *J. Phys. B: At. Mol. Opt. Phys.*, **40**, 2847 (2007)

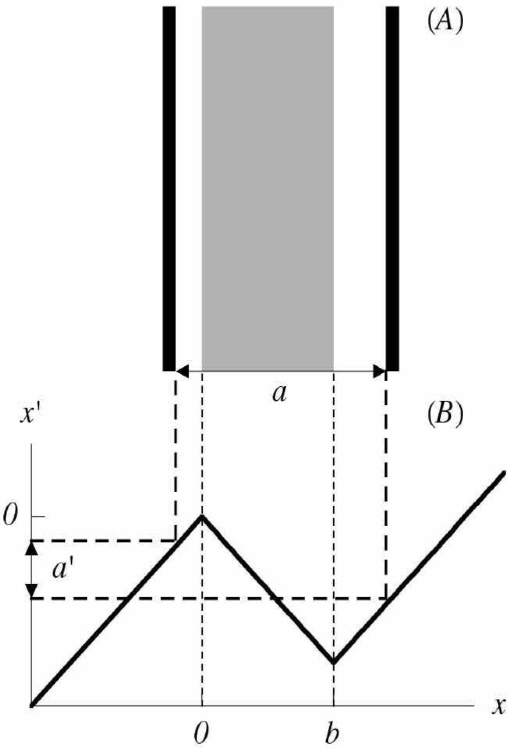
This Work			Biémont et al.		Ojha and Hibbert		
λ(Å)	Upper level	f_1	Upper level	f_1	Upper level	f_1	Expt.
1097	$(^3P)5s\ ^4P_{5/2}$	0.0022	$(^3P)3d\ ^2F_{5/2}$	0.0122	$(^3P)3d\ ^2D_{5/2}$	0.0423	0.0088
1088	$(^3P)3d\ ^2D_{5/2}$	0.0567	$(^3P)3d\ ^2D_{5/2}$	0.0688	$(^3P)3d\ ^2F_{5/2}$	0.0159	0.081
1095	$(^3P)3d\ ^2F_{5/2}$	0.0322			$(^3P)5s\ ^4P_{5/2}$	0.0011	

◄ Table: Comparison of our length form oscillator strengths f_1 for the lines at λ1088, 1097, 1095Å with other available theoretical and experimental work. The lower level of the transitions is $3s^23p^5\ ^2P^0_{3/2}$.

Quantum levitation by left-handed metamaterials

Metamaterials can be used to fabricate high-resolution "perfect" lenses and even invisibility cloaks. We reveal another surprising property of perfect lenses: they can reverse the direction of the attractive Casimir force between parallel conducting plates. As Hendrik Casimir demonstrated in 1948, in otherwise *empty* space the electromagnetic zero-point energy increases with the conductors' separation, whence the attractive force. Our analysis of the force-reversal exploits a special property of so-called left-handed metamaterials which make perfect lenses: the constitutive Maxwell equations for such materials are the same as they would be in an empty space obtained by changing the sign of the coordinate perpendicular to the optical axis of the lens. What is the implication for the Casimir force? Suppose that the space between the conducting plates is largely filled with a left-handed medium (see figure) and that the plates' separation is increased by a small distance. Because of the coordinate sign change, the zero-point energy behaves as it would in an empty space when the conductors are brought together - it decreases. The Casimir force is thus repulsive. We estimate that it could be great enough to levitate a 0.5 micron-thick aluminum foil. ■

Ulf Leonhardt and **Thomas G. Philbin**, 'Quantum levitation by left-handed metamaterials', *New Journal of Physics* **9**, 254 (2007)



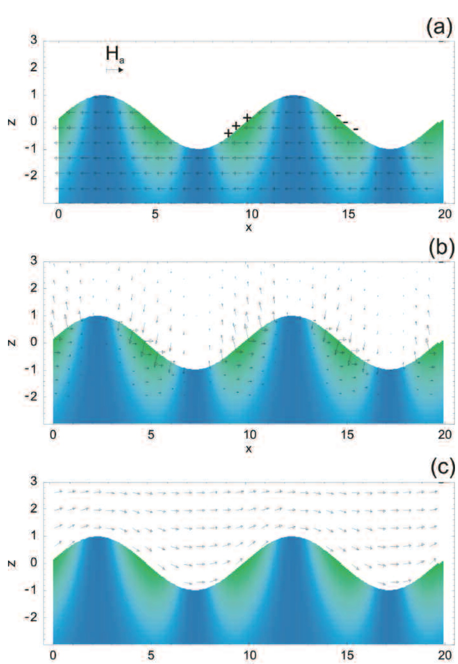
► In **(A)** a perfect lens of thickness b is sandwiched between two mirrors a distance a apart. **(B)** shows how the x-dimension in physical space is related to a transformed x'-dimension where there is no material and the electromagnetism is that of empty space. The separation between the mirrors in transformed space is a' = |a-2b|. Now if a < 2b, as is drawn, a decrease in the separation a' in transformed space corresponds to an increase in the separation a in physical space; the Casimir attraction in transformed space is turned into a repulsion in physical space.

How would a superconducting liquid flow in a magnetic field?

Superconducting samples lying around in the lab are all solids, and their melting temperature far exceeds the critical temperature. Nevertheless, there is no a priori requirement that superconductivity must occur only against a crystalline background. Phonons, the key to the BCS mechanism, are also present in liquid metals, and recent work by Babaev and co-workers surmise that liquid metallic hydrogen might be superconducting.

This paper describes how a hypothetical liquid that exhibits the Meissner-Ochsenfeld effect is influenced by an applied magnetic field. Clearly, both the hydrodynamical (flow) and the hydrostatic properties can be altered by the applied field. Droplets of the Meissner fluid deform due to the interplay between surface tension and demagnetization, and the applied magnetic field can be used to tune the droplet shape and oscillation frequency. A change in the frequency also occurs for surface waves (see Figure). A magnetic field applied parallel to the surface and orthogonal to the wave vector typically affects the dispersion relation most strongly for wave lengths of the order of microns to centimeters.

To demonstrate the predicted phenomena that mix superconductivity and hydrodynamics, it is proposed to use a colloidal suspension of coated superconducting nanoparticles, such as the samples investigated by Tao and co-workers. It would be hard to achieve perfect conductivity in these suspensions, but they do exhibit the Meissner effect and its hydrodynamic properties will be influenced as described in this work. ■



◄ The magnetization of a Meissner fluid with a surface wave is shown in panel (a); the applied field is parallel to the surface and to the wave propagation direction. The magnetization induces surface charges on the rising and descending wave slopes, as indicated. The shading (from dark blue - low to light green - high) indicates the concentration of magnetic charge. In panel (b) and (c), the demagnetization field and the total magnetic flux are shown, respectively

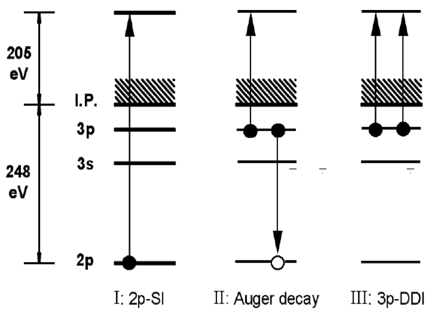
A. Maeyens and **J. Tempere**, 'Magnetohydrodynamic properties of incompressible Meissner fluids', *Eur. Phys. J. B* **58**, 231 (2007)

Inner shell single or direct double ionization in argon?

In recent years, it has become possible to experimentally study electron impact ionization processes in a kinematically complete way, that is to say to measure the correlated fragments from a collision process with their energies and angles resolved. Such coincidence experiments give a much deeper understanding of the dynamics of the collision process and the nature of the target wave-function than that which could be gleaned from a less differential measurement.

In Naja *et al* (2007) the method is applied to study the electron impact ionization of argon.

The kinematics were chosen in such a way that two different processes might compete, namely *3p* outer shell direct double ionization (DDI) and single ionization (SI) of the *2p* inner shell followed by Auger emission. Further, the energy of the ejected electron from the SI process was chosen to be identical to that of the Auger electron, thus the indistinguishability of the final



▲ Schematic diagrams to illustrate the 'routes' leading to the same doubly ionised final state.

state electrons adds a further level of complexity to the analysis of the data. However, the perfect accord that other studies have shown between theory and experiments for the SI process away from the region where double ionization and Auger contribute encourages the authors in the view that they can now for the first time estimate the effect of these processes.

A. Naja, E.M. Staicu-Casagrande, X.G. Ren, F. Catoire, A. Lahmam-Bennan, C. Dal Cappello and C.T. Whelan,
'An (e,2e) - (e,3e) investigation of argon: Competition between inner shell single ionisation and direct double ionisation processes', *J. Phys. B: At. Mol. Opt. Phys.*, **40**, 2871 (2007)

Thirsty passengers [DOI: 10.1051/epn:2007019]

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As a rule of thumb, commercial aircraft consume some 10 cm^3 of fuel per seat per second. That sounds like a lot. Imagine the whole cabin taking a sip each second, with the flight attendant beating time. Funny. But that's what the fuel consumption amounts to.

No wonder, one might think: at such tremendous speeds the drag must be enormous. Compare that with the slow boats of yesteryear, which took a week to cross the Atlantic. They must have been a lot less wasteful than those fast planes nowadays.

But wait: shouldn't we look at fuel consumption per *kilometer* rather than per second? Back to the rule of thumb: 10 cm^3 per second is 36 litres an hour, during which the plane flies some 900 km. That yields 4 litres per 100 km. Modern efficient aircraft do a bit better than the rule of thumb, and arrive at, say, 3 litres per 100 km. So: two passengers consuming a joint 6 litres per 100 km are just as wasteful as if they were sharing a reasonably efficient car.

What about the slow boat? Surprise. A large passenger boat or a cruise ship consumes about 25 litres per 100 km per passenger. Despite its moderate speed, the boat is much worse than the plane, in terms of fuel consumption per passenger km. How come? A bit of physics leads the way. Of course, the drag is determined not only by speed but also by the density of the fluid. Water and air differ by three orders of magnitude. It's even more than that: since commercial aircraft cruise at 10 km, and since the density goes roughly as exp(-h/8km), they cruise at roughly1/4 of the standard value.

But perhaps the biggest difference is the payload. On a cruise ship, the mass of the passengers plus their luggage typically amounts to a few tenths of a percent of the total mass. The reason, of course, is that a cruise ship is a floating village, with shops, restaurants, swimming pools and the like. Even a huge modern vessel such as the Queen Mary 2 with its 150 000 tons carries 2600 passengers only. Compare that with a big airliner. The total mass of its passengers is well above 10 % of the aircraft.

One can agree that: in the interest of energy and the environment, we travel much too much, kerosene is much too cheap, and we fly much too often. But if we *have* to, crossing the Atlantic by boat would be even worse. ■

Physicist glances at cultural heritage

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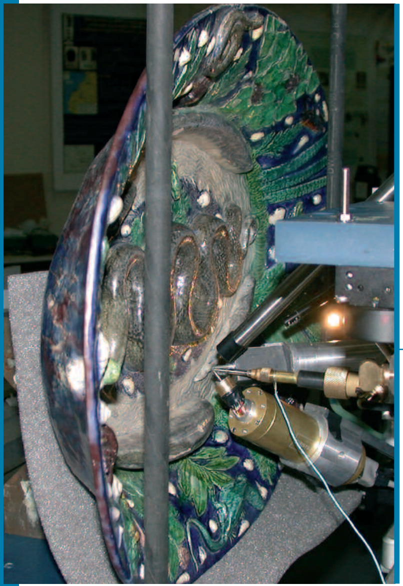
It is nowadays regarded as a necessity to preserve the past production of human activity, as well as to understand the knowledge and the skills associated with the objects; hence the development of many disciplines such as history, archaeology, conservation, life science, physics, chemistry, *etc.* applied to cultural heritage. Multidisciplinary investigations are currently performed by curators, chemists, physicists, geologists, conservators *etc.* that aim at helping the restoration and the conservation of objects as well as improving the understanding of their fabrication by ancient artists or craftsmen, and of their use. Specific analytical techniques have been implemented, of which many derive from physics.

Multidisciplinary and multi-scale examinations of objects are a prerequisite to any detailed analytical investigation. This is the domain of historians and curators. In addition to direct visual observation, these specialists are helped by the use of various electromagnetic radiations such as infra red, ultra violet and X rays. The radiography of paintings has been performed more than 10,000 times since it began in the 1920's. These techniques give information beyond the surface and allow the discovery of details about the fabrication of the objects or about their deterioration or their ancient restoration. An example of such a multidisciplinary research was undertaken recently on the *Mona Lisa* by Leonardo da Vinci. All the partners of the C2RMF, curators from the Louvre Museum associated with specialists of French and Canadian research centres, developed a common study of the famous painting [1].

Resulting from such investigations, many questions are often raised concerning the origin and the processing of the materials, the alteration of the object, the date of manufacture, *etc.* To attempt to bring answers, it is necessary to use various types of analytical techniques dealing with the electrons and the nuclei in order to determine detailed characteristics of the materials, such as chemical compositions, atomic arrangements in molecules or in crystals, lattice imperfections, *etc.*



◀ **Fig. 1:** View of a colourful ceramic platter in position for PIXE/PIGE analysis with AGLAE. The horizontal pipe holds the beam exit window; it is surrounded by various types of detectors and art work monitoring devices.

Dating past events (geological events, evolution of living species, *etc.*) is fascinating ; nuclear physics is involved in most of the dating techniques. Applications to cultural heritage studies are useful mostly for the past 20-30000 years and exceptionally for older times. For such a time span, ^{14}C is particularly suited (the ^{14}C half life is 5730 years) to date organic materials left by living species when they stop being in chemical equilibrium with their environment. The decay of radioactive ^{14}C is directly related to the age of the death of animals or plants. It requires the measurement of $^{14}C/^{12}C$ ratios less than 10^{-12} that is currently carried out by accelerator mass spectroscopy (AMS). AMS gives dates with very small amounts of carbon (1 mg) and has such a sensitivity that ages as old as 50000 years are determined [2]. In a detailed study concerning the disappearance of men from Greenland around 1500, the change of diet composition was tracked from terrestrial to marine food according to the concentrations of the stable carbon isotope ^{13}C [2].

As a complement to the previous technique, thermoluminescence (TL) dating is applied to minerals; it has been used to date ancient ceramics for the last 30-40 years [3]. TL is a universal tool for dosimetry; it applies to heated minerals giving the possibility of measuring the total dose of natural radiation recorded since the last temperature increase (T>350°C). In order to calculate the "age", the annual dose rate must be known for the whole life of the artefact after the thermal event. The dose rate is related to the concentrations of radio-elements (uranium, thorium, potassium) inside the object and in the environment [3]. Errors on "age" can be as small as 5-10% in the best cases. Among many sources of uncertainty are the unknown humidity level in the objects during their storage and also the possible application of ionizing radiation, mostly X or g rays, that induces an artificial ageing (laboratory study, airport safety, *etc.*) [3]. In spite of these limitations, TL dating is commonly used, not only in archaeology, but also for museum collections and in the art market where the results should be considered with some caution.

The strategy of analysis depends on many parameters such as the questions to be answered, the nature of the materials (organic, mineral), their alteration with time, the necessity of non-destructive analysis, *etc.* This approach is at the encounter of humanities, earth sciences, chemistry and physics. A large variety of materials are currently studied, from metals, ceramics, stones to organic materials. The present article gives examples related to inorganic materials. The techniques used for the analysis of materials (X ray fluorescence, electron microscopy, X ray diffraction, infra-red absorption, *etc.* in the laboratory or at synchrotron radiation facilities) all derive from physics. Several important techniques used at the C2RMF involve ion beam analysis (IBA); the C2RMF has been pioneering in IBA of art works thanks to the design and construction of an attachment for non-destructive analyses at atmospheric pressure [4].

Ion beam analysis of chemical elements

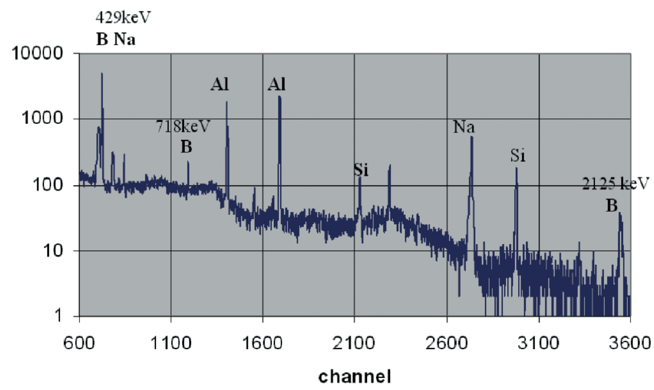
Materials are fully characterized once the chemical composition, the crystal lattice and the microstructure (grains, lattice imperfections, *etc.*) of the various phases are determined. This requires extensive investigations. Chemical element analysis is the most common because it is done by the spectrometry of X rays emitted under the impact of X rays (fluorescence; XRF), of electrons in a scanning electron microscope (SEM-EDX) or of particles (Particle Induced X-ray Emission, PIXE) in an accelerator such as AGLAE (Accélérateur Grand Louvre d'Analyse Elémentaire located at the C2RMF). XRF and PIXE are performed directly at atmospheric pressure without taking specimens from the objects; they are non-destructive and give information on the superficial layers (10-50 µm from the surface). SEM-EDX is routinely used because it combines imaging and analysis; small samples (usually less than 1 mm) have to be taken from the art works when the whole object cannot be inserted in the vacuum chamber of the SEM.

AGLAE and its applications have been described in many publications [4 - 6]. The equipment is based on a 2 MV NEC tandem accelerator 5SDH-2 that is used with beams of protons, deuterons and α-particles, and less frequently of heavier ions such as O or N. The beam exits to the atmosphere through a 0.1 µm thick window made of silicon nitride. This external beam allows the analysis to be performed, usually in a flow of helium, at atmospheric pressure (figure 1), thus avoiding the need to introduce the objects into a vacuum chamber with the risk of damaging fragile art works. With this system, beam diameters as small as 20 µm are currently achieved.

All the ion beam analysis (IBA) techniques are available at **AGLAE**. PIXE is the most common analysis because it readily gives quantitative compositions and it has limits of detection (typically 5-10 ppm) much lower than SEM-EDX (0.1%) because of the reduced "brehmstrahlung" for heavy particles. PIXE, SEM-EDX and XRF have the same limitations for the analysis of light elements, i.e. below sodium in the periodic table. This difficulty is overcome with **AGLAE** by using nucleus transitions associated with γ ray emission (Particle Induced Gamma Emission, PIGE) or nuclear reaction analysis (NRA), thus giving access to fluorine, boron, nitrogen, *etc.* in art works.

Depth profiling near the surface can be obtained by these techniques, for instance using beams inclined at various angles in PIXE/PIGE or using resonant NRA. However, such profiling is usually made at **AGLAE** by Rutherford back-scattering (RBS), most often with incident α-particle beams [5]. Hydrogen profiling has also been performed by elastic recoil detection analysis (ERDA) with α-particles [7].

In the following, we give two examples to illustrate these techniques applied to ceramics, with first a PIGE analysis of boron in glazes of wares fabricated between the middle age and the 19th century and second a PIXE / RBS study of lustre on Hispanic ceramics.

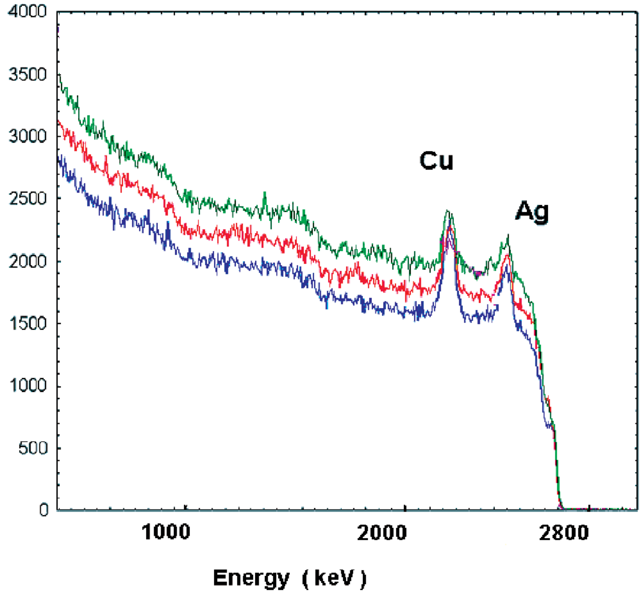


▲ **Fig. 2:** PIGE spectrum of the glaze of a ceramic platter possibly made by Bernard Palissy. The glaze is on a snake (figure 1) and is grey; its B_2O_3 concentration is 1.1%.

Boron has appeared in glasses in the 17th-18th century with a massive presence in the 19th century due to a decrease of its price after the discovery of large quantities of borax in Death Valley (California) [8]. Boron cannot be detected by PIXE, then, we use PIGE induced by 3 MeV protons. The emission of γ rays corresponds to the reactions displayed in table 1; a spectrum for an ancient ceramic glaze (figure 1) is shown in figure 2. The concentrations for the three emissions of boron are used to verify that there is no coincidence in γ emission energy with other nuclei, giving thus reliable results. The concentration c is determined from the ratio of the peak areas of the art work (figure 2) to a standard for boron.

We have examined 33 ceramic objects covered with glaze produced between the Middle Ages and the 19th century to check for the presence of boron. Each object was submitted to one or two PIGE measurements. In the example of figure 2, the presence of boron confirms that the ceramic platter is not from the renaissance, but very likely a 17th century fabrication.

Indeed, among the 33 objects, there were medieval tiles from the "châteaux de Vincennes" and objects from Arras. From the Renaissance, PIGE was performed on fragments of objects from the Della Robbia's activities between 1450 and 1550, tiles made by Masséot Abaquesne who died in 1564, and shards of Palissy (1510 - 1590) wares found at the time of excavations made near the Louvre museum in the 1980's. In none of these objects, the concentration of B_2O_3 is above the detection limit that is around 0.05 % (weight percent). A number of glazes on ceramic wares from followers of Palissy contains B_2O_3 concentrations between 0.2% and 0.75%. Finally, PIGE was performed on various colours of two glaze palettes made by Avisseau (19th century); B_2O_3 concentrations between 3% and 15% have been found in 7 cases out of 35 PIGE ···



▲ **Fig. 3:** Rutherford backscattering spectra (RBS) obtained at one helium atmosphere taking three different points on a lustre ceramic ware (RFM 3) from Seville. A 50µm diameter 3 MeV α-particle beam was used. The spectra were simulated with SIMNRA [11] to obtain the concentration profiles of the various elements; they correspond to atomic concentrations of 4% Ag and 18% Cu in a 110 nm thick glaze layer at the surface.

••• measurements. The present results on glazes are in agreement with those found for glass [8].

In the last few years, there has been a strong interest for ancient lustre ceramics that have been investigated using SEM, transmission electron microscopy (TEM), X-ray diffraction, IBA, *etc*. [9 - 11]. Lustre is a ceramic decoration that appeared in the 9th century in the Middle East and spread around the Mediterranean basin in the following centuries. Lustre gives a metallic aspect which is due to copper and silver nano-particles distributed into a thin layer under the glaze surface. These particles can be visualized by TEM [9]. RBS provides a fast and universal technique to obtain concentration profiles of copper and silver in art works; it is non-destructive and is currently performed on valuable lustre ceramic wares from museum collections [10]. A study has been recently performed on shards excavated from a workshop in Seville that was unknown for any production of lustre ceramics [11]. The chemical composition of the glazes, determined by PIXE is typical of the Iberian production with 50% SiO_2, 35% PbO, 7% SnO_2. Concentration profiles have been determined by RBS. In places, the profiles show a loss of lead due to surface weathering during the underground storage over centuries [11]. The lustre layers are revealed by the Ag and Cu peaks (figure 3), both elements being present in all the lustre objects from Seville. Quantitative profiles are obtained with the SIMNRA simulation code. The layers containing the metallic particles are particularly thin (100-200 nm) and generally not covered by a 20-100 nm glass layer commonly found in other productions; they are rich in Cu. The ratio of Ag to Cu concentrations is found to vary considerably with the origin of the wares, lustre ceramics rich in Ag being yellow and those rich in Cu being red. External beam RBS is a very convenient non-destructive technique to obtain characteristics of art work sub-surface layers, as in the case of lustre ceramics [11].

Potters making lustre ceramics can be considered as early "nanotechnologists". However, nanoparticles were produced even earlier in dyeing hair and wool black [12]. It is important that the dyeing treatment leaves unchanged the mechanical properties of the fibres; this is achieved by 5 nm size PbS grains aligned along the axis of the hair, produced according to a recipe applied during the last 2000 years to darken hair. These ancient formulas included $PbO+Ca(OH)_2$ [12], lead acetate being present now in a popular men's hair colouring available in the market. This opens a possible inexpensive way to produce semiconductor quantum dots!

Synchrotron radiation

Synchrotron radiation methods find increasing number of applications in the field of cultural heritage. This has prompted the creation of dedicated committees at synchrotron facilities (for example, "Environmental and Cultural Heritage matters" at the European Synchrotron Radiation Facility; ESRF). Similar to **AGLAE**, synchrotrons offer powerful techniques combining high lateral resolution, high sensitivity, and, in addition, access to other physical and chemical information. Examples of application are various, going from "hard matter", studying corrosion in ancient metals or decoration of jades, glass or bronzes, to "soft matter", such as paper, textile, wood and passing through hybrid materials such as cosmetics or paintings.

In cosmetics from ancient Egypt, lead compounds are ubiquitous, with mostly black lead sulphide (PbS) and white lead carbonate ($PbCO_3$) in eye make-up [13]. Unexpected white constituents (laurionite PbOHCl; phosgenite $Pb_2Cl_2CO_3$) have been identified by X-ray diffraction; these compounds are not found in nature and have been synthesized in ancient Egypt by wet chemistry [13]. Laurionite and phosgenite were added because of their pharmaceutical properties. The microstructure of lead compound grains was evaluated by analysing the diffraction peak broadening and by TEM to identify the powder processing (grinding, thermal treatments, wet chemistry) for the cosmetic manufacture [14,15].

High energy X-ray radiations could be particularly suited for painting analyzes. Studies can be performed directly on the entire painting such as, for example, by K-edge imaging (radiography with X-rays of energy below and above the absorption edge), which will offer a direct visualization of the elemental distributions at the painting scale. But, analyses are generally carried out on micro-samples taken from the art work. The success of synchrotron techniques for such studies is linked to the intrinsic characteristics of the paintings that make classical analyses very hard. First, the amount of matter is usually tiny (less than 1 mm thickness), hence requiring sensitive techniques. Second, paintings always exhibit multi-layered structures, with layer thicknesses of ~10 µm; this leads to the favouring of micro-imaging techniques, with a good lateral resolution (about one micrometer). Third, painting fragments are very complex in term of chemistry, as they are made of mineral and organic matters, amorphous and crystallized phases, major and minor elements. Accordingly, a multi-modal approach is usually essential to solve the chemical complexity of such hybrid materials. In particular, the combination of micro X-ray fluorescence, micro X-ray absorption near edge spectroscopy (XANES), micro X-ray diffraction and micro-FTIR (infrared) spectroscopy is a key tool for the complete elucidation of painting compositions in order to derive information on its history (painter techniques, pigment synthesis, authentication…) and on its preservation for the future (mechanisms of degradation, processes of restoration…).

As an example, the combination of micro X-ray fluorescence (μ-XRF) and micro X-ray spectroscopy (μ-XANES) was successfully employed to explain the blackening processes damaging red Pompeian paintings [16]. The conservation of Pompeii and surrounding cities is crucial because these cities are unique snapshot of the every-day life in the Roman Empire at the beginning of the 1st century. Unfortunately, some of the beautiful red wall paintings, which contributed to the Pompeii reputation, are suffering from degradation following their excavation. Many paintings are covered with a deep red pigment, mercury sulphide (HgS), commonly named cinnabar. Since Antiquity, this pigment is known to be potentially unstable. Indeed, in certain circumstances, it can turn into sad grey-black shades (Figure 4, left).

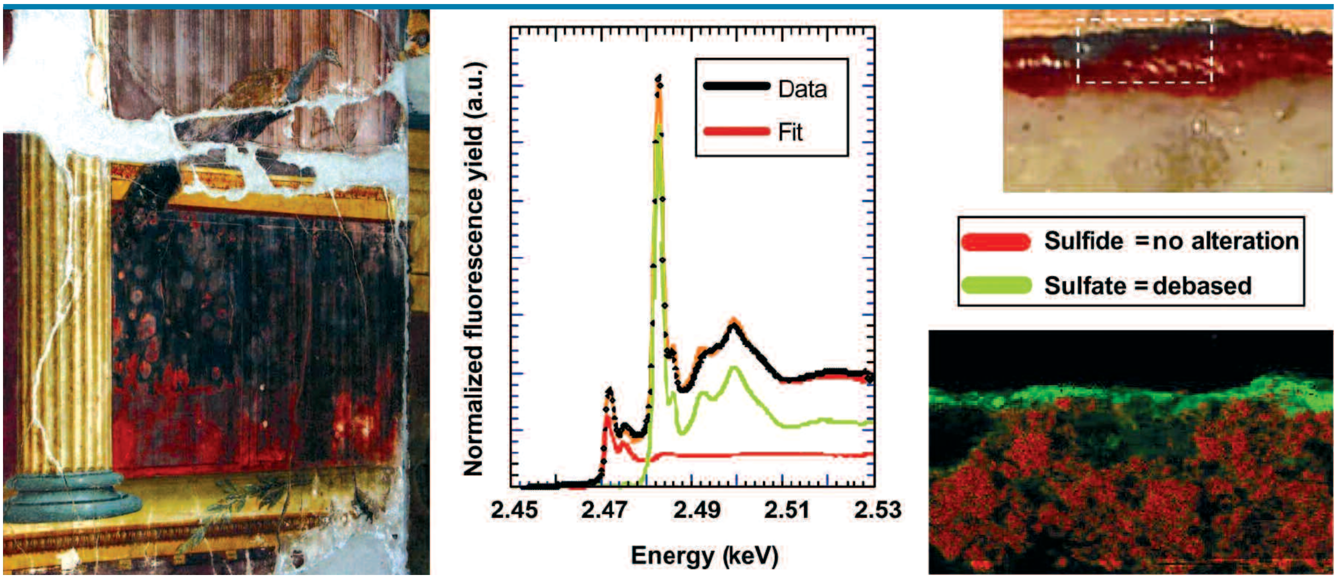
The common assumption proposed to explain this phenomenon is the phase transformation of red cinnabar (hexagonal phase) into black meta-cinnabar (cubic phase) under light. Different analyses were performed at the ID21-beamline (ESRF) to tackle this problem [16].

Micro X-ray fluorescence signals were mapped over pink, grey or black surfaces. Thus, elemental distributions and colours were directly correlated. Two main elements revealed a clear correlation with alterations. Chlorine was found to be associated with a grey alteration. Chlorine K-edge spectroscopy (XANES) demonstrated that it was involved in various species: NaCl and lilac-grey mercury-chalcogen-halide/oxide phases. Analyses performed on darker parts of the painting, showed a high accumulation of sulphur without chlorine. X-ray absorption spectroscopy (XANES) at the sulphur K-edge revealed the speciation of sulphur and refuted the hypothesis of a phase transformation into meta-cinnabar. Amazingly, instead of this suspected phase, another compound was identified: calcium sulphate, namely gypsum (Figure 4, middle). So, instead of a "simple" phase transition, sulphur was subjected to oxidation going from a reduced sulphide (S(-II)) to an oxidized sulphate (S(+VI)) state. Most presumably, this gypsum ($CaSO_4 , 2H_2O$) results from the reaction of SO_2 with the calcite ($CaCO_3$) present in the mortar. This assumption is supported by the fact that chlorine can catalyse the linkage reaction $HgS \rightarrow Hg + S$, thus providing a source of sulphur for further reactions with the oxygen of air and the final formation of SO_2.

Taking benefit from the clear difference of oxidation between original cinnabar (reduced sulphur, S(-II)) and debased sulphur (sulphates, S(+VI)), it was possible to map the distribution of the different species, by tuning the excitation energy at 2.472 and 2.482keV respectively. In this way, maps of the two kinds of sulphurs were obtained on the surface of different fragments [16]. In addition, an in–depth analysis was also performed. The question was how to image the diffusion of the alteration process inside the pigment layer. A sample was embedded in resin and polished perpendicular to the surface. Therefore, all the layers were accessible from the mortar to the surface. The pigment layer was 100 μm thick (figure 4, right, upper) rendering the use of micro-probe essential (0.7μm horizontal by 0.3μm vertical). Figure 4 (right, lower) shows that debased sulphates (in green) are present in a very thin superficial layer of about 5μm. Below, a thick layer of intact cinnabar (in red) is still present.

This work refuted the classical explanation proposed for cinnabar blackening. Instead, a complex pathway involving the reaction of both chlorine and sulphur dioxide was identified [16]. This study exploits the high spatial resolution, low •••

▼ **Fig. 4:** Darkening of cinnabar (HgS) mural paintings from Pompei. Left; photograph of a damaged zone (provided by M. Pagano). Middle; micro-XANES at the sulphur K-edge. The experimental data (black) are fitted by a combination of cinnabar (red) and gypsum (green). Right; cross-section of a painting sample observed in optical microscopy (upper), a detail being mapped by micro-XANES (lower), showing the distribution of the various sulphur species.



••• detection limit and high chemical sensitivity provided at the ESRF – ID21 X-ray microscope, in particular in the XANES mode. A complete elucidation of this phenomenon will require the analysis of a wider variety of samples originating from various environmental contexts (inside or outside buildings; in various climates; with or without protecting overlayer…).

A similar set-up was recently and successfully used to identify uncommon pigments in 16th century paintings. The aim of the study was the elucidation of the Grünewald technique to render metallic aspects in several of its masterpieces (the *Isenheim Altarpiece* and the *Basel's crucifixion*). The same combination of micro-fluorescence and micro-X-ray absorption provided images of micrometer grains of grey stibnite (Sb_2S_3) dispersed in a lead white matrix [17].

Yet, paintings are not made only of minerals. They can also be composed of organic matter, which can vary depending on the layer (gluing layer, ground layer, priming layer, coloured layers, glazes, varnishes, restoration layer). FTIR spectroscopy has already demonstrated its ability for the identification of the various organic material used in paintings (oil, resin, gum, protein…). The combination of a microscope with FTIR spectroscopy was a decisive step for the study of painting as it was possible to see and to choose the location of the spectrum acquisition. An even more decisive step was achieved thanks to the synchrotron sources which provide a much brighter source compared to usual thermal sources. With such equipment, the beam size can be easily lowered below $10 \times 10\ \mu m^2$ without significant lost of flux [18-19]. This latter possibility is essential for the discriminative analysis of each layer of the painting. Recent analyses of paintings from various times and various places should be published soon.

Conclusions and perspectives

The aims of heritage research are to understand the past through the study of objects, establishing detailed information on date, place, technology, materials, *etc*. The efforts in investigating and preserving the heritage are steadily growing in our societies. Through a few examples, we hope to have shown the importance of advanced tools derived from various fields of physics. The laboratory of C2RMF provides an easy access to **AGLAE** for IBA studies of art works that come on a daily basis from nearby museums. **AGLAE** is unique because it is dedicated to non-destructive analyses of art works and has been used in collaboration with curators for more than a decade. Thanks to the support of the European union (EU-ARTECH programme), **AGLAE** is also accessible to researchers from other countries for cultural heritage investigations. New laboratory techniques involving small size beams for 3 dimension analyses are now in development. These take advantage of the progress in sources, optics and detectors, that derive from facilities existing at synchrotron radiation facilities.

Non-destructive analyses are the best approach for art works. However, transportation of valuable or oversize objects is at present a strong limitation on their study at large scale facilities. Portable light weight systems are an alternative and are already available for X-ray fluorescence and diffraction, infra red and Raman spectroscopy, *etc*. Other portable instruments are in development that will extend this approach in the study of cultural heritage objects.

γ energy	429 keV	718 keV	2125 keV
Reaction	$^{10}B\ (p, \alpha_1\ \gamma)\ ^{7}Be$	$^{10}B\ (p, p_1\ \gamma)\ ^{10}B$	$^{11}B\ (p, p_1\ \gamma)\ ^{11}B$
Yields at 3.1 MeV	7.2×10^6	1.3×10^6	4.8×10^6

▲ **Table 1:** PIGE conditions for the analysis of boron

Progress in the knowledge and the conservation of heritage depends not only on the availability of complementary analytical techniques, but also on the close collaboration of many disciplines including physicists, geologists, chemists and curators, art historians, conservators, archaeologists, *etc*. a condition that is not always easy to fulfil. ■

About the authors

The research activity of **J.Castaing** derives from his background in solid state physics and materials science that he applies to the study of heritage objects. After gaining his Ph.D. from the University of Orsay, he joined the CNRS to create a research group on the plasticity of ceramics and spent several years in the USA and in Spain. He has had a number of additional responsibilities, in particular, Head of the laboratory CNRS UPR 1341, Advisor of the "Ministre de la Recherche", *etc*.

After gaining the "agrégation" of chemistry at the "École Normale Supérieure" of Lyon, **M.Cotte** obtained her PhD for her research, at the C2RMF, on lead-based cosmetics and pharmaceutical compounds used in Antiquity. During her post-doc at the ESRF, she has enlarged the application of micro X-ray and FTIR spectroscopies to paintings.

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Cosmic rays studied with a hybrid high school detector array

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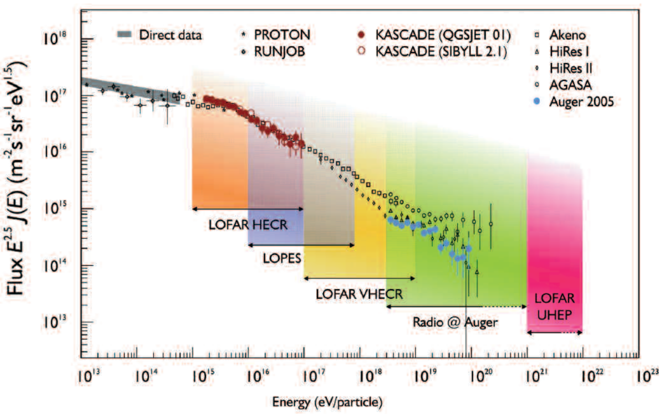
"Cosmic rays" is the generic name for different types of particles that hit the Earth's atmosphere with about the speed of light, varying in energy over a wide range. It was found that with increasing energy the number of cosmic rays arriving at the Earth drops sharply, see the flux-power spectrum in Fig. 1. The cosmic ray (CR) composition consists of protons (86%), α-particles (11%), nuclei of heavier elements (1%), electrons (2%) and neutrinos (<1%) [1]. Most cosmic rays up to Gev energies are thought to be produced in our galaxy by stars and beyond these energies in supernova remnants (SNR); however the origin of the highest energetic particles is still unclear. An upper limit to the energy has been observed around 100 EeV (GZK cutoff [2], [3]). A uniform distribution on the sky strongly indicates that the highest energy CRs are produced in a variety of distant extra-galactic sources. Source candidates are collimated relativistic matter streams (jets) associated with galaxies emitting powerful radio emission (radio galaxies), as well as radio-loud young galaxies called quasi-stellar objects (quasars). Furthermore, bursts of high frequency electromagnetic emission called gamma ray bursts (GRBs) and magnetars, which are very compact stars with strong magnetic fields, are also candidates for the origin of the high energy CRs since they may be capable of the extreme particle acceleration required.

In the Earth's atmosphere these CRs initiate a cascade of particle collisions in which a large multiplicity of secondary particles of all kinds are produced. The creation and annihilation of particles in the cascade establishes a so-called air shower pancake traveling through the atmosphere. Additionally, the charged particles in the pancake - mainly the electrons and their counterparts the positrons - get deflected in the Earth's magnetic field and emit beamed coherent radiation called geosynchrotron emission [4]. The number of particles in the air shower and the peak voltage of the radio emission detectable on the ground depend approximately linearly on the energy of the primary particle. The radio emission increases with increasing angle between the cosmic ray trajectory and the Earth's magnetic field [5].



▲ **Fig. 1:** Cosmic ray energy flux spectrum. The flux has been multiplied by a factor of $E^{2.5}$. Picturing the spectrum as an extended leg, the so-called knee and ankle are clearly visible at energies of about 3 PeV and 4 EeV, respectively. The very high energy cosmic rays (VHECR) are of interest for NAHSA and LORUN, which are sensitive to energies beyond 100 PeV (PeV = 10^{15} eV; EeV = 10^{18} eV).

▲ **Fig. 2:** LORUN antenna and the team of students that have been working on it on top of the building of the Radboud University Nijmegen (from left to right: Stefan Jansen, Karel Kok, Andra Verstee, Andreas Nigl, Jaap Kroes, Sandra Petrovic and Pim Schellart). The green LOFAR prototype antenna in the middle accommodates two (crossed) inverted-v-shaped dipoles in the legs of the PVC structure connected to two low-noise amplifiers (LNAs) located in the top box. The middle pole contains two cables for power and two for signal from the LNAs to the receivers.

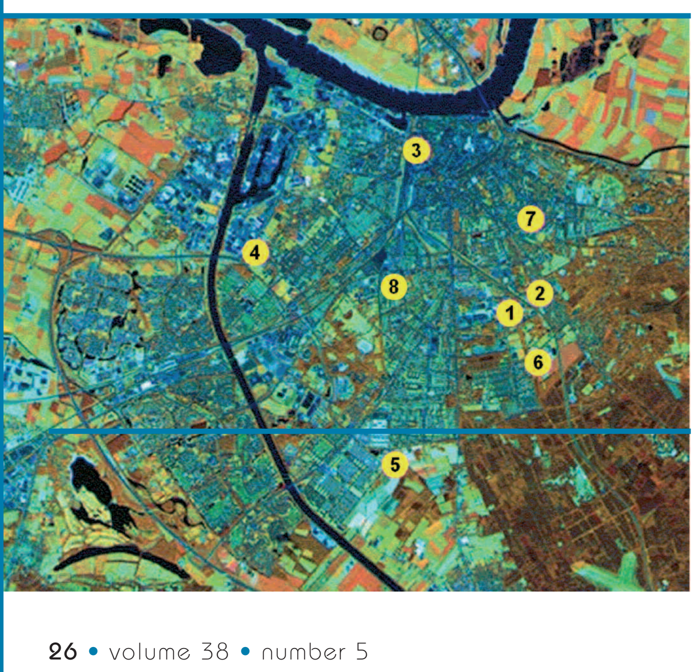
Why air showers?

Every second, one low energy cosmic ray particle is hitting every square meter of the Earth's atmosphere. The resulting shower is attenuated in the atmosphere before reaching the ground and can, however, only be detected directly by a detector on a plane or balloon. The latter is the way cosmic rays have been discovered in 1912 by Victor F. Hess [6]. High energy cosmic rays hit an area of a square kilometer only once per year, thus requiring an expensive detector covering a large area for an effective measurement. On the other hand, from the air shower initiated by the primary particle, several hundred thousands of particles reach the ground within a radius of a few hundred meters, depending on the energy of the cosmic ray. Therefore, analyzing the shower to infer information •••

... about the cosmic ray particle is much more efficient. The largest cosmic ray detector, the Pierre Auger Observatory (www.auger.org) is currently under construction in Argentina, South America, and it is named after the discoverer of particle air showers [7]. This instrument detects the air showers mainly with particle detectors covering an area of 3000 km^2. The number of particles measured by the particle detectors allows one to estimate the energy of the primary particle, the direction of origin, and to find the lateral extension from a shower core, which depends on the species of the primary particle [8]. Next to particle detectors, four air fluorescence detectors measure the fluorescence light yield of about 10% of all detected showers.

▲ **Fig. 3:** Twin particle detector station on top of the building of the Radboud University Nijmegen. The ski boxes accommodate scintillator plates connected to a photo multiplier tube (PMT). The two poles between the ski boxes carry a weather station and the GPS for timing information. An analog signal cable runs from each box to the coincidence electronics.

▼ **Fig. 4:** Nijmegen with the locations of the NAHSA twin detectors and LORUN at position 1 on top of the building of the Faculty of Natural Sciences of the Radboud University.



In The Netherlands, ASTRON is building the largest low frequency radio telescope, which is called LOw Frequency ARray (LOFAR, www.lofar.org) and will be able to detect the radio emission from air showers with about 5000 small radio antennae grouped into about hundred stations of 200×200 m^2. Currently three test stations for LOFAR exist, two of which are optimized for cosmic ray air shower measurements. The first is the LOfar PrototypE Station (LOPES, www.lopes-project.org), which is made up of 30 simple dipole antennae to measure radio emission from all directions and became operational in March 2003. LOPES is triggered by particle detectors of the KArlsruhe Shower Core and Array Detector (KASKADE, www-ik.fzk.de/KASCADE_home.html) situated on the Forschungszentrum Karlsruhe in Germany. The second prototype was built in December 2004, it is called LOfar at Radboud University Nijmegen (LORUN), and it is made up of four (crossed) dipole antennae on top of the building of the Radboud University Nijmegen (see Fig. 2). LORUN is triggered by two particle detectors, which are part of the High School Project on Astrophysics Research with Cosmics (HiSPARC). The pulse detected in the electric field of each antenna carries information about the longitudinal development of the shower such as the atmospheric depth at which the shower emission was maximal. This emission maximum provides a measure to distinguish between different species of primary particles. Furthermore, the radio antennae can be used as an interferometer to improve the accuracy in determining the direction from where the cosmic ray came [9].

High school arrays

Projects such as HiSPARC (www.hisparc.nl), the California HIgh school Cosmic ray ObServatory (CHICOS, www.chicos.caltech.edu) or the Stockholm Educational Air Shower Array (SEASA, http://neutrino.phys.washington.edu/~walta) place particle detectors on top of buildings such as, for example, schools and universities. Those particle detector arrays are scientifically interesting, since with the large area they cover, they contribute to the world record number of detected ultra high energy cosmic rays (UHECR). Furthermore, the high school arrays could be sensitive to the Zatsepin–Gerasimova effect [10,11], in which highly energetic nuclei disintegrate in interactions with solar photons. As a result two simultaneous air showers could be observed on Earth. The confirmation of this effect would prove that a part of the high energetic radiation originates from interacting nuclei.

The HiSPARC project is made up of five clusters located in five Dutch cities. One cluster is the Nijmegen Area High School Array (NAHSA, http://hisparc.hef.kun.nl) in Nijmegen, which has been taking data since June 2002 and provides the triggers for the LORUN radio antennae. The other clusters are on buildings in Amsterdam, Leiden, Utrecht and Groningen. In the scope of HiSPARC, high school students receive hands-on training about how to build a particle detector and learn about its scientific applications. As a result, students extend the array and gain access to astro-particle physics and scientific instruments.

HiSPARC/LORUN Setup

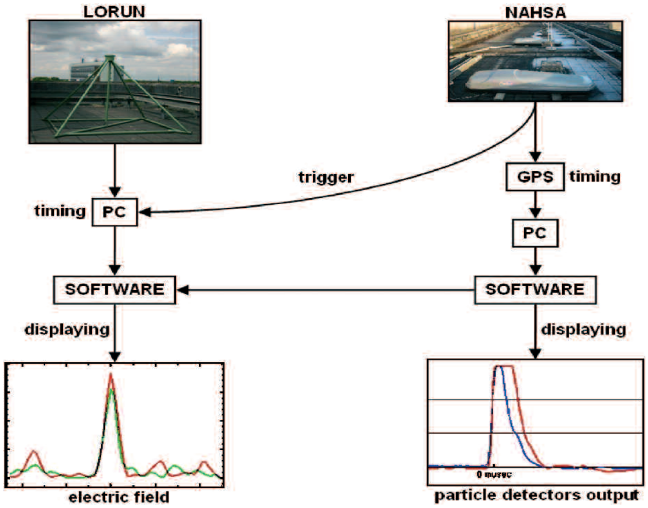
Two particle detectors and four radio antennae have been placed on the roof of the building of the Faculty of Natural Sciences of the Radboud University, Nijmegen. The radio antennae and the data acquisition hardware for LORUN were provided by the Netherlands Foundation for Research in Astronomy (ASTRON, www.astron.nl). Each LORUN antenna accommodates two crossed dipoles, which are facing azimuth directions of 330° and 60°. Each dipole's signal is amplified and pre-filtered by a low-noise amplifier (LNA), further filtered by a band pass filter for the frequency band from 40 to 80 MHz and then digitized. The high performance Analog-Digital Converters (ADCs) combine a dynamic range of 12 bit with a rate of 80 million samples per second, which translates to a time resolution of 12.5 ns and a data rate of ~150 MB per second per channel (dipole). Because of the inverted-V-shape design of the antenna dipoles, the whole sky is instantly measured with a primary beam of 90° centered on the zenith.

The LORUN antennae are located near two scintillator-particle detectors of NAHSA accommodated in ski-boxes (see Fig. 3). NAHSA is made up of in total 8 twin detector stations of 0.5 m^2 each, located on high school buildings all over Nijmegen, with distances between 500 meters and 5 kilometers (see Fig. 4). More details on NAHSA can be found in [12].

The LORUN/HiSPARC hybrid system is triggered by a coincidence detection of two HiSPARC scintillators within a 1 μs time window for simultaneous data acquisition (DAQ) of both systems (see Fig. 5). The trigger rate counts up to more than 1000 events per day. HiSPARC measures traces of the current produced in the photo multiplier tube (PMT), which is generated by the amount of light produced in the detector by the shower particles. Each scope trace lasts 5 μs with a time resolution of 20 ns and is stored together with a Global Positioning System (GPS) timestamp. The LORUN system stores about half a millisecond of time series data before and after the trigger of each dipole with a time resolution of 12.5 ns. The read out and storage of the radio data takes about one second during which LORUN does not accept another trigger. The PC clock of LORUN is synchronized with the PC of the particle detector, using a network time protocol (NTP) to an accuracy of a few microseconds, so that the triggered events can be matched.

The triggered events of both experiments are matched off-line at the end of each day. Only events that were triggered by two NAHSA twin-detector stations are combined to exclude false-detections. About 10 events are obtained per day with energies beyond 10 PeV, corresponding to the sensitivity of this setup. The software scripts which perform the matching and storing of the recorded radio data are described in [12].

The radio data of the ten events per day are processed for coincidences of pulses detected by the eight radio dipoles around the trigger time. The shower emission wave-front crosses the detector from a certain direction and thus does not arrive at all antennae at the same time. Therefore the search for the pulses is performed in a time window determined by the light travel time across the maximum distance of all antennae pairs of 50 meters (170 ns). Unfortunately, there is environmental man-made radio frequency interference (RFI) produced by radio, TV and mobile phone broadcasting, which is narrow band, raises the noise level and makes the identification of pulses difficult. Therefore, the time-series from the dipoles are Fourier transformed and a sub-band from 45 MHz to 60 MHz with little RFI is chosen. The remaining RFI is down-weighted to reduce its contribution to the spectral power. After this digital filtering the spectrum is inverse Fourier transformed to obtain the air shower pulse. The off-line data analysis so described is performed with a graphical user interface of the LOPES-Tools, which provides FFT, filtering and beam-forming. For more details see the manual for the software package in [13].



▲ **Fig. 5:** LORUN/HiSPARC setup. LORUN is triggered by a coincidence detection of the two HiSPARC scintillators (top right photograph) within 1 ms. More than 1000 events are triggered per day. HiSPARC stores oscilloscope traces (bottom right plot) of both scintillator plates combined with a GPS timestamp. Each scope trace lasts 5 μs with a time resolution of 20 ns. The LORUN system stores about half a millisecond of time series data before and after the trigger of each dipole with a time resolution of 12.5 ns (bottom left plot). A LORUN antenna accommodating two dipoles is shown in the top left photograph.

First Results

The triggered and matched events were analyzed for coincident pulses in the measured electric field of the dipoles. Three candidates were found in the period from 2005-01-01 to 2005-08-01. HiSPARC detected all three events in two twin particle detectors, which are labeled with the station numbers 1 and 2 in the NAHSA layout in Fig. 4. Those two particle detector stations are spaced by 500 meters. LORUN measured these events with up to three operational dipoles. All three events were estimated to have a primary energy of larger than 0.2 EeV by the HiSPARC analysis software.

The first cosmic ray candidate was detected by two crossed dipoles, which are accommodated in the same antenna structure. Both antennae showed nice pulses of 50 ns length at the delay-corrected trigger time. The energy of the primary particle was estimated at more than 0.2 EeV.

The second cosmic ray candidate was detected in two radio antennae spaced by 30 meters. The relative peak height detected in the two parallel dipoles is proportional to the relative particle counts of HiSPARC (see Fig. 6). The difference in arrival time between the radio pulses is consistent with the time delay in arrival of detected particles at the two twin stations of NAHSA. The NAHSA detectors are spaced by 500 meters on a baseline nearly parallel to the LORUN antennae, which results •••

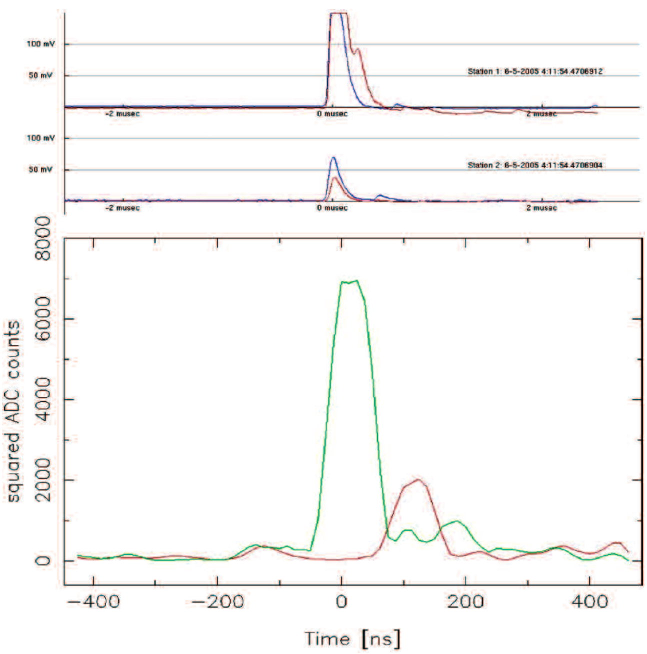
••• in an estimated zenith angle of minimum 30°. The measured inclination suggests a strong primary particle, since the particle air shower has to reach the detector on a longer inclined trajectory through the Earth's atmosphere, without being attenuated. The energy was estimated at more than 0.3 EeV.

The third cosmic ray candidate was detected with three dipoles. The same two parallel dipoles of the previous event detected a much stronger radio pulse than a third perpendicular dipole, which is facing an azimuth direction of 330° and is part of the antenna structure of one of the parallel dipoles. Thus, the signal received in the North-South direction was much smaller than the signal received in the East-West direction. This result is in agreement with a geomagnetic emission mechanism, in which the Lorentz force deflects the charged air shower components in an East-West direction. The zenith angle was estimated at a minimum of 10° and the primary particle energy at more than 0.2 EeV.

Outlook

After setting up the hardware for the LOFAR prototype LORUN, it was straightforward to combine it with HiSPARC in a pathfinder experiment to detect radio emission and particles of cosmic ray air showers in coincidence. The NAHSA/LORUN experiment has been setup with the efforts of several undergraduate students. The HiSPARC experiment NAHSA in Nijmegen can benefit from the synergies of a hybrid detection of cosmic ray air showers in the radio regime combined with particle counts. The radio antennae have a high duty cycle and provide an independent way to determine the origin and primary energy of cosmic rays. The most powerful aspect of the radio detection is that the received signal integrates the whole longitudinal shower development, whereas particle detectors only receive those shower particles which arrive at ground level.

This pathfinder experiment has planted the seed to increase the outreach of cosmic ray science and the LOFAR project, with the opportunity for high school students to extend NAHSA and further HiSPARC stations in The Netherlands by adding radio antennae. However, additional development is needed in order to make the complete setup available for high schools. NIKHEF is developing a new readout for HiSPARC, as well as a readout scheme for radio detection of cosmic rays at Auger. Both of these developments will soon make a hybrid setup at high schools a reality. ■



▲ Fig. 6: Second cosmic ray candidate detected in two LORUN antennae spaced by 30 meters and two NAHSA twin detector stations spaced by 500 meters. BOTTOM: One dipole detected the right small peak (red) and a parallel one detected the left large peak (green). TOP: The relative peak height is proportional to the relative particle counts. The difference in arrival time at the radio dipoles is consistent with the time delay in arrival of particles at the NAHSA stations on a baseline parallel to the LORUN antennae, which results in an estimated zenith angle of 30˚. The measured inclination suggests a strong primary particle, since the particle air shower has to reach the detector on a longer inclined trajectory through the Earth's atmosphere, without being attenuated. The energy was estimated at more than 0.3 EeV.

Biography

Andreas Nigl is a mechanical engineer and he is doing his PhD research studies on cosmic rays at the Radboud University, Nijmegen in the scope of the LOFAR project. He is part of the LOPES group and collaborating with scientists of the Pierre Auger Observatory working in Nijmegen and at the Forschungszentrum Karlsruhe.

Charles Timmermans is a physicist working for NIKHEF at the Radboud University, Nijmegen. He is part of the Pierre Auger Collaboration, studying radio detection of cosmic rays at the highest energies, and he is a recipient of the 2007 EPS Outreach Prize.

Acknowledgments go to the team of students who helped to set up the experiment, to scientists and engineers from ASTRON, to Cees Brouwer and Peter Dolron of IMAPP and to the TechnoCenter of the Radboud University, Nijmegen.

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Near Eastern ancient bronze objects from Tell Beydar (NE-Syria): insights into their corrosion

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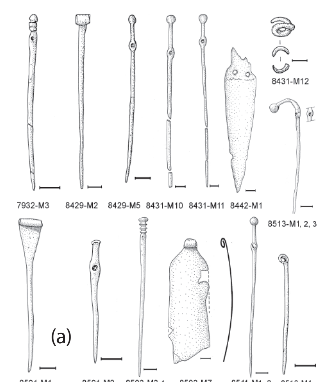
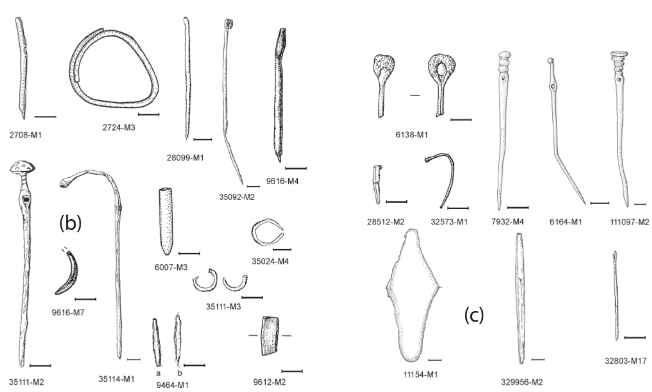
The site of Tell Beydar is located in north-eastern Syria, somewhat 30 km north of the modern city of Hasake, along the river Khabur (Figure 1) [1]. The history of Tell Beydar starts with the foundation of Nabada, its ancient name, around 2800 BC. Semitic nomad tribes were most probably the founders of this city. A palace was built around 2500 BC and the city passed through a period of great prosperity. At the end of the 25th century BC Tell Beydar was placed under the reign of the kingdom of Nagar (Tell Brak), whose king was visiting Nabada at regular periods in order to participate in certain religious and political events. The city was dominated by Akkadian oppressors during the Akkadian period (2350-2200 BC) and was finally abandoned. The lower parts of the city were again inhabited in 1500 BC by the Mitanni. In the 7th century BC Assyrians built their homes at Tell Beydar. Again Tell Beydar was departed until the Seleucidians and Parthians started to inhabit the upper town in the 4th century ad [2].

Excavations at Tell Beydar have been conducted by a European-Syrian mission under the direction of the European Centre for Upper Mesopotamian Studies in Brussels [3]. All of the bronzes discussed in this work (twenty in total) were excavated during the 1994, 1998 and 1999 field seasons. The samples date to the Early Dynastic II-III period (2700-2300 BC).

In a preceding study, chemical analysis and metallographic examination of a set of copper alloy objects were performed [4]. The objective here was to identify the metals used at Tell Beydar during different periods of occupation. Drawings of the objects are shown in Figure 2. Results showed that four different compositional groups could be distinguished based on their arsenic and tin content: a low arsenic group (As < 2 w%), a high arsenic group (As > 2 w%), an intermediate tin group (Sn between 3 w% and 6 w%) and a high Sn group (Sn> 7 w%). Moreover a clear chronological sequence in the use of copper alloys at Tell Beydar could be observed. Throughout the EDII period (2700-2600 BC) low and high arsenical bronzes were in use simultaneously, while there is clearly no evidence of the presence of tin bronzes. Later, during the EDIII period (2600-2300 BC), tin bronzes come into use and the presence of high arsenical bronzes ceases. Finally during the Akkadian (2300-2200 BC) period results show that both tin bronzes and high arsenical bronzes are no longer present. The fact that Tell Beydar was part of another kingdom during this Akkadian period is a possible explanation for the disappearance of the tin bronzes. Later on, during the Seleucid and Parthian occupation (400 BC – 200 AD), tin bronzes appear again in the metal repertoire of Tell Beydar. Apart from these conclusions the results also indicated that the studies of Tell Beydar bronzes have possibly a different provenance. The study of the microstructure revealed that, in general, the same basic working techniques were used during the period studied. Basically the rough shape of the object was formed by casting the liquid metal into a mould. The object was hammered into shape, both cold and hot, after cooling down. Although it is clear that the same basic methods were used throughout the various periods, the evolution of the microstructure shows that metal smiths were achieving better control over the process of cold and hot working the metal. At the end of the development period the metal smith knew how to create objects having the same composition but with different properties, especially hardness.

◄ **Fig. 1:** Map of Syria



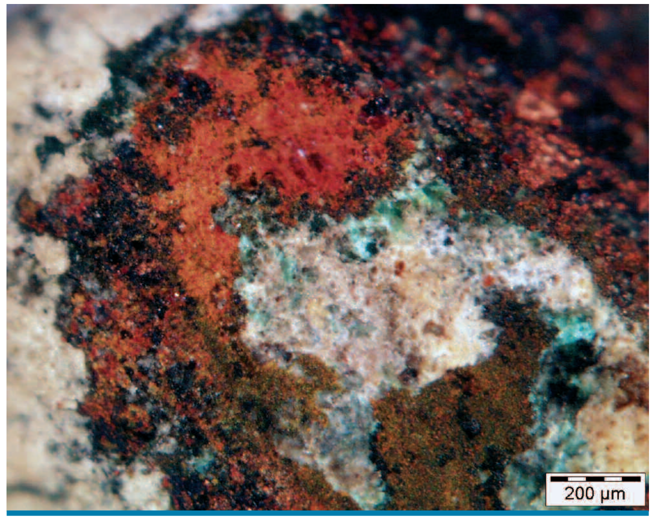


►bronzes originating from the EDII period (a), the EDII period (b) and the Akkadian, Mitanni and Secludic Parthic periods (c). The scale bar at the right hand side of each object indicates a length of 1 cm.

The aim of this work was to study the influence of the alloying elements on the corrosion behaviour. Numerous studies deal with corrosion products on copper-tin alloys [5-7]. Information on the corrosion of copper arsenic alloys, however, is very scarce. In this work the assumption has been made that the corrosive environment to which all the studied bronzes were exposed was approximately the same, as most of the bronzes studied originate from burial sites in the same geological region. Hence, the original composition of the bronzes will be considered as the main variable affecting the corrosion, although it needs to be realised that other factors (*i.e.* temperature, burial depth, position of the objects in relation to other objects and the presence of certain micro-organisms in the soil) besides the composition can have a possible effect.

Experimental

A total of 20 objects were analyzed. Their chemical bulk composition as measured by scanning electron microscopy with an energy dispersive spectrometer (SEM-EDS) is listed in Table 1 [4]. Small samples (3-4 mm) were carefully removed using a jeweller's piercing saw. Prior to any sample preparation treatment, a stereo optical light microscope was used to obtain a visual description of the corroded surface. The samples were consequently embedded in an epoxy resin, after which they were ground using silicon carbide and polished with diamond sprays of decreasing grain sizes down to 0.25 µm. The cross-sections obtained in this way were investigated using an Olympus LM SZX-12 optical research stereomicroscope equipped with a digital camera system DP 10 to obtain in a rapid manner visual information about the structure of the corrosion layer. The same samples were used for SEM-EDS measurements, while thin sections with a thickness of about 300 µm were prepared for the synchrotron radiation X-ray diffraction (SR-XRD) analysis.



▲ **Fig. 3:** Optical micrograph of the surface of sample n17.

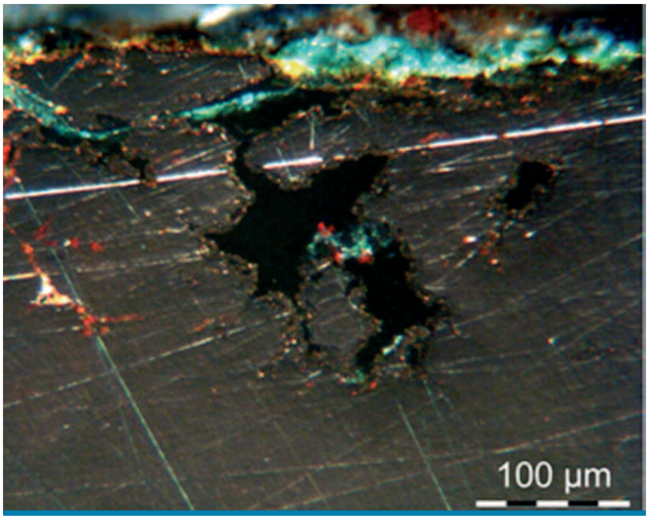
Previous experiments have shown that the combination of optical microscopy, SEM-EDS and SR-XRD give the most informative results to investigate the corrosion of archaeological bronzes [8]. Therefore, whenever possible the combination of these techniques was used in this work to obtain a thorough overview about the influence of the alloying elements on the corrosion behaviour for copper-tin and copper arsenic alloys. In some cases, however, SR-XRD could not be used due to the brittle nature of the corrosion products which made it very difficult to obtain thin sections of the samples without damaging the corrosion structure of the bronze.

Backscattered electron (BSE) images and elemental X-ray maps were acquired using SEM-EDS. A Jeol JSM6300 scanning electron microscope equipped with a PGT-digital energy dispersive X-ray detector and PGT software was used for this purpose. Typical acquisition settings included a current of 6-8 nA, an acceleration voltage of 20 keV, a working distance of 15 mm and a detector to sample distance of 50 mm. The X-ray acquisition mode was set to fast mapping and the acquisition time was typically between 30 and 60 min.

The SR-XRD measurements were performed at station 9.6 of the Synchrotron Radiation Source (SRS) at Daresbury Laboratory, U.K. An intense beam was used (ca 100 s collecting time during single-bunch mode and beam current > 20 mA), with high energy (*i.e.* high penetration) photons (E=14.25 keV, λ= 0.87 Å) and a small beam footprint (100 µm) defined by collimator slits. The XRD patterns were collected in transmission by a QUANTUM-4 CCD area detector. A microscope alignment system allowed the location of the beam on the desired part of the sample. Data analysis was carried out using the ESRF package FIT2D [9] and reference data from the JCPDS PDF cards were used to identify the corrosion compounds.

Type	Sample	Archaeological Number	S	Fe	Ni	Cu	As	Sn	Sb	Pb
Low arsenical bronzes	n17	35024-M4	0.02	0.33	0.18	98.95	0.51	-	-	-
	n34	35170-M1	0.80	0.58	-	98.29	0.33	-	-	-
	n36	28099-M1	0.59	0.18	0.10	98.72	0.41	-	-	-
Intermediate arsenical bronzes	B4	9616-M4	0.17	0.36	0.08	98.04	1.22	0.10	0.04	-
	B11	9620-M3	0.05	0.55	-	98.20	1.21	-	-	-
	B16	32573-M3	0.17	0.52	-	96.98	1.95	-	0.34	-
	Bey20	8513-M4	0.16	0.59	-	97.79	1.28	0.05	0.14	-
	n5	35114-M1	0.06	0.26	-	98.66	1.02	-	-	-
	n29	32956-M2	0.29	0.78	-	97.72	1.21	-	-	-
	B9	9616-M7	0.56	0.28	0.08	96.60	1.69	0.37	0.42	-
	n6	35111-M2	0.27	0.33	0.07	97.41	1.35	0.48	0.09	-
High arsenical bronzes	n7	35111-M3	-	0.29	-		97.13	2.58	-	-
	n31	35092-M2	0.03	0.75	-	96.41	2.36	0.14	0.28	-
Tin bronzes	B18	28018-M1	0.04	0.02	0.45	92.66	0.51	6.82	-	-
	B22	9612-M2	-	0.12	-	93.33	0.33	6.23	-	-
	B23	9464-M1	0.32	0.48	-	94.64	1.16	3.40	-	-
	n25	32803-M17	0.17	0.25	0.37	95.86	2.40	0.95	-	-
	n30	28512-M2	0.11	0.15	0.51	93.23	0.77	5.22	-	-
	n33	35152-M3	0.46	0.80	0.32	85.99	1.47	4.77	-	6.18
	n37	32907-M2	0.06	0.23	0.60	90.09	0.68	7.70	-	0.73

◀ **Table 1:** Elemental composition of the analyzed samples (wt%) measured using SEM-EDS. The error is below 10%, except for sulphur which is below 30%. – means below detection limits.



▲ **Fig. 4:** Optical micrograph of a cross section of sample n17.

Results and discussion

Bronzes with a low arsenic content

A total of 3 samples with an arsenic content below 1 wt% were analysed. Table 1 lists their elemental composition showing only minor differences in their composition. Experiments on the corroded surface with the above mentioned analytical techniques demonstrate that the corrosion crust consists of various layers (not clearly separated), with a total of about 200-500 µm in thickness. The crust is composed of malachite ($CuCO_3.Cu(OH)_2$) with embedded soil particles, underneath cuprite (Cu_2O) and nantokite (CuCl). Table 2 summarizes the typical corrosion features encountered on low arsenical bronzes and is in what follows elaborated in more detail.

Figure 3 shows an optical image obtained from the surface of sample n17, demonstrating the presence of dark brown to orange cuprite. In addition, light green corrosion products can be distinguished covered by white compounds which are probably remaining soil particles. Optical micrographs obtained from cross-sections of the samples visualize the structure of the corrosion crust (Figure 4). The most remarkable feature is the advanced intergranular corrosion. In addition the pitting corrosion can be observed as a green layer (nantokite) in contact with the metal. This layer is followed by a reddish cuprite layer, with on top green corrosion compounds (malachite). This corrosion pattern is typical for bronze disease [10].

The results are confirmed by the elemental distribution patterns obtained with SEM-EDS (Figure 5). A chloride layer in direct contact with the metal can be observed in the X-ray maps. The chloride layer is covered by a cuprite layer and by a layer that contains copper and soil elements such as silicon.

XRD patterns were recorded along a line starting from the outer layer into the bulk metal. Results show the following sequence of corrosion compounds: (a) malachite; (b) malachite, cuprite; (c) malachite, cuprite, nantokite; (d) cuprite, nantokite. This sequence implies that the corrosion crust is composed of three layers: a malachite layer, a cuprite layer and a nantokite layer. Similar results were found for the other samples in the same group. In Figure 6, a typical diffractogram is shown.

Bronzes with an intermediate arsenic content

Eight bronzes with an intermediate-arsenic content (between 1 and 2 wt%) were analysed. The chemical bulk composition of the bronzes is again listed in Table 1 and shows a close similarity, except for 2 bronzes, n6 (35111-M2) and B9 (9616-M7), which have higher contents of tin and antimony (the sum of both elements being above 0.5 wt%).

The corroded surfaces of the studied bronzes are all similar in appearance, mainly consisting of green, red and black corrosion compounds together with white soil particles. Optical micrographs of the cross-sections of the samples show two different corrosion structures: (1) a three-layered structure of 1000-2000 µm thickness for the majority of the samples and (2) a two layered intergranular corrosion structure of 300-500 µm thickness for both samples with higher contents of tin and antimony.

Results show that the three-layered structure consists of (1) a black to grey nantokite layer in direct contact with the metal; (2) a red cuprite layer; (3) a green layer of malachite with calcite and quartz particles. The two-layered structure consists of (1) a top layer of malachite and soil and intergranular corrosion composed of cuprite and nantokite which is depleted in arsenic and penetrates into the bulk of the metal. An overview of the results is given in Table 3.

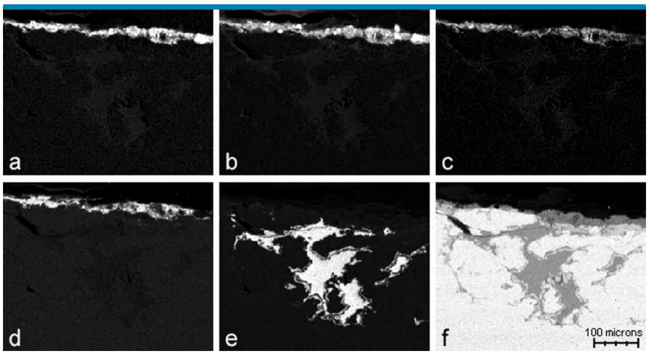
Bronzes with a high arsenic content

Only two bronzes with a high arsenic content were available that had not been previously cleaned, meaning that only these are suitable for this study. Table 1 shows their composition. In contrast to the previous samples with a low and intermediate arsenic contact, it was clear that both samples showed a significant difference in corrosion structure. Sample n7 (35111-M3) is almost completely corroded while sample n31 (35092-M2) is hardly affected by corrosion. Table 4 gives an overview of the results obtained.

Tin bronzes

A total of 7 bronzes with a tin content above 1 wt% were analysed. Their chemical bulk composition is given in Table 1. Optical micrographs of the surface show compounds with different shades of green and blue, as well as red compounds and white soil particles. Cross-sections show two different corrosion structures: (1) intergranular corrosion enriched in tin and (2) a three-layered corrosion composed of malachite, paratacamite, cuprite, nantokite and cassiterite. Table 5 summarizes typical corrosion features observed for both corrosion structures.

▼ **Fig. 5:** X-ray maps of sample n17 showing the elemental distribution of **(a)** Al, **(b)** Si, **(c)** Mg, **(d)** Ca, **(e)** Cl and **(f)** Cu.



Intergranular corrosion

The BSE image in Figure 7 illustrates the intergranular character of the corrosion as it occurs for most of the tin bronzes. X-ray images of sample B22 (Figure 8) show that chloride surrounds the central part of the sample containing the intergranular corrosion. The chloride containing layer is covered by a surface layer which contains copper and soil elements. At the interface between the outer layer and the internal layer, tin is enriched. Additional SR-XRD analyses show the presence of the minerals quartz (SiO_2), calcite ($CaCO_3$), kaolinite and montmorillonite (both of them phyllosilicates) in the outer layer of the sample. Underneath this layer, cuprite, nantokite and cassiterite (SnO_2) were identified. The observations made for the tin bronze here are comparable to results described by Robbiola [5].

▼ **Table 2:** Corrosion characteristics of low arsenical bronzes

Layer structure	no clearly separated layers irregular intergranular corrosion
Thickness	200 – 500 µm
Surface appearance	light green powdery and red crystalline compounds white soil particles
Major compounds	soil, malachite cuprite, nantokite
Samples	n17, n34, n36

▼ **Table 3:** Corrosion characteristics of intermediate arsenical bronzes

Layer structure	3 layers evenly structured	2 layers intergranular corrosion depleted in arsenic
Thickness	500 – 1000 µm	300 – 500 µm
Surface appearance	green, red and black corrosion compounds white soil particles	
Major compounds	malachite, quartz, calcite cuprite nantokite	malachite, soil cuprite, nantokite
Samples	n5, n29,B4,B16,B11,Bey20	n6,B9

▼ **Table 4:** Corrosion characteristics of high arsenical bronzes

Layer structure	3 layers	Alternating structure
Thickness	almost completely corroded	< 100 µm
Surface appearance	bright green to blue corrosion red crystalline compounds	green and brownish red compounds
Major compounds	malachite, soil arsenic enrichment layer cuprite nantokite	nantokite cuprite
Samples	n7	n31

▼ **Table 5:** Corrosion characteristics of tin bronzes

Layer structure	2 layers intergranular corrosion	3 layers evenly structured
Thickness	100 – 1000 µm	far advanced corrosion
Surface appearance	white soil compounds red crystalline compounds corrosion with different shades of green and blue brown to black corrosion	
Major compounds	different copper alteration compounds intergranular enrichment in tin	brochantite, paratacamite cuprite nantokite, cassiterite
Samples	n25, n30, n33, B22	B18, B23

Layered corrosion

Two of the tin bronzes showed a layered corrosion structure. The results are very similar to the three-layered structure of the intermediate-arsenic content bronzes: a nantokite layer in direct contact with the bulk metal is covered by a cuprite layer which is covered by an outer layer containing calcite, quartz and copper alteration products. The alteration product of copper in the outer layer was identified by SR-XRD to be brochantite ($Cu_4(SO_4)(OH)_6$) and paratacamite ($Cu_2(OH)_3Cl$), an observation which is different from those for the arsenical bronzes where malachite was the major corrosion compound of copper. The presence of brochantite is surprising as it is well known that it occurs mainly on bronzes exposed to an atmospheric environment and is rarely observed for bronzes buried into the soil [5]. One possible explanation for this different behaviour between the arsenical and the tin bronzes is that the brochantite was formed after the excavation, an assumption supported by the fact that the bronze disease, at least for sample B18, is active in contrast to the other examined samples where it is passive. The presence of paratacamite, an alteration product of nantokite, supports the hypothesis of the activated bronze disease.

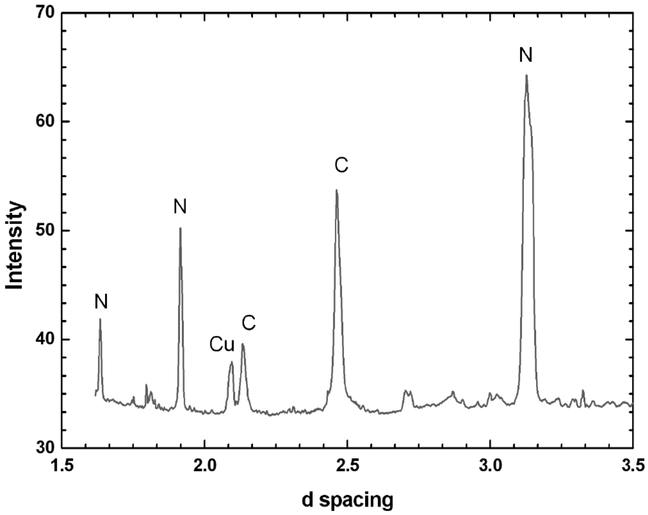
Conclusions

The corrosion of the Tell Beydar bronzes was investigated using a variety of analytical methods. The results show that the structure and the composition of the corrosion are influenced by the original composition of the bronze alloy.

In general the corrosion observed on the bronzes is controlled by the presence of chlorides in direct contact with the metal. This type of corrosion is well known as "bronze disease". Although this corrosion is known to be generally very active, it was not yet in the active state for the examined bronzes. This is demonstrated by the absence of copper trihydroxychlorides (*e.g.* atacamite and paratacamite). Nevertheless in the future care must be taken to preserve the bronzes after excavation. It is well known that the corrosion of bronzes containing chlorides in contact with the metal is readily activated in the presence of humidity. Therefore conservation scientists advise to store the bronzes in relative dry conditions (below 40 % of relative humidity).

The corrosion of bronzes with a low arsenic content does not show in general a clearly layered structure. Intergranular corrosion covered by an outer corrosion layer was observed, which is composed of nantokite and cuprite while the outer corrosion layer contains the compounds cuprite and malachite.

Layered corrosion structures were observed for bronzes containing arsenic between 1 and 2 wt%. In this case a three-layered structure could be distinguished consisting of a nantokite layer in direct contact with the metal, followed by a cuprite layer and layer containing malachite and some minerals originating from the soil such as quartz and calcite. Two samples with an intermediate arsenic content, however, show a different corrosion structure, of the two-layered kind of structure. The difference in corrosion structures for the intermediate-arsenical bronzes is most probably due to



▲ **Fig. 6:** Diffractogram of the corrosion of sample n17.

differences in composition. In the case of the two-layered corrosion structure the bronzes contained copper and arsenic and smaller amounts of antimony and tin.

The corrosion of the tin bronzes consists mainly of an intergranular structure, with is enriched in tin. Tin is also enriched at the interface of internal corrosion with the outer corrosion layer, which forms evidence for the selective dissolution of tin from the alloy. Also tin bronzes with a three-layered corrosion structure similar to the corrosion structure on intermediate-arsenical bronzes were observed, be it with different compounds: the outer layer containing brochantite instead of malachite. The layer in direct contact with the metal contains nantokite and cassiterite. The similarity in corrosion structure between the tin and arsenical bronzes illustrates that, in addition to the composition of the bronze as a factor influencing the corrosion, other factors such as for example the corrosive environment are also of importance. ■

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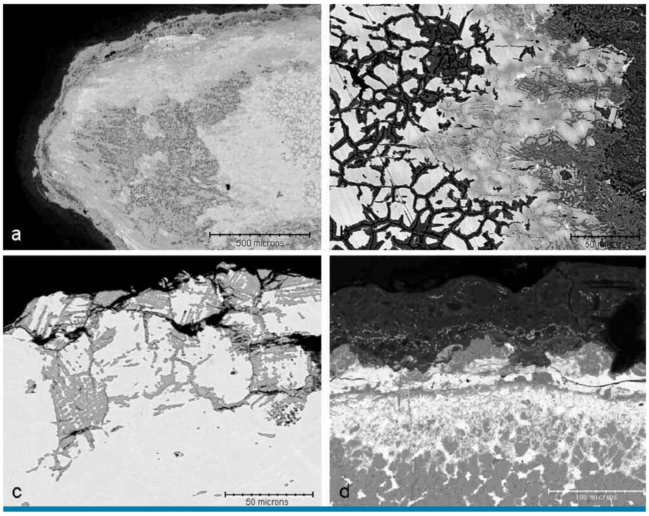

▲ **Fig. 7:** BSE images of samples **(a, b)** B22, **(c)** n30 and **(d)** n33, illustrating the intergranular character of the corrosion.

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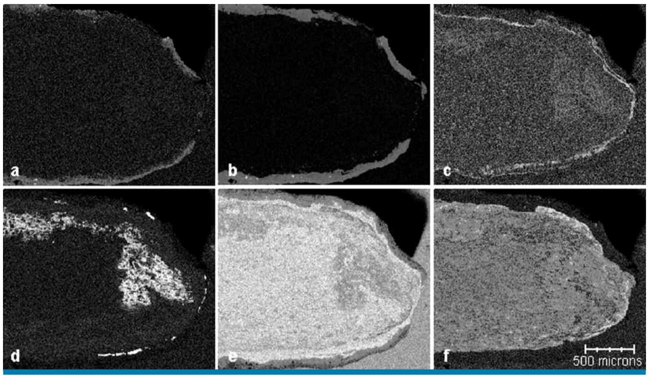

▲ **Fig. 8:** X-ray map of sample B22 showing the elemental distribution of **(a)** Al, **(b)** Si, **(c)** S, **(d)** Ca, **(e)** Cl and **(f)** Sn.

The Science Museum Príncipe Felipe of Valencia, Spain

Manuel Toharia,
Director of the Science Museum and of the Hemispheric.
President of the Spanish Association for Scientific Communication

The "Museo de las Ciencias Príncipe Felipe" (MCPF) opened its doors in November 2000. It occupies a total surface of 42,000 m^2 in a wonderful building thereof 28,000 are used for its exhibition activities, in particular with temporary interactive -hands-on- exhibits. Its philosophy, based on a continuous education of its visitors follows the principles pioneered in the sixties by the Exploratorium of San Francisco. This means that next to the visit of its display rooms, the MCPF proposes a large spectrum of educational activities on science. The various programmes on public understanding of science aim to encourage intellectual curiosity reinforce a critical spirit among the visitors. It also tries to teach in an informal and appealing manner the knowledge of basic and applied science as well as its related methods and techniques. Thus many useful educational tools are proposed to school teachers and their students.

The MCPF is part of a more ambitious architectural complex, the 'City of Arts and Sciences', which includes "l'Hémispheric", an IMAX dome and planetarium, "L'Oceanografic", a huge aquarium of more than 80,000 m3, and the "Palau de les Arts", the Opera theatre.

▲ Designed by the valencian architect Santiago Calatrava, the building has a contemporary architectural style that makes the "container" of the Museum an integral part of its content.

Physics in the Museum

Among experimental sciences, physics might be the most represented one in interactive science museums. This is also true for the MCPF, in particular with the "Exploratorio" space that proposes experiments on mechanics, kinetics, electronics, and optics among others.

In the various scenarios of "Science on Stage" many applications of physics, chemistry, mathematics and biology are presented. Following a script the museum's demonstrators help the spectators understand the most entertaining, even amusing or surprising, science lessons.

Once every quarter the museum organizes also a "Café de la Sciencia" in collaboration with the Spanish Association of Scientific Communication (AECC). A renowned scientist answers the questions of the public on a given topic and in a relaxed atmosphere.

This year 2007 Valencia has been the capital of sailing with the America's cup event. At this occasion the museum organized a special exhibition named "A toda vela". During the whole year about fifty interactive demonstrations explain many aspects of physics in relation with water, air, novel materials and boats. Topics like navigation, meteorology, geography, astronomy and astrometry are covered. The visitors can also look at a true sailboat of the class America, the "Desafio Iberdrola" with its almost 40 meter height mast.

◄ Hands-on Experiments: discovering the physics of rotating objects

► "Desafio Iberdrola" a sailboat of the class America, exposed within the temporary exhibit "A toda vela"

In 2008 a formula-one (F1) urban race circuit will take place for the first time in Valencia in second position after Monaco in the world championship. At this occasion the museum prepares a large exhibit on the "History of Speed". But before, in November 2007, the museum will host the Intergovernmental Panel on Climate Change (IPCC) of the United Nations, which will present its fourth report on climate changes. In parallel to this event, numerous activities such as conferences, debates, and an interactive exhibition will be organized. ■