newsletter

NEWSLETTER OF THE EUROPEAN LOW GRAVITY RESEARCH ASSOCIATION

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President's page

Dear ELGRA members,
Please find before you the 7th ELGRA Biennial NewsLetter which now carries its own ISSN. Since the last issue from the end of 2009 the landscape for microgravity-related science has changed quite significantly. At that time the main European contribution to the research capacity of the International Space Station, the Columbus module, was just fully operational. Since then, quite some experiments have been performed in Columbus and other modules. However, some challenging times are ahead. The Space Shuttle will be decommissioned soon. This leaves the science community with a serious reduction in download capacity. All sciences will suffer from this situation; in particular those studies where ground-based analysis has a major share. ESA and others try to relieve this burden by developing on-board analysis instruments, but surely these cannot replace the research capacities and capabilities available in ground laboratories. A solution to this limitation needs be found soon. At the same time, new American space companies are developing modules that could be used to return our samples. I hope European scientists are provided means to make use of these or other download capacities.
You will soon receive the printed publications from the last ELGRA Symposium in Bonn (Germany). Most papers are already online. This thematic edition of Microgravity Science and Technology (MST) very well reflects the current status of our present research. As ELGRA we are pleased to have established firm relations with MST and its publisher Springer. We are investigating the possibility to have MST as a regular journal for all ELGRA members.
Please note that ELGRA organizes its next Biennial Symposium – the 21st since its foundation – during September 6–9, 2011 in Antwerp, Belgium. Profs. Floris Wuyts and Valentina Shevtsova, from the University Antwerp and the Free University of Brussels, respectively, will be our local organizers.
I also want to thank the ELGRA members for their support by assisting young researchers on their path to gravity-related research through the ELGRA Mentorships. For the past years ELGRA has been active to support the ESA educational programs Fly-Your-Thesis (FYT), Spin-Your-Thesis (SYT) and Drop-Your-Thesis (DYT). It is very encouraging to see such an enthusiastic interest of the young generation for our field.
As for previous ELGRA symposia we expect large student participation in our next Symposium and we shall do our best to support their venue. In addition, we shall organize a contest for the best student studies in both Physical and Life Sciences, as we did previously. The winners, in addition to receiving the ELGRA Award, will present their work to the plenum during a general session. Our Symposium gives us the opportunity to award the ELGRA Medals. Every two years, ELGRA honors two scientists in Life and Physical Sciences for their outstanding contribution to Microgravity Research. It is also the occasion at which the new management committee of ELGRA will be elected during the General Assembly. I would like to sincerely invite volunteers interested in serving our Association to contact me directly. At the next General Assembly the management committee will face a significant renewal. At least, a new president and a new vice-president need to be elected.
ELGRA is an active organization and supports a number of national and international scientific meetings such as the joint meetings with ESA or with the International Society for Gravitational Physiology (ISGP). As ELGRA we are looking into the possibility to organize even further joint conferences.
The near future will bring some major changes regarding gravity-related research in Europe. I sincerely hope that the various national programs, ESA through its ELIPS program, but also the European Union through its EC-SPACE/FP-8 will provide suitable opportunities for the user community to carry out excellent science. With the prospect of extending the lifetime of the ISS to 2020 (and perhaps 2026) a bright future seems to be ahead, although we Europeans should also keep in mind non-ISS microgravity platforms, not only for the after-ISS era.
I wish you an excellent year 2011 and look forward to welcoming you all in Antwerp to make our next Symposium a great success!

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The Bonn Meeting

The ELGRA Biennial Symposium and General Assembly *In the Footsteps of Columbus* took place in Bonn (Germany) from September 1 to September 4, 2009 at the University Club of Bonn, a small and pleasant conference site a few steps from the river Rhine in the centre of Bonn. The symposium was attended by about 150 scientists from 22 nations. 89 oral presentations and 59 posters were presented.

Apart from providing a forum for discussions and exchange of results and ideas among scientists using (micro-) gravity in the fields of materials and fluid sciences, life sciences and technology the ELGRA Symposium 2009 focussed on

- Columbus and other modules on ISS
- Life support systems in space
- Living under extreme conditions
- Counter-measures/artificial gravity
- Magnetic levitation (compensation of the gravity force)
- Exploration issues
- Soft matter mechanics of living cells
- Plasma and dust
- European–Chinese relations and projects
- Workshop on animal research and related technology

The seven plenary lectures presented by Reinhold Ewald, Vadim Nikolayev, Laurence R. Young, Klaus Palme, Gregor E. Morfill, Ilia V. Roisman, and Christoph Lasseur. In addition the recipients of the 2009 ELGRA Medal, Alberto Passerone and Dag Linnarson, gave impressive presentations, reviewing their work (see also page 34).

For the first time in the series of symposia, ESA's Topical teams have been invited to organize their TT Meetings as splinter sessions next to the symposium. This offer was well received and the following teams took chance of this opportunity.

- Topical Team *Psychosocial and Neurobehavioral Aspects of Human Spaceflight*
- Topical Team *Thermophysical Properties*
- Topical Team *Complex Plasmas*
- Topical Team *DOLFIN*

ELGRA has invited selected student teams (pre-doctoral level) to submit their work to a special Student Session. The six teams selected have received a free student membership to ELGRA for one year. In addition, the presented oral communications and posters were considered for a distinction award. The winning teams, headed by Camilla Pandolfi (Life Sciences) and Santiago Arias (Physical Sciences), have been elected by all participants of the symposium (see also page 30).

The organizers have encouraged submitting the papers presented at the symposium to Microgravity Science and Technology. The special issue will become available in January 2011 as volume **23** (1). It will comprise twelve and nine papers from physical and life sciences, respectively.

The ELGRA General Assembly was held from 18:30 to 19:40. The minutes of the General Assembly can be found on page 35. During the symposium ELGRA President Jack van Loon chaired a round-table discussion with representatives from ESA regarding the Future of Microgravity Research in Europe. The discussion was partly focussed on the limited possibilities for individual scientists to perform their research in the ISS as was promised at the start of the ISS. The current trend goes to larger but less facilities and instruments. The projects currently being carried out is based on a broad consensus from a large part of the user community. Such an approach does not always result in significant scientific innovations.

On the social side, the participants enjoyed a reception in Town Hall Bonn. The conference dinner on Thursday took place on a boat during a cruise on the river Rhine. Since is has become dark very early the buffet received even more attention. During the dinner Student Awards were handed over.

The local organizers did an excellent job in preparing the symposium including all events and the catering. Images from the symposium can be downloaded from www.flickr.com/photos/elgra.

Figure 1: Participants of the ELGRA Symposium 2009 gathering in the garden of the University Club in Bonn.

Announcement of the

ELGRA Biennial Symposium and General Assembly 2011

Gravity: from μ to x!

September 6–9 , 2011

Antwerp University, Antwerp, Belgium

for further information, please visit www.elgra.org

Opinion

Flagship instrumentation for the ISS

Research in materials science provides the basis for further developments in most modern technologies, e.g. semiconductors for information technology and photo voltaic applications, and metals for nano- and biotechnology as well as for aerospace and automotive applications, to name a few. Almost all industrially used materials are molten in some processing step, specifically in casting. Solidification from the melt leaves its fingerprints in the final material. Hence, it is of utmost importance to understand the properties of the molten state and its solidification behavior. The challenge in further developing processing techniques and materials is to move from a trial-and-error approach to computer-assisted materials design. However, this is still hampered by an incomplete understanding of the basic physical mechanisms that underly mass transport and solidification, as well as by a lack of available thermophysical property data.

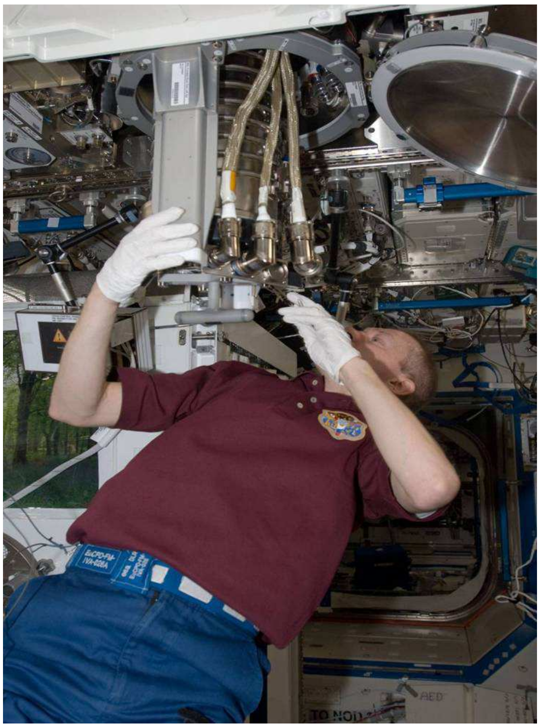

Figure 1: Frank de Winne during commissioning of MSL aboard the ISS, November 2009 (photograph: NASA).

With the advent of microgravity platforms a new experimental tool has become available to study the properties of liquids and their solidification behavior under purely diffusive conditions. In the absence of gravity driven flow and sedimentation effects, seminal microgravity experiments have been performed since then, shedding new light onto old problems and, in some cases, rendering accepted textbook knowledge erroneous. Recent microgravity experiments on directional solidification under controlled flow conditions or on diffusion of mass in liquid alloys have shown, that widely accepted physical laws have to be reconsidered. Another important breakthrough was the advent of containerless processing techniques in the microgravity environment. This technique gave access to the measurements of growth velocities as a function of undercooling, which lead to a revision of theories for dendritic growth and grain refinement. In addition, containerless processing solved the problem of dealing with high-temperatures, and chemically reactive metallic melts. Therefore, it allowed to accurately measure their thermophysical properties. These experiments represent important milestones.

The challenge is to transform these experiments into a systematic and vivid research program. Compared with present-day research projects making use of earth-bound large-scale facilities (e.g. for neutron and X-ray scattering) the access to space is rather limited and the implementation time from idea to sample processing is rather long. As a matter of fact experimental results in general not only answer, but also generate new questions. Therefore, the opportunity to carry out entire experiment series is needed, which allow for a continuous adaption of processing parameters and sample environment. In addition, a short realization time is required if results from microgravity experiments should pave the way for new research fields and trigger new (earth-bound) experiments. In this context the materials science laboratory (MSL) with its furnace inserts and electromagnetic levitation device (MSL-EML) aboard the International Space Station (ISS) is the European microgravity platform in the years to come for research devoted to materials science.

MSL is an experiment facility in the Materials Science Research Rack with a modular design that allows for an in-orbit exchange of dedicated furnace inserts. Currently equipped with the Low Gradient Furnace (LGF) for investigations in the area of flow effects on directional solidification of Aluminium-based alloys, MSL is operational since November 2009. A second insert, the Solidification and Quenching Furnace (SQF) was transported to the ISS and is awaiting its commissioning. For MSL-EML the first experiments were selected. Beginning of operation aboard the ISS is foreseen for 2012. Science for the MSL equipment is eventually centered around proposals of three announcements of opportunities (AO's) of the European Space Agency (ESA) of the years 1999 to 2004. And even more MSL research projects have been selected for the pool of potential flight experiments as a result of ESA's AO 2009 round. MSL serves numerous and large international research teams with in total more than 200 partners of universities, research institutions, and industry. MSL is operating nominally. During its first year aboard the ISS twelve solidification experiments were performed successfully and the sample cartridges safely returned to earth with the space shuttles.

The processing of the first batch of MSL experiments marked the begin of the ISS utilization in the field of materials science. However, due to a number of limitations, the design and performance of the MSL furnaces and of MSL-EML have been downscaled from initial expectations. Specifications of state-of-the-art (earth-bound) laboratory equipment outperforms that of the MSL furnaces and the levitation device in many aspects. For example, the MSL furnaces suffer from limited maximum temperature and limited maximum temperature gradients, and the lifetime of MSL-EML is limited by the lifetime of the levitation coil, which cannot be replaced in-orbit. Fortunately enough, additional diagnostics tools, not available in the present configuration, can be implemented at a later stage for MSL-EML (inductive measurement technique, oxygen sensor).

In the years to come MSL is envisioned to be the workhorse of the materials science experiments aboard the ISS. New 2nd generation inserts are currently under development. Together with

EADS Astrium and partners three fully MSL compatible inserts were designed, built, and installed in laboratories at the University of Freiburg and my institute in Cologne. A float zone furnace with rotating magnetic field for crystal growth (Freiburg), a high temperature isothermal furnace, e.g. for diffusion experiments at temperatures up to 1600°C (Cologne), and a X-ray radiography insert that allows for an in-situ observation of diffusion and solidification processes in metallic melts (Cologne) are now operational. These inserts also represent state-of-the-art laboratory equipment. The use of in-situ techniques aboard the ISS will become even more attractive, since it overcomes the restricted download capacities after the end of the space shuttle operation in 2011.

Figure 2: Compact and fully MSL compatible 110 kV X-ray radiography insert for in-situ monitoring of interdiffusion and solidification processes.

With an ISS utilization scenario up to the year 2020 and beyond, the scene is set for a regular access to space that is needed for systematic research under microgravity conditions. To make maximum use of the space station in the field of materials science, the instrumentation aboard the ISS must comprise state-of-the-art and innovative experiment facilities. From a programmatic perspective, the philosophy of multi-user facilities, maximizing the number of users, but not necessarily the scientific outcome, needs to be reconsidered. All-in-one devices suitable for every purpose, a maximum number of scientists, and many research fields will at the end of the day in most cases not lead to the anticipated breakthrough results. Consequently, flagship instrumentation has to be selected at an early stage and if inevitable, at the cost of a diversified research program. It must be designed and built according to latest specifications and efficiently implemented aboard the ISS. In the following continuous access to these facilities has to be granted. Only then we have a laboratory in space.

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A MISsed opportunity

The ESA Mouse In Space (MIS) facility has recently been stopped for further development by a decision of the Program Board. Depending on whom you ask, this could be a temporary delay or even a complete cancelation. Animal research is a vital part in biological and medical research. Going from single cell biology to human physiology requires animal models. To better understand the adaptations of astronauts to microgravity or the changes gravity conditions requires the use of mammalian models (mice, rats etc.). Our current level of knowledge, suite of treatments and diversity of pharmaceutics is for the most part based on animal research. One reason for this decision is (lack of) funding. Surely, choices have to be made with a limited budget. But over the years and with various large entities like space agencies I also see another trend that policy makers are less and less inclined to support animal research. Large entities tend to be more and more sensitive to a very small group of persons like animal activists to dominate the public opinion. Complying to such a forceful and unbiased view of life sciences makes large entities hesitant to make important progress in science and hampers the progress in understanding gravitational physiology in this case. I think we all can very well explain to the general public why we need to make use of mammalian models for our research. All colleagues working with animals that I met over the last decades underline the principle to use as little animals as possible to provide the answers required for a particular study. All animal experiments have to be authorized by an animal welfare committee before they can be performed. One has to comply with the *3 **R**s*: **R**eplacement (use of non-animal methods such as cell cultures, human volunteers and computer modeling instead of animals), **R**efinement (use of methods that alleviate or minimize potential pain, suffering or distress, and that enhance animal welfare for those animals that cannot be replaced) and **R**eduction (use of methods that enable researchers to obtain comparable amounts of information from fewer animals, or more information from the same number of animals). Actually the 3Rs also comply very well with space related experiments where in-flight resources are very limited. Space agencies, with there high level of technology, could therefore play an important role in developing technology in support of the 3Rs' paradigm. All space-flight related animal studies also have to be reported and be compliant with the recently established COSPAR (International Council for Science, Committee on Space Research) Panel on the Care and Use of Animals in Space-borne research.

Animal (rodent) studies are vital in the preparation for future long duration missions to Moon and Mars. Especially the ESA MIS facility with its advanced life support system and elaborate centrifuge capability could play a leading role in this work. I hope the MIS facility is only temporarily delayed and opportunities will be found for European animal physiologists to perform their gravity related research.

See also: Blottner et al., J. Comp. Physiol. B **179**, 519–533 (2009); doi: 10.1007/s00360-008-0330-4.

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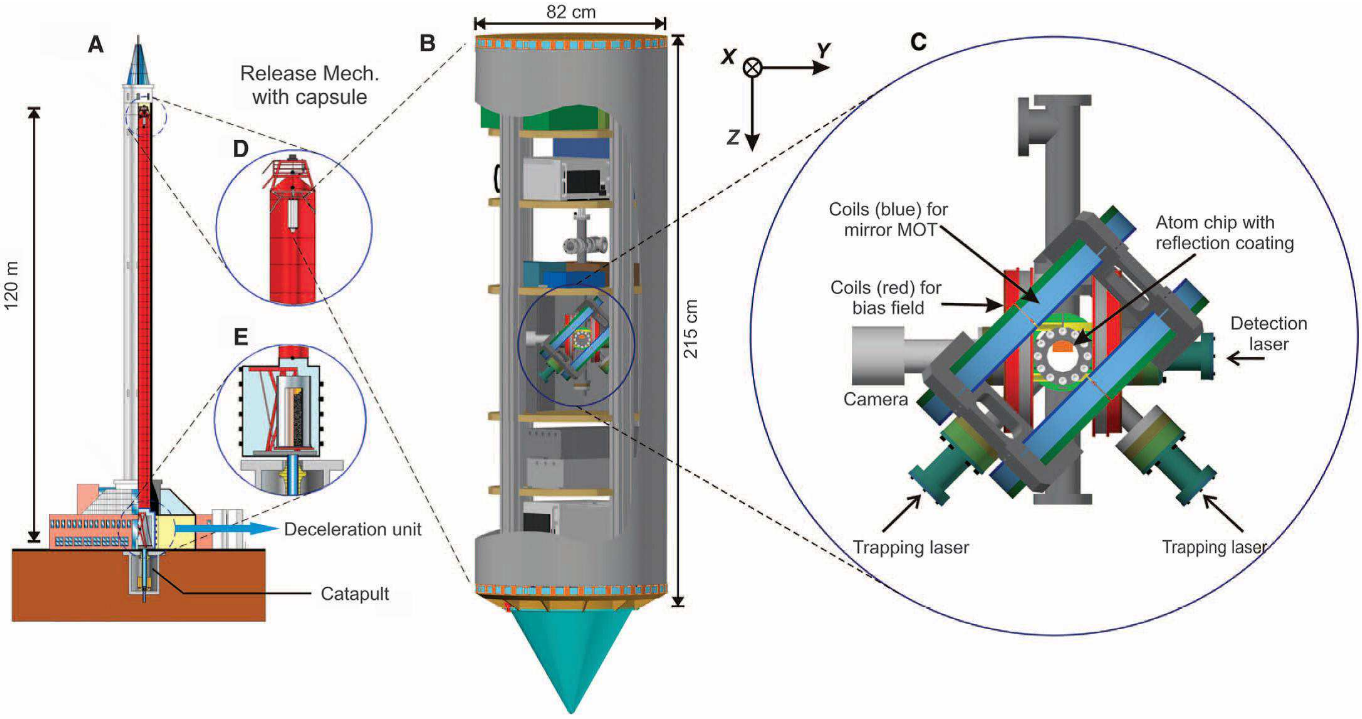

Figure 1: Cuts through the ZARM drop tower facility in Bremen (A) and the capsule (B) containing the heart of the BEC experiment (C). The capsule is released from the top of the tower (D) and is recaptured after a free fall of 4.7 s through an evacuated stainless steel tube at the bottom of the tower by a 8-m-deep pool of polystyrene balls (E). In the process of recapturing the capsule, the experiment has to survive decelerations up to 500 m/s^2 (about 50 times the local gravitational acceleration). The capsule contains all of the components necessary to prepare and observe a BEC, such as the laser systems for cooling the atoms, the ultrahigh-vacuum chamber with the atom chip, the current drivers and power supplies, a charge-coupled device (CCD) camera, and a control computer. Source: T. van Zoest, et al., Bose-Einstein Condensation in Microgravity, Science **328**, 1540 (2010).

Science

Science reports on the first Bose–Einstein condensation in microgravity

T. van Zoest,[1] N. Gaaloul,[1] Y. Singh,[1] H. Ahlers,[1] W. Herr,[1] S. T. Seidel,[1] W. Ertmer,[1] E. Rasel,[1]* M. Eckart,[2] E. Kajari,[2] S. Arnold,[2] G. Nandi,[2] W. P. Schleich,[2] R. Walser,[3] A. Vogel,[4] K. Sengstock,[4] K. Bongs,[5] W. Lewoczko-Adamczyk,[6] M. Schiemangk,[6] T. Schuldt,[6] A. Peters,[6] T. Könemann,[7] H. Müntinga,[7] C. Lämmerzahl,[7] H. Dittus,[7] T. Steinmetz,[8] T. W. Hänsch[8] and J. Reichel[9], [1]*Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany,* [2]*Institut für Quantenphysik, Universität Ulm, Albert Einstein Allee 11, 89081 Ulm, Germany,* [3] *Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstrasse 4A, 64289 Darmstadt, Germany,* [4]*Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany,* [5]*Midlands Ultracold Atom Research Centre, Birmingham B15 2TT, UK,* [6]*Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7, 10117 Berlin, Germany,* [7]*Center of Applied Space Technology and Microgravity (ZARM), Universität Bremen, Am Fallturm, 28359 Bremen, Germany,* [8]*Max-Planck-Institut für Quantenoptik and Sektion Physik der Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München, Germany,* [9]*Laboratoire Kastler-Brossel de l'Ecole Normale Supérieure, 24 rue Lhomond, 75231 Paris, France,* rasel@iqo.uni-hannover.de

Albert Einstein's insight that it is impossible to distinguish a local experiment in a *freely falling elevator* from one in free space led to the development of the theory of general relativity. The wave nature of matter manifests itself in a striking way in Bose-Einstein condensates, where millions of atoms lose their identity and can be described by a single macroscopic wave function. We combine these two topics and report the preparation and observation of a Bose-Einstein condensate during free fall in a 146-meter-tall evacuated drop tower. During the expansion over 1 second, the atoms form a giant coherent matter wave that is delocalized on a millimetre scale.

The gedanken experiment of a freely falling elevator was crucial for the development of the theory of general relativity (GR) [1]. In such an environment, there are locally no gravitational forces, an idea that gave birth to the equivalence principle. Whereas GR rules the macroscopic world, quantum mechanics (QM) dominates the microscopic scales and reveals the wave nature of matter. Bose-Einstein condensates (BECs) [2,3] exist on the border between quantum and classical physics; they are governed by the laws of QM but can take macroscopic dimensions. We took advantage of the absence of gravity in a freely falling elevator to follow the long-time (1 s) evolution of a BEC. In particular, we report the preparation and observation of a BEC during free fall in the 146-m-high drop tower (ZARM) in Bremen, Germany, reaching expansion times up to 1 s that are difficult to reach in Earth-bound laboratories.

The extended time of free fall allows us to observe the ultraslow expansion of the released BEC to a macroscopic matter-wave packet, which provides us with a probe that is highly sensitive to magnetic and gravitational fields and represents a testing ground for physics at ultralow energy scales. We have performed more than 180 experiments to demonstrate the feasibility of coherent matter-wave experiments in microgravity [4], thus opening up a new avenue for high-precision measurements in space [5]. The drive for large expansion times of a BEC is motivated by the increase in sensitivity of an inertial sensor based on an atom interferometer with the square of the time [6] the atoms spend in the interferometer. As a result, cold atom-based sensors, such as gyroscopes or gravimeters [7], might reach an unprecedented sensitivity that is necessary to perform tests [8] of GR. Moreover, recent advances in atom-optics technology have led to the preparation of tests of the equivalence principle with matter waves [9, 10] rather than macroscopic systems.

In fig. 2, we display the long-time evolution of a BEC during the extended free fall in the drop tower. Three absorption images corresponding to expansion times of 30 ms (fig. 3a), 500 ms (fig. 3b), and 1000 ms (Fig. 3C) are shown. This limit is difficult to reach in standard BEC experiments but is relevant for the observation of quantum reflection [11] or Anderson localization [12,13]. Future atom interferometers in space will probe the boundary between GR and QM. Details of the experiment, the technology and the results can be found in [14].

This project is supported by the German Space Agency with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 0346.

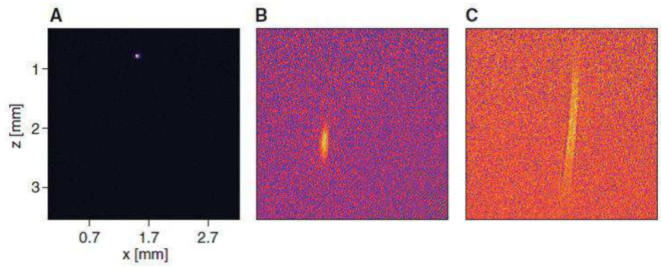

Figure 2: Gallery of absorption images of BECs created and observed in free fall (A to C). The series starts with a time of flight of 30 ms (A), which is typical for Earth-bound laboratory experiments. The following two figures correspond to expansion times of 500 ms (B) and 1 s (C). In the latter case, the BEC extends over a distance of more than 2 mm in the z direction. Source: T. van Zoest, et al., Bose-Einstein Condensation in Microgravity, Science **328**, 1540 (2010).

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Articles Welcome

Many thanks to all contributors of this issue of the ELGRA NewsLetter!

Please note that all ELGRA members are invited and encouraged to submit material including meeting announcements and reviews, reports or summaries, books announcement and reviews, brief research highlights, member news and editorials. Please send your contributions to the ELGRA Publications Editor (see cover page).

News

The first partial-gravity research campaign in Europe

S. J. de Vet, M. G. Kleinhans, H. Markies, A. C. in 't Veld and F. N. Postema, *Institute for Biodiversity and Ecosystem Dynamics, FNWI, University of Amsterdam, Postbus 94214, 1090 GE Amsterdam, The Netherlands,* s.j.deVet@uva.nl

A Dutch team of scientists from the University of Amsterdam, Utrecht University and the Technical University of Delft took to the skies in September 2009 to carry out the very first partial-gravity research campaign in Europe. The Netherlands Space Office-funded flights logged 46 parabolas during the first campaign and aimed at studying the avalanching behaviour of granular sediments on other planetary bodies.

Figure 1: Flight crew and scientists with their Cessna Citation II laboratory aircraft in the background (courtesy F. van Olden).

Up until now avalanching processes have been assumed to be independent of gravity. It influences the angle of repose found in piles of grains such as rice, sand, diamonds or oranges and is usually assumed be constant around 30 degrees. Effects of reduced gravity on avalanching may be especially relevant in landscapes for the interpretation of hillslope processes, wind dunes or the lee side of river deltas. Such landscape features are important for determining the present morphodynamics and paleoclimate from the geomorphology observed on rocky planetary bodies such as Mars. Experiments from the University of Amsterdam and Utrecht University, therefore, employed rotating drums and thin avalanche aquariums (hele-shaw cells) to record the changes in the angles of repose during avalanching in reduced gravity and to study auto-organisation (sorting) processes in sediment mixtures with varying grain sizes and angularities.

The flights were carried out using a specially developed partial-gravity flight director onboard the Cessna Citation II research jet maintained by the TU Delft and NLR. Meanwhile a new research campaign with the Citation is in the making. Partial-gravity research is moving to the forefront with the European Space Agency recently announcing their own partial-gravity parabolic flight campaign.

Nobel Prize for Physics 2010

Report by J. W. A. van Loon, *Dutch Experiment Support Center, University of Amsterdam, van der Boechorststraat 7, 1081BT Amsterdam, The Netherlands,* j.vanloon@vumc.nl

Andre Geim received the 2010 Nobel prize for physics, shared with his colleague Konstantin Novoselov. He received the prize for his initial work on graphene, the two-dimensional form of carbon. Geim is a remarkable mind. He is also active in the development of new adhesive materials based on natural structures, so called biomimetics. However, more interesting for our society is that Geim, together Berry also received the 2000 Ig Nobel Prize in physics. The received this *alternative* Nobel prize based on their experiments with a levitating frog (actually a toad) while he was working at the High Magnetic Field Laboratory in Nijmegen, NL. The Ig Nobel awards ceremony is traditionally closed with the words: *If you didn't win a prize - and especially if you did - better luck next year!*. A comment in an article in The National, titled *A noble side to Ig Nobels*, says that although the Ig Nobel Awards are veiled criticism of trivial research, history shows that trivial research sometimes leads to important breakthroughs". This statement surely holds for his original work on levitating biological samples. This alternative for real microgravity / near weightlessness experiments has gained quite some attention in the last decade. See also *In focus: Magnetic levitation* on page 8 in this ELGRA NewsLetter.

Figure 1: Nobel price winner 2010 Andre Geim.

Figure 2: Levitated frog.

In focus: Magnetic levitation

Magnetic gravity compensation in fluids

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The opportunities of space experimentation are rare and their waiting time is often very long. For this reason, other ways of achieving reduced gravity (or simulated reduced gravity) are often used as a replacement. Magnetic gravity compensation in fluids is increasingly popular as a means to achieve low-gravity for physical and life sciences studies. Comparing to other approaches, this means has several undeniable advantages.

- It is performed in a ground-based facility with no moving parts so that a good security level can be achieved,
- the low gravity duration is unlimited,
- in principle, no waiting time is required,
- reasonable cost,
- possibility of a constant controlled gravity level (that of Moon, Mars etc.),
- possibility of controlled time variation of gravity (simulating acceleration of space vessels).

However, there are some important limitations; they will be explained below.

Magnetic gravity compensation means (total or partial) controlled reduction of the gravity force *at each point of the object*. This definition is not equivalent to that of magnetic levitation. The latter requires that the object be suspended, which does not necessarily means that the gravity is compensated *inside* the object when it is rigid or is inside a rigid container. An example of levitation without compensation is a transparent bowl placed on a superconductive disk [1]. The bowl contains water with a goldfish. The whole system is levitated. The photo published in [1] shows that the meniscus of the water is flat, which means that both water and fish still experience the strong gravity.

The substances of practical interest for microgravity studies seem to be non-magnetic, which means that they do not possess their own magnetic field or develop it when put into an external field. However this is not entirely true. Their induced field exists but it is χ times smaller than the external field. The χ value is much smaller than unity.

One can distinguish two classes of substances: para- and diamagnetic. For paramagnetic substances $\chi > 0$, which means that their own field has the same direction as the external field. The direction of the own field of diamagnetics is opposite to the external field (i.e. $\chi < 0$). It is important to note that χ is proportional to the density ρ of the substance, so that the specific magnetic susceptibility $\alpha = \chi/\rho$ can be introduced.

The force that acts on the unit volume of a substance in the magnetic field B (measured in Tesla) is $\vec{F}_m = (\chi/2\mu_0)\mathrm{grad}(B^2)$, where $\mu_0 = 4\pi \cdot 10^{-7}$ [T·m/A] is a universal constant. This expression means that the magnetic force is not created in the homogeneous field (where the gradient is zero). The general idea of magnetic gravity compensation consists in counterbalancing the gravity force per unit volume $\vec{F}_g = \rho\vec{g}$ (where $\vec{g}$ is the gravity acceleration) with the magnetic force $\vec{F}_m$, so that their vectorial sum $\vec{F}_m + \vec{F}_g = 0$ at each point of the fluid. Note that the proportionality $\chi \sim \rho$ mentioned above means that ρ cancels from the compensation criterium which can be rewritten as

$$\frac{\partial(B^2)}{\partial z} = \frac{2\mu_0 g}{\alpha},$$

where z is he vertical axis. One notices that the quantity $G = 2\mu_0 g/\alpha$ is substance dependent. It defines a value of the B^2 gradient necessary to compensate the gravity in a particular substance. This parameter is presented in the fig. 1 for various diamagnetic substances. Several important conclusions can be made from the above compensation criterium. First, one notices that it contains neither the mass nor the density. The mass invariance means that if the sample consists of several pieces of the same substance but of different masses, the gravity is compensated in each of them. The density invariance enables the gravity compensation in the samples consisting of gas, liquid or solid phases of the same substance, which is helpful to study e.g. crystallization or evaporation.

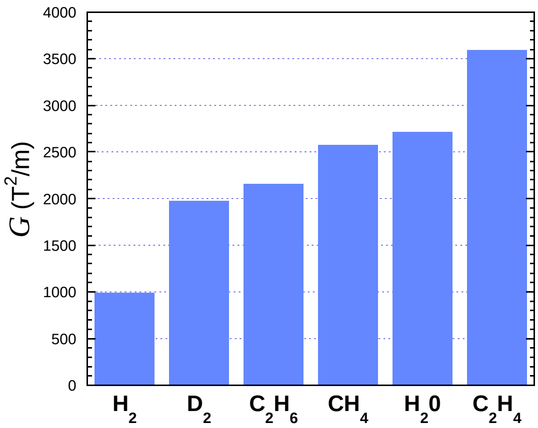

Figure 1: The values of $|\mathrm{grad}(B^2)|$ required for gravity compensation for different diamagnetic fluids.

One notices that there is a strong variation of G from one to another substance. It means that if a mixture is used, the gravity can be compensated exactly only for one of its components. This fact presents one of the limitations of the magnetic gravity compensation because the other components are still subjected to some effective gravity acceleration that should be carefully estimated. This applies e.g. to multi-component biological tissues.

Probably the most restrictive limitation of the magnetic gravity compensation method concerns the magnetic force field heterogeneity. It turns out that the ideal compensation cannot be achieved in a given volume, even if the fluid is homogeneous [2]. In most cases, it can be achieved in only one isolated point. However, one may approach the ideal compensation conditions with a given accuracy in any volume.

The compensation quality can be characterized by the spatial distribution of the effective gravity acceleration $\vec{g}_{eff} = \vec{g} + (\alpha/2\mu_0)\mathrm{grad}(B^2)$ or with the non-dimensional acceleration heterogeneity $\vec{\varepsilon} = \vec{g}_{eff}/g$. These quantities are defined by the design of the superconductive solenoids used to create the magnetic field and are specific to each of them.

Note that these quantities are vectorial and for most installations the magnitude of the radially directed component ε_r is at least one order of value larger that the axial component ε_z. The terms "radial" and "axial" are relative to the vertical axis to the cylindrically symmetric solenoid. The maps for the spatial distributions of ε_r and ε_z are very important parameters and are specific to the installation *and* to the levitated substance.

It turns out that one may estimate ε with precision even without these maps [2]. For a spherical volume of radius R, the value of the constant G specific to the given substance, the required field B created by the installation and the heterogeneity are linked by the following expression: $B = \frac{1}{2}\sqrt{3GR/(2\varepsilon_r + \varepsilon_z)}$. For instance, to provide the gravity heterogeneity $\varepsilon_z = \varepsilon_r = 1\,\%$ inside a sphere of 50 mm diameter for water, the magnetic installation should create the field $B = 41$ T. This value is close to the world field record obtained with the hybrid (superconductive+resistive) installations. Such a gravity compensation installation would be extremely expensive. For the field $B = 16.5$ T (maximum field of the existing magnetic compensation installations, see below), the estimation results in the heterogeneity $\varepsilon = 1.2\,\%$ attained within 10 mm diameter sphere.

Some precautions need to be taken in order to avoid a sample-induced additional magnetic force heterogeneity [3]. It may appear if the cell contains the magnetic atoms (Fe, Co, Ni, etc.). For example, the stainless steel as a material for the container or its support needs to be avoided and replaced by diamagnetic metals or their alloys (titan, brass, etc.).

The available magnetic gravity compensation installations worldwide are shown in the table below with their main parameters such as the maximum allowed values of B and G and the maximum diameter of the experimental cell that can be used (see [3] for references).

Location	B, T	G, T^2/m	Ø, mm
Nottingham, UK	16.5	2940	50
Nijmegen, NL	∼ 17	∼ 3000	40
Gainesville FL, USA	15	3000	66
		760	195
Providence RI, USA	9.5	3200	11
Xi'an, China	16.12	3026	51
Hiroshima, Japan	15	∼ 3000	50
Tohoku, Japan		∼ 4000	52
Tsukuba, Japan	8.5	448	50
	17	1600	
Grenoble, France	10	1000	50
	2	10	180

More powerful installations that can provide $G \geq 2900$ T^2/m can levitate water (see fig. 1). They are constructed in such a way that the slot (called bore) where the cell is placed is at ambient atmosphere and temperature. They can be used for the experiments with the biological tissues described in the next article of this issue. Some installations are suitable for the experiments with the cryogenic fluids. This is the case of two last installations created in our group, HYLDE (Hydrogen Levitation DEvice) and OLGA (Oxygen Low Gravity Apparatus). Important results on the dynamics of phase transitions (phase separation under vibration, evaporation and boiling dynamics, etc.) have been obtained in HYLDE, see [3] for their review. OLGA is helpful in simulating the behavior of the liquid oxygen in the fuel tanks and cryogenic engines of Ariane rocket. The magnetic gravity compensation remains the only way of low gravity experimentation with oxygen because of its high corrosion capability. In particular, OLGA allows the space vessel acceleration (or deceleration) to be simulated by fast change of the magnetic field [4]. Both OLGA and HYLDE are the ground-based facilities of the ESA and are available to the scientific community.

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Tuneable gravity using strong gradient magnetic fields

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Magnetic levitation is now well established as an attractive method to realize microgravity conditions, as one of the Earth-based alternatives for experiments in space. Over the years this has led to the worldwide installation of many superconducting magnet systems dedicated to achieve magnetic levitation in reasonably large volumes for extended periods of time. An important design target for such magnets is the capability to, at least, levitate water, requiring a magnetic field gradient equal to 1360 T^2/m, which is important in view of applications in fluid dynamics and biology. As shown below it is, however, often desirable to have even higher field gradients at your disposal. These high field gradients can be readily obtained by using the large water-cooled electromagnets that are available at some large installations around the world, specialized in making the highest possible static magnetic fields. This contribution shows how these strong magnets can be used to produce large gradient magnetic fields, what are the precise specifications of the magnetically tuneable gravity and how this can be applied in three distinct types of magnetic levitation.

Maximizing the gradient magnetic fields

An obvious approach to maximize the magnetic forces is to maximize the magnetic field strength. At present, the highest static fields are generated using powerful electromagnets, operated alone (up to 35 T) or in combination with a superconducting magnet (hybrid magnet, up to 45 T). Figure 1 shows a picture of a 33 T poly-Bitter magnet at the High Field Magnet Laboratory (HFML) in Nijmegen [1]. Comparable systems are available at the LNCMI in Grenoble (France), the NHMFL in Tallahassee (USA) and the TML in Tsukuba (Japan).

Figure 1: A picture of a 33 T poly-Bitter magnet. The magnet consists of 4 electrical coils, mounted inside a 1 m diameter, 1 m high cylindrical housing. At maximum field the electrical current is about 37000 A using a power of 17 MW. The magnet is cooled by cold water (12 °C) at a flow of 145 l/s. Access for samples and in-situ measurement equipment is possible from above and below the magnet, inside a 32 or 50 mm diameter vertical bore.

The profile of the magnetic field $B(z)$ within this 33 T magnet is shown by the solid line in fig. 2a. The field is maximal at vertical position $z = 0$ and decreases in either direction. An object with volume V and magnetic susceptibility χ experiences a magnetic force F_m given by:

$$F_m = \frac{V\chi}{\mu_0} B(z)B'(z), \tag{1}$$

which depends on both the magnetic field strength $B(z)$ and the field gradient $B'(z) = dB/dz$ ($\mu_0 = 4\pi \cdot 10^{-7}$ H/m is the magnetic constant). F_m thus strongly depends on the position inside the magnet and is equal to zero at the field center ($z = 0$) and maximal at some positions above and below $z = 0$ (dashed line fig. 2a). The precise profile of the magnetic force is given by the geometry of the magnet and thus varies from magnet to magnet. For the case of the 33 T magnets at HFML the maximum magnetic force is situated at 60.7 mm from the field center with a gradient of $B(z)B'(z) = \pm\, 6.058 B_0^2$ and a field strength of $B = 0.786 B_0$. The dashed line in fig. 2a illustrates that with center field $B_0 = 33$ T the maximum gradient is equal to 6600 T^2/m. At that position the field strength is 26 T. These strong gradient magnetic fields can be used for several distinct types of magnetic levitation experiments.

1. Regular magnetic levitation

The magnetic force can be used to counterbalance the gravitational force $F_g = mg$, with m the mass of an object ($m = \rho V$, with ρ the density) and g the gravitational acceleration. Levitation occurs when $F_m = F_g$, leading to the following condition:

$$B(z)B'(z) = \frac{\rho}{\chi}\mu_0 g, \tag{2}$$

which only depends on the ratio of ρ and χ and is independent of the volume of the object. Given the usual profile of magnets (fig. 2a) this leads to magnetic levitation that is stable for diamagnetic material ($\chi < 0$), in both horizontal and vertical directions [2]. Filling in the parameters of water gives a value of $B(z)B'(z) = -1360$ T^2/m, which typically occurs around $B_0 = 15$ T. It is convenient to define a dimensionless effective gravity according to:

$$G_{\text{eff}} = 1 - \frac{\chi}{\rho\mu_0 g} B(z)B'(z) \tag{3}$$

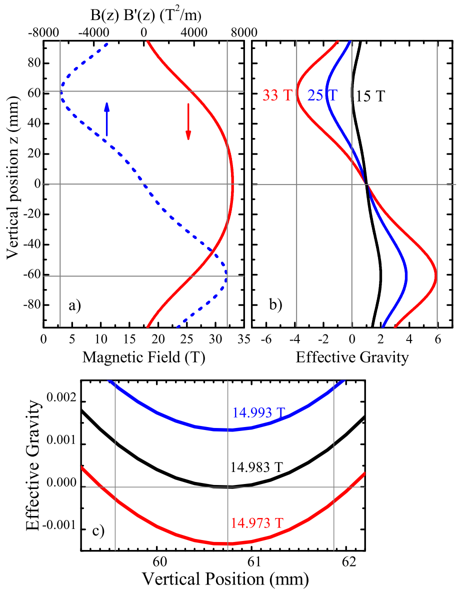

Figure 2: a) The magnetic field profile $B(z)$ of a poly-Bitter magnet at the maximum field of 33 T (solid line, bottom scale). The resulting magnetic force is proportional to $B(z)B'(z)$ (dashed line, top scale). b) The effective gravity, calculated for water with formula (3), as a function of position at different center magnetic fields B_0. c) The effective gravity for water around the levitation position for several values of B_0. In a region of several millimeters milligravity can be reached.

This equation reveals that G_{eff} can be varied continuously within a magnet by varying position and field strength (fig. 2b). In the field center, where $B'(0) = 0$, the effective gravity is equal to 1 (normal gravity), irrespective of B_0. Above (below) $z = 0$ the effective gravity is reduced (enhanced). Around $B_0 = 15$ T the field gradient is sufficiently strong to reach $G_{\text{eff}} = 0$ for water at $z =$ 60.7 mm, simultaneously with $G_{\text{eff}} = 2$ below the field center at $z = -60.7$ mm. This situation can be used conveniently to study the effect of gravity by positioning three samples at the $G_{\text{eff}} = 0$ ($z = 60.7$ mm), $G_{\text{eff}} = 1$ ($z = 0$) and $G_{\text{eff}} = 2$ ($z = -60.7$ mm) points within the magnet. In this case the $z = 0$ position is also important as a control to verify whether the magnetic field itself has any influence on the experiment. Increasing the center field strength leads to much higher values of the effective gravity: for $B_0 = 33$ T it is possible to continuously vary $G_{\rm eff}$ from -4 to 6 (fig. 2b). In order words magnets can be used to **tune the effective gravity**, including normal gravity, inverted gravity and microgravity, as well as Lunar and Mars gravity.

The tuneability of $G_{\rm eff}$ within a magnet is a powerful tool. However, a disadvantage of this effect is that it is very difficult to realize true microgravity ($G_{\rm eff} < 10^{-6}$) in extended regions of space. Figure 2c illustrates this point. Within a region of several millimeters milligravity ($G_{\rm eff} < 10^{-3}$) can be reached. Expansion of this region would require magnets that are optimized for generating a maximum, homogeneous field gradient ($B(z)B'(z)$), rather than a maximum field strength B.

2. Magneto-Archimedes levitation

So far we have neglected the influence on the medium in which the levitation occurs, as if considering levitation in vacuum. In many experiments the levitating object is situated in a medium with a density $\rho_{\rm med}$ and a magnetic susceptibility $\chi_{\rm med}$ that are different from those of the object. In normal gravity (and without magnetic forces) this leads to buoyancy forces given by the difference in density (as first described by Archimedes). In the presence of magnetic field gradients this leads to a "magnetic buoyancy" that depends on the difference in magnetic susceptibility. The condition for magnetic leviation now relies on balancing buoyancy rather than gravitational forces, leading to the expression:

$$B(z)B'(z) = \frac{\rho - \rho_{\rm med}}{\chi - \chi_{\rm med}} \mu_0 g, \tag{4}$$

which in general leads to a different value of the magnetic field gradient, as compared to that given by equation (2). In some cases levitation is facilitated by this magneto-Archimedes effect, when the object is positioned in a paramagnetic ($\chi > 0$) medium, such as pressurized [3] or liquid [4] oxygen. In other cases, especially for diamagnetic media, it is more difficult to reach levitation. An important biological example is the magnetic levitation of paramecium in water that requires much higher field gradients than regular levitation [5]. Similar effects can be expected for balancing gravity of the different components within biological cells. In these cases the ability to apply the highest possible field gradients is crucial.

3. Suppression of buoyancy-driven convection: application in crystal growth

In the past many studies have been performed to apply microgravity conditions during crystal growth to improve the quality of crystals. A growing crystal extracts solute from the solution and thus locally reduces the mass density of the solution. Under the influence of gravity the diluted liquid close to the crystal surface will rise due to buoyancy, which leads to a convection pattern, comprising a thin (typically 0.1-0.3 mm) laminar flow boundary layer (depletion zone) and a so-called growth plume on top of the crystal (fig. 3a). This buoyancy-driven convection maintains a high growth rate and continuously supplies impurities to the surface of the crystals and is, therefore, detrimental for the crystal quality. Without convection, as under microgravity conditions, this plume disappears; diffusion remains the sole means of mass transport, and the depletion zone expands to infinity (fig. 3b).

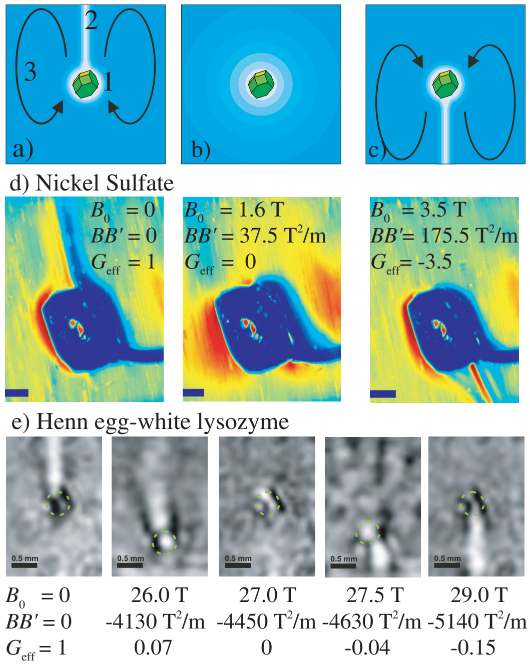

Figure 3: a) A growing crystal depletes its surrounding solution leading to a depletion zone (1), a growth plume (2) and a convective flow (3). b) At zero effective gravity convection is canceled and the diffusion field expands. c) In inverted gravity the buoyancy driven convection is reversed and a downward growth plume is formed. d) False-color Schlieren images of a growing nickel sulfate crystal, corresponding to normal, zero and inverted gravity [6]. e) Shadowgraphy images of a growing lysozyme crystal (dashed circles) under various conditions of effective gravity [7]. Scale bars correspond to 0.5 mm.

The criterion for damping convection during crystal growth is quite different from that for both regular and magneto-Archimedes levitation. This follows from the fact that for small variations in concentration c of the solute, both the density and the susceptibility depend linearly on concentration, i.e., $\rho(c) = \alpha c + \rho_0$ and $\chi(c) = \beta c + \chi_0$. This means that equation (4) changes into:

$$B(z)B'(z) = \frac{\alpha}{\beta} \mu_0 \, g \; . \tag{5}$$

The suppression of buoyancy depends therefore on the concentration dependence of the density and susceptibility (α and β), and not on the density and susceptibility themselves, as for normal and magneto-Archimedes levitation. The buoyancy forces need to be balanced in a liquid with a *continuous* range of concentration dependent *diamagnetic* susceptibilities and densities, requiring very different values of the field gradient.

The suppression of buoyancy-driven convection by gradient magnetic fields has recently been demonstrated for the growth of both paramagnetic [6] and diamagnetic [7] crystals. Figure 3d shows false-color Schlieren images of a growing paramagnetic Nickel Sulfate crystal positioned in the maximum field gradient *below* the field center. Without applied magnetic field (normal gravity) the image shows a narrow depletion zone and a clear upwards growth plume. At a field gradient $B(z)B'(z) = 37.5\,\mathrm{T}^2$/m the growth plume disappears, leading to an expanded depletion zone. For even higher field gradients the growth plume is directed downwards as a result of the inverted effective gravity [6]. Figure 3e shows similar shadowgraphy images for a diamagnetic hen egg-white lysozyme (HEWL) crystal, positioned at the maximum field gradient *above* the field center. At zero field and field gradient the convection plume is clearly visible as a white streak rising upward from the crystal. In the picture the crystal itself is blurred because for shadowgraphy out-of-focus images have to be taken. Most strikingly, the growth plume disappears, and thus convection is suppressed, at a gradient magnetic field of -4450 T^2/m (fig. 3e middle panel), whereas higher field gradients lead to inverted gravity and a downwards growth plume. Note, once more, that the field gradient required for dampening the buoyancy-driven convection is much higher than that for regular magnetic levitation. Both for Nickel Sulfate and HEWL the experimentally determined values for $B(z)B'(z)$ compare favorably well with the measured values for α and β [6,7].

Especially the last example involving diamagnetic protein crystals is of particular interest, because high quality protein crystals are essential for accurate structure determination by X-ray crystallography, and knowing their structure is of great technological importance. Space based protein crystal growth in zero gravity has therefore been actively pursued. To show that indeed the suppression of convection affects crystal growth, the growth rate of two lysozyme crystals at $G_{\rm eff}$=1 and 0 has been measured, at otherwise identical conditions. It was found that the growth rate drops by a factor of fifteen, from 30 $\pm$ 2 to 2 $\pm$ 2 μm per hour when convection is stopped and the depletion zone is expanded [7], similar to results obtained under space-based microgravity.

Conclusion

Gradient magnetic fields offer a powerful way to tune the effective gravity under Earth-based conditions, with relatively easy access and availability. This paves the way for many interesting experiments in a wide variety of research disciplines. Water-cooled poly-Bitter magnets provide a very useful tool to generate the highest possible magnetic field gradients that can be used for regular and magneto-Archimedes levitation, as well as to manipulate convection in fluids. Access to these strong magnets can be obtained via the submission of a proposal for magnet-time within the EuroMagNETII consortium (www.euromagnet2.eu).

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Stable diamagnetic levitation of water droplets and biological organisms

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1. Introduction

A levitated droplet of a homogeneous liquid such as pure water, or a well-mixed solution, behaves in very nearly the same way as a droplet in orbit: just as the centrifugal force balances the gravitational force on an orbiting spacecraft, the diamagnetic force opposes the force of gravity on the levitating liquid, *down to the molecular level*. However, there are some subtle effects of *tidal* forces on a levitated droplet—forces due to non-uniformity of the effective gravity—as Vadim Nikolayev outlined in his paper on page 8. For biological (and all non-homogeneous) material, the situation is made a little more complicated by magnetic alignment effects and stresses induced by the differing magnetic susceptibilities of biological tissues. We can, however, control for these effects by running identical experiments at different positions within the gradient magnetic field, as we shall discuss below.

2. Stable levitation of water droplets

In 1991, Beaugnon and Tournier succeeded in levitating droplets of water and organic liquids inside the vertical bore of a high-field Bitter magnet (resistive electromagnet) at the Grenoble High Magnetic Field Laboratory [1,2]. The levitation was *stable*: if displaced slightly, a combination of magnetic and gravitational forces returned the droplet to its equilibrium position [3,4]. Droplets of helium and hydrogen at cryogenic temperatures have since been levitated, too; see [5,6] and references cited within, and [7].

If a spherical water droplet is 'plucked', say by a puff of air, it oscillates, ringing like a bell at several different frequencies. The frequencies depend only on the liquid's surface tension and density, and the radius of the spherical drop at rest (this assumes that viscous effects are negligible, which is the case for water droplets larger than a few micrometres in diameter). Lord Rayleigh determined the dependence of the frequencies on these quantities in 1879. Hence, by measuring the oscillation frequencies of a freely-suspended droplet, we can determine the surface tension of the liquid, without requiring any mechanical contact with the liquid.

We can levitate cm-sized droplets diamagnetically to measure the Rayleigh frequencies, but there is a caveat: the 'restoring forces' that push the droplet back toward its stable equilibrium point, act as additional cohesive forces on the drop, perturbing its spectrum of oscillation frequencies slightly [8,9]. We can think of these forces as tidal forces: spatial variation in the gravitational field is responsible for the sea tides (and also for the 'spaghettification' of an unfortunate astronaut falling into a black hole!) Although such forces shift the frequencies by only a few percent, in order to use the oscillation frequencies to determine surface tension accurately, one must be able to account for this shift.

The magnetic and gravitational forces acting on the droplet's surface are given by the gradient of the magnetogravitational potential $U = gz - \chi B^2/(2\rho\mu_0)$ at the surface of the drop; the definitions of these symbols are given in Peter Christianen and Vadim Nikolayev's articles. The equilibrium shape of a liquid with no surface tension follows the contours of U—i.e. the surface of the drop is an equipotential—as demonstrated recently by Lorin et al., who have levitated liquid H_2 close to its critical point [6]. For small tensionless drops at the stable levitation point, this shape is spheroidal, but as the drop becomes larger, it assumes an inverted conical shape. However, for water droplets with diameter of, roughly, a centimetre or less, the surface tension dominates the magnetic and gravitational forces on the drop, so that its equilibrium shape is nearly spherical. In this case, however, the potential U is not constant over the droplet's surface.

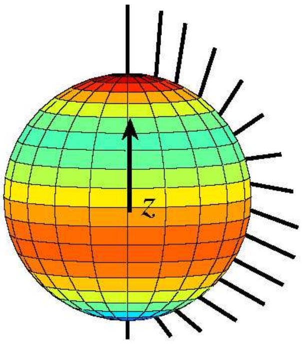

Figure 1: The colours show the magnitude of effective gravity at the surface of a levitating 7.5 mm water droplet: blue, 0.01 g; yellow, 0.03 g; red, 0.05 g. The effective gravity points toward the interior of the droplet; radiating lines show its direction, at the droplet's surface [8].

The forces normal to the surface of the droplet are well approximated by a spherically-symmetric part—i.e. a force that acts uniformly over the drop's surface—plus a quadrupole and an octopole component—forces that depend on the location on the surface (fig. 1). For measuring droplet oscillations, one tries to ensure that the tidal forces act as uniformly as possible over its surface. By tuning the current in the solenoid, we can reduce the quadrupole component to zero. The octopole component cannot be removed so easily, however: it is a feature of the magnetogravitational potential 'trap' produced by a vertical-bore solenoid and is responsible for the finite size of the trap. The variation in effective gravity over the surface of the droplet shown in fig. 1 is due to the octopole. Fortunately, the effect of the octopole on the oscillations is not significant, as long as the vibration amplitude is small, and the equilibrium drop shape is nearly spherical [8]. The perturbation of the oscillation frequencies owing to the spherically-symmetric component of the tidal force is relatively simple to account for [8].

In 1863, Plateau was inspired to experiment on a spinning droplet of oil, neutrally buoyant in a water/alcohol mixture, to model the shape of the spinning Earth. He recognised that the liquid's surface tension, holding the drop together, could model the action of gravity holding a planet together. Despite the attraction of its simplicity, Plateau's technique suffers from the viscous drag of the surrounding fluid on the spinning oil drop. By using diamagnetic levitation, we can sidestep the problem of the drag forces.

We can spin a diamagnetically-levitated water droplet easily by directing a jet of air at it [9], or by spinning the air surrounding the drop (by a fan, say). An alternative method is to pass a small electric current through a droplet with a little salt dissolved in it. If the current flow is perpendicular to the magnetic field direction, the Lorentz force on the current-carrying ions in the liquid generates a torque which can be used to spin-up the droplet: 1 mA in a 12 T magnetic field is enough to spin up a 1 cm water drop to several revolutions per second within a few seconds. The current is applied by inserting two thin wires just below the surface of the liquid, and applying a voltage between them. This method allows precise control over the torque applied to the droplet, and alterations to the applied torque can be achieved instantaneously. Recently, by using this technique, we were able to observe a three-lobed equilibrium shape of a spinning liquid droplet, predicted theoretically, but not clearly observed before [10] (fig. 2). One can also use this method to excite waves that travel equatorially around the droplet. These waves distort the droplet into curious-looking triangular, square and pentagonal shapes that are static in the reference frame of the laboratory [10].

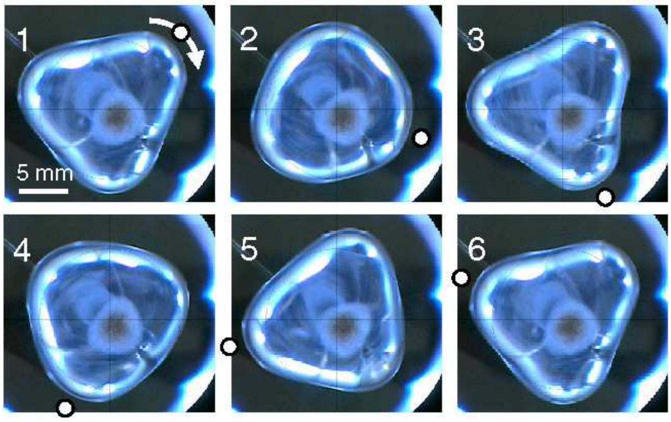

Figure 2: A levitating 1.5 ml water droplet, with a three-lobed shape, spinning at 3.3 rps [10].

3. Biological Organisms

In 1997, Andre Geim (this year's Nobel Prize Winner in Physics), along with researchers from the Universities of Nijmegen and Nottingham, succeeded in levitating a live frog (and any other diamagnetic objects to hand, such as their lunch!) at the High Field Magnet Laboratory, Nijmegen. In the same year, James Valles and co-workers at Brown University demonstrated levitation of frog's eggs and, later, yeast and swimming paramecia. More recently, a mouse has been levitated at the JPL in the US, and liquid bacterial cultures in our superconducting magnet in Nottingham, UK [11]. In a forthcoming paper, we show how fruit flies respond to levitation in the same magnet.

Since the majority of an organism is composed of water, it levitates at approximately the same position in the magnetic field as a water droplet. As a first approximation, we can assume that the effective gravity acting on the organism is the same as that acting on water.

For convenience, we label the levitation point of water, the '0 g* point' (to be precise, there are two levitation points on the bore axis, within approximately 2 cm of each other, depending on magnet geometry and magnet current: one is stable, the other is not [8]. We shall not distinguish between them here). Typically, the magnetic field is ~ 10 T at this point, for a magnet with a bore a few cm in diameter, depending on the geometry of the magnet—it is 12 T in our 5cm-bore magnet in Nottingham. Below this point—8 cm below, in our magnet—at the geometric centre of the solenoid, where the field-gradient is zero (see Peter's article) the effective gravity is g, and the field is ~ 15 T. We label this the 1g* point to distinguish it from the 1g environment outside the magnetic field. An equal distance below the centre of the magnet, where the diamagnetic force and gravitational force are additive, there is a $2\times$ normal gravity point (2 g*). By comparing the response of the organism to the three effective gravities, and to 1g outside the magnet, it is possible, experimentally, to control for the effects of the strong magnetic field [11,12]. Note that, since the effective gravity varies continuously as one ascends the magnet bore, one can identify points between 0 g* and 1 g* that simulate the gravity on Mars, or the Moon, say [12].

On Earth, the weight of a biological organism is supported by mechanical stresses within it. In orbit—or in deep-space—there are no such gravitationally-induced stresses. By levitating a *homogeneous* material, we can reduce these gravitational stresses to (nearly) zero, simulating a weightless environment.

Variations in magnetic mass susceptibility χ/ρ between the biological structures within an organism causes the effective gravity to vary from point to point within the organism, as outlined by Vadim Nikolayev. This inhomogeneity in the effective gravity generates additional internal stresses within the organism. To compare the stresses induced by the gradient magnetic field with gravitationally-induced stresses, it is useful to think of the induced stresses as originating from two sources: i) stresses, GRA, induced in the organism by a homogeneous effective gravity—approximately the effective gravity on water; and ii) additional stresses, VAR, owing to inhomogeneity in the effective gravity. If we only have GRA stresses, as in a homogeneous substance, the diamagnetic force simulates the gravitational force closely. VAR stresses can be considered artifacts of the levitation technique in this context. Both GRA and VAR depend on the field-gradient product of the magnetic field $B\nabla B$; i.e. they depend on the position in the magnetic field. Note that, at the 1 g* point, VAR=0 since $\nabla B = 0$. In 1 g, VAR=0 since there is no magnetic field. At the 0 g* point, on the other hand, GRA=0, but VAR $\neq 0$ for a biological organism.

Fortuitously, for most biological tissues, χ/ρ differs by only up to ~ 10 percent from the susceptibility of water [13]. Hence, in many organisms, we can expect the influence of VAR to be small compared to GRA. Valles et al. estimated the internal stresses induced in a levitated frogs egg, from the measured susceptibilities of a few major cellular constituents [14]. They concluded that the stresses VAR induced in levitating eggs were considerably smaller, by order 10 times, than the gravitationally-induced stresses, GRA, in 1 g. Thus, in this case, levitation approximates zero-gravity in the sense that GRA is reduced to zero and VAR is small. On the other hand, *Arabidopsis* seedlings grown at 0 g* maintain a sense of 'down': roots grow toward the ground in 0 g*, even in darkness [15]. Probably, this is because the statoliths—starch-rich organelles in the cells of the roots, supposed to be involved in gravisensing—have a significantly smaller χ/ρ than water, and thus VAR is significant. This suggests that to interrupt the seedlings' gravity sense, one needs a $B\nabla B$ large enough to float starch in water, significantly greater than that required to levitate the plant.

Additional stresses can be introduced through magnetic alignment. Many biological structures contain long sequences of regularly-oriented peptide bonds—a planar bond—or aromatic rings [16]. There is a torque on such structures in a magnetic field, due to the diamagnetic *anisotropy* of the peptide bond (and aromatic ring); the diamagnetic susceptibility is greater along the direction perpendicular to the bond plane. Some cell structures contain enough such sequences that the magnetic torque on the structure in ~ 1 T can overcome the randomising effect of thermal motion, resulting in some degree of magnetic alignment [17]. The cleavage planes of developing frogs eggs have been shown to align strongly with magnetic field direction at ~ 1 T, owing to the magnetic alignment of microtubules in the mitotic apparatus of the cells [18]. We can control for the effects of magnetic alignment (and other, more subtle magneto-chemical effects, including magnetic-sense perception), by comparing results from 1 g* with those in 1 g.

The effective gravity varies spatially, even for a pure substance like water, as we have discussed above. In our magnet at Nottingham, the effective gravity rises to approximately 10 percent of g, 10 mm from the 0 g* point. By confining the organism inside a container, we can control the range of effective gravities to which it is exposed. The spatial variation in gravity generates tidal stresses, just as it does in a droplet. The relatively small shift in the oscillation frequency of a cm-sized water droplet—the tidal forces are weak compared to the surface tension of water—suggests that such tidal forces should have little effect on similarly-sized biological organisms. Even so, we could experimentally test for the influence of the tidal forces. At the 1 g* point, the tidal stresses are larger, by a factor of order 10 compared to 2 g* and 0 g*, owing to the larger spatial variation of the diamagnetic force there. Hence, an indication of the importance of tidal stresses could be obtained by comparing results from the 0 g* and 2 g* positions with those from 1 g*.

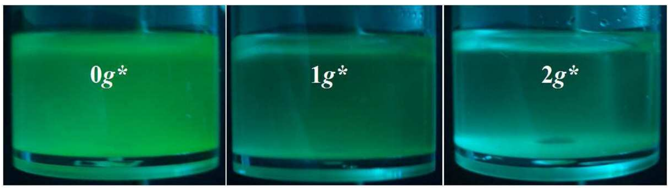

Figure 3: Samples of fluorescing E.coli bacteria in a liquid medium, showing that sedimentation is inhibited in 0 g* [11].

Diamagnetic levitation studies of organisms in liquids requires additional care. Bacteria in liquid media grow slightly, but reproducibly, quicker in 0 g* than in the other positions, due to increased O2 availability [11]. One reason for this could be that the sedimentation rate of the bacteria is significantly reduced in 0 g* (fig. 3), as in space. However, when the bacteria are respiring aerobically, the gradient magnetic field can cause convection of the liquid in the 0 g* position, transporting O_2 around the culture. Essentially, this effect is caused by the attraction of the paramagnetic oxygen molecules, dissolved in the liquid, to the magnetic field. This effect is, of course, *not* present in orbit, because there is no strong magnetic field there.

4. Conclusion

Diamagnetic levitation has many attractive properties as a ground-based 'zero-gravity simulator', as outlined already by Vadim Nikolayev. By using a superconducting magnet, we can maintain levitation practically indefinitely: our 17 T Oxford Instruments 50 mm-bore superconducting magnet in Nottingham runs for approximately 18 months, continuously, at high field, between servicing periods. A new 60 mm-bore magnet, currently being built at Nottingham, will have similar capabilities. As with all ground-based techniques, one should be alert to artifacts caused by the method of 'simulation'. For biological organisms, we should take care to consider the effect of additional stresses induced by the strong magnetic field. In fluids, there can be subtle effects caused by the spatial variation in effective gravity, and spatial variations in the liquid's susceptibility. Once these caveats are taken into account, diamagnetic levitation can be a powerful technique to complement existing ground-based methods for simulating zero-g, such as clinorotation and random-positioning.

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ELGRA Student Organization

The participation of students in different flight opportunities and other activities related to altered gravity has significantly increased during the last years as a consequence of a growing student interest in this research field. Along this line the ESA Educational Programs Drop (DyT), Spin (SyT)and Fly your Thesis (FyT) and the ELGRA Student Contest continue to encourage the next generation of scientists and engineers to inquire in the effects of altered gravity.

Nevertheless, there is no dedicated platform for students to meet and exchange their ideas which would facilitate their engagement in this field of science. On this background, and as result of the initiative of students who have taken part in different activities related to altered-gravity research, the idea of establishing a network among students involved or interested in this discipline was born.

ELGRA and LEEM (Laboratory for Space and Microgravity Research, www.leem.es) have endorsed a *Student Initiative on Altered Gravity* whose mission will be the promotion of different research opportunities in the field of altered gravity among students in Europe, the support towards a development of student projects, and actions to bringing together students with experts, scientists, and organizations in the sector.

Under the auspices of ELGRA, as reference society in altered gravity, and with the collaboration of LEEM, which is focused on the support of space related projects for students and young professionals, this international non-profit network will establish the following activities.

- Provide information about existing opportunities at the different European countries,
- establish links among students, scientists, and organizations which can provide technical and financial support to students engaged in altered-gravity projects, and
- organize workshops to give visibility to the results obtained by the students and to act as meeting points for European students in the altered-gravity field.

The network envisaged will be open to all students interested in altered gravity. They will be eligible to serve as local representatives in their respective countries, constituting the board of directors of the organization and acting as points of contact between students and third parties.

The first steps towards the activities mentioned will be initiated during the next months. For that reason, all students interested in joining or motivated in developing this network are encouraged to contact the representative for this initiative Mr. Amalio Monzón.

This initiative will provide a good opportunity for students all around Europe to get introduced into this field as well as will as bringing altered gravity closer to the next generation.

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Figure 1: Students from the Polytechnic University of Catalonia (Spain) assembling their experiment ABCtr MicroG for ESA's 51st Parabolic Flight Campaign in October 2009. From left to right: Sergi Varquer, Alberto González and Arnau Rabadán. The student's project has successfully been submitted to the Fly-your-Thesis program in 2009. The aim of the project is to record the behavior of enzymes that modify the assimilation of drugs by the human body. The photograph is copyright by ESA.

Reports from national delegates

France

France, through CNES and ESA, has had activities in life and physical sciences in space for several decades. Over the years, France has developed an expertise in many areas, with a focus on human physiology, fluid physics, fundamental physics, biology and exobiology.

More specifically, in physiology, CNES, in cooperation with DLR, has developed the instrument CARDIOLAB for cardiovascular research on board the ISS. There is also a cooperation with Russia on CARDIOMED, an equipment for medical operations which has been on the Station since 2010. Besides, new perspectives in cardiovascular research with China are initiated. Other areas of interest in physiology are neurosciences and nutrition, for which many experiments are performed on the ISS in cooperation with several space agencies around the world. One has also to mention that in MEDES, a CNES subsidiary, many bed-rest campaigns have been performed (some of them including artificial gravity through a short-arm centrifuge) to simulate the effects of weightlessness on the human body.

Figure 1: The DECLIC instrument is prepared at the Toulouse Space Centre in 2006. Credits: P. Jalby.

As far as fluid physics is concerned, the highlight is DECLIC, an instrument operational on the ISS since 2009. DECLIC, which stands for **DE**vice for the study of **C**ritical **LI**quids and **C**rystallization, has been realized in cooperation with NASA. CNES is also developing research in granular matter.

PHARAO, an atomic clock with a very high precision, is under development at CNES and is to be integrated in the Atomic Clock Ensemble in Space (ACES) project of ESA, which is supposed to be attached to an external pallet of COLUMBUS in a few years. It will provide a very high precision of time and may lead to several terrestrial applications.

France has been active for years in biology. CNES is now pursuing the development of an advanced incubator, called PHENIX, with a fluorescence capability. In exobiology, many French experiments are performed on the ISS (EXPOSE instrument) and also on the Russian platform FOTON.

Most of the experiments in the fields mentioned before are operated from CADMOS, the French center of the COLUMBUS ground segment, co-funded by ESA and CNES and located in the CNES premises in Toulouse. CADMOS is in particular the leading European center for physiology.

Last but not least, France provides parabolic flights to Europe thanks to the NOVESPACE company. Experiments on board the zero-g aircraft often prepare the ones to be performed later on the ISS.

In summary, CNES has a variety of activities in life and physical sciences in space, mostly done in European or international cooperation.

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The Czech Republic

The Czech Republic has a long tradition in the field of microgravity, in particular in biology, physiology, psychology, sociology and materials research. Czech scientists primarily cooperated with specialists from the former Soviet Union within the frame of the Intercosmos Programme. A large number of experiments were prepared for the spaceflight of the first Czech astronaut Vladimir Remek. As the next Czech achievement, four high-temperature furnaces for materials research have been installed and operated by the crews on the Salyut and Mir orbital stations.

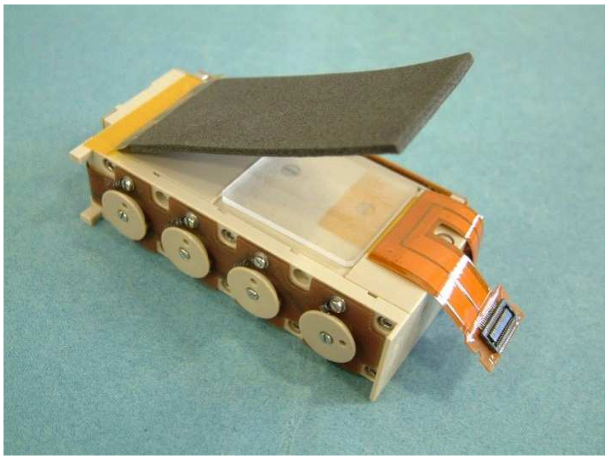

Figure 2: The container for the BASE-B/C experiment with detectors which was exposed onboard ISS in the framework of the DOBIES project. Credits: Nuclear Physics Institute ASCR.

Today, most of the Czech microgravity activities are realized through ESA. The first project along this line was DOBIES (Dosimetry on Biological Experiments in Space). It was finished in 2008. The objective of this project was to develop a standard dosimetric method as a combination of different techniques to estimate the absorbed dose, the dose equivalent and the linear energy-transfer spectrum in biological samples irradiated in space. The project's indirect continuation is being prepared together with international partners for an implementation in terms of ESA's International Life Science Research Announcement. Two further projects have been selected by ESA and are scheduled for implementation. These projects focus on metabolic and cardio-vascular demands and on effects of in-flight exercise countermeasures, effects of different exercise intensities and modes of the kinetics of gas-exchange and the cardio-vascular system. Both projects will be realized jointly with German colleagues. Within ESA's European Programme for Life and Physical Sciences, the European Laser Timing experiment is being fully realized in the Czech Republic. Its main task is to synchronize, via an optical link, the atomic clock in space ACES (Atomic Clock Ensemble in Space) with others clocks on the ground.

During the last two years the Czech space community has successfully rebuilt its activities. It is hoped that the Czech Republic will be able to increase its contribution to the field of microgravity research.

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The Netherlands

Several Dutch microgravity experiments were prepared or performed successfully within the ESA ELIPS program in recent years. Unfortunately, some experiments were also de-selected, in part due to, e.g., the inability of the hardware manufacturers involved to implement the required science. Also, some experiments had malfunctions during flight. The SODI-Colloid experiment (PI Prof. Wegdam, UvA, Amsterdam) is launched to the ISS and will be executed soon. A cell biological experiment from Prof. Peppelenbosch (EUR, Rotterdam) is in preparation for the MASER 12 sounding rocket flight. The experiment will be housed in the BIM module and plunger boxes, developed by Dutch Space and CCM. Launch is currently scheduled for November 2011 (see fig. 3).

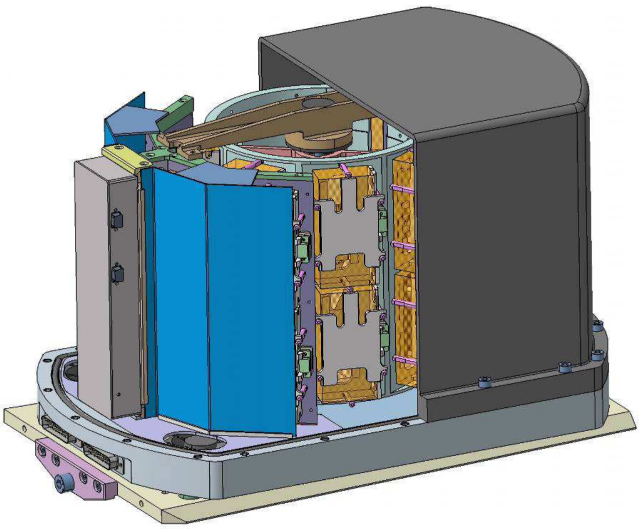

Figure 3: The BIM module for cell biological experiments in sounding rockets. Photograph: Dutch Space.

Dutch scientists were also quite successful during the last ESA AO in 2009. Out of the 79 experiments that were selected for flight, 15 included Dutch investigators, either as study coordinators (PI) or as Co-I. So, there is a nearly 20% participation of Dutch scientists within this ESA program.

The Dutch born ESA astronaut André Kuipers (fig. 4) is scheduled to be launched to the ISS via Soyuz for six months stay starting December 2011. Kuipers visited ISS for the first time during the very successful Dutch Soyuz mission, DELTA, in April 2004. Kuipers' mission in 2011 is supported through a national program mainly for educational and PR activities.

The Dutch national microgravity sciences activities are supported via a combined grant program also including Earth observation and planetary sciences. This program is evaluated every five years. Since the last evaluation in 2005 microgravity was ranked as lowest priority. This resulted in reduced programmatic support. Especially national support for technology/industrial activities regarding microgravity payloads was strongly reduced or even stopped. The next evaluation of the program is scheduled for spring 2011. We truly hope that the limited support for microgravity activities within the Netherlands and support for ESA programs will be increased or at least be continued. However, the general current tendency is towards stopping specific support for the science community which would virtually cut off Dutch researchers to make use of the ISS and other platforms for their science. This is certainly not in line with increasing the ISS operational phase to 2020 or maybe even 2026. It is also not in line with the level of support for this research in other European countries. Also the use of the promising commercial platforms such as DragonLab or Virgin Galactic will be nearly impossible for Dutch researchers. We are looking forward to outcome of the review and are confident that the evaluation committee values the past episode in (micro-) gravity research positive in order to continue national support for this program.

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Figure 4: André Kuipers will be staying in ISS for 6 months starting December 2011. Photograph: ESA.

Topical teams

Physical sciences

VIP-GRAN

VIP-GRAN is the acronym for **V**ibration **I**nduced **P**henomena in **Gran**ular media. The TT aim is to support the development of an experimental apparatus, which is now in phase B, in the space station in order to study the dynamics and the statistical mechanics of an ensemble of real particles that dissipates due to collision, i.e. ball–wall collision and ball–ball collision, and to solid friction. Special care is taken to study the limits of weak interaction between the balls because of their small number (Knudsen regime) and the limit of strong interaction when the mean free path between two ball collisions is less than the cell size.

Different ball sizes will be investigated, as well as different cell shapes and cell sizes and the effect of parameter of vibration. Attention will be paid to properties of mixing and segregation. Comparison with different limit cases will be achieved, i.e. with dissipative billiard models and with the statistical mechanics of gases or liquids.

A long-time low-gravity environment is needed in this domain, because it is the only way to realize the experimental situation in which inelastic collisions are the only interaction mechanism. From a statistical mechanics point of view, vibrations are used to maintain the kinetic energy of the 'gas', whereas the granular pressure is measured by simple pressure sensors, the temperature evaluated by the velocity of the particles and the mean flow through averaging.

An intensive study of the dissipative collapse is one of the natural goals of the research program in order to build up an experimental phase diagram of granular matter under vibrations. Another subject of interest is the segregation mechanism of binary mixtures. A third topic is the generation and control of convective flows in dense granular media in a vibrated container and in micro-gravity.

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Photovoltaic Silicon

Following ESA's announcement of flight opportunities in summer 2009, 25 laboratories, with the support of 15 industrial companies, proposed a large research project aiming to use microgravity conditions in order to better understand the physico-chemical phenomena involved during the industrial solidification of bulk silicon ingots. These ingots are later cut in wafers for solar cells.

Due to the shortage of ultra pure silicon, feed material industrials are using more and more polluted silicon. This renews the interest in studies of silicon solidification, focusing on the behavior of impurities. Twelve different space experiments, some in sounding rockets, others in the ISS, have been proposed in the following fields

- Effect of convection on the dissolution rate of crucible materials in molten silicon
- In situ X-ray observation of the solid-liquid interface
- Precipitation, pushing and engulfment of SiC, Si_3N_4 and other particles
- Segregation at grain boundaries
- Segregation and inclusions in Si-metal alloys
- Measurement of diffusion coefficients by shear cell and XRR techniques

This new (July 2010) Topical Team is aiming to help managing the overall project in order to link the individual space experiments.

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ATLAS – Atomic transport in liquids and semiconductors

The ATLAS kick-off meeting took place in April 2008 at the Institute for Materials Physics in Space of the German Aerospace Center in Cologne. Twenty participants from nine countries including Japan and Canada, a mixture of experimentalists, theoreticians and simulation experts, started a fruitful collaboration. All activities were planned straightforward in splinter meetings held, e.g. in Noordwijk, Montreal and Grenoble. As a result of these activities various proposals as answers to the ESA AO call in 2009 were submitted, e.g. the project proposals SiSSi, LIPIDIS, DIFFSOL and GRADECET. The projects cover materials like molten Silicon, molten Silicon-Germanium alloys, molten Al-based and Ti-based alloys as well as transparent model systems. The scientific objectives are related to mass transport problems, which occur mostly during fabrication or during use as technical alloys for applications. All scientific experiments are accompanied by theoretical investigations as well as numerical simulations. Currently, ESA investigates the feasibility of the proposed space experiments. The experiment techniques range from classical methods to advanced methods like X-ray radiography for in-situ observation. A second period for the topical team will allow to keep the network alive and will allow to bridge the time span until the successfully peer-reviewed projects can start.

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Figure 1: Participants of the ATLAS kick-off meeting.

Critical point studies in complex plasmas

The transition between the vapour and liquid phases of a pure fluid is one of the most fundamental in nature. The reference point, from which all of the transition properties of such a fluid can be derived, is called the *critical point*. In a wide domain around the critical point, important parameters such as isothermal compressibility, the density of the gas and liquid phases, and the surface tension, obey universal laws. The highly variable properties of near-critical fluids make them very appealing for studying many interesting phenomena that, because of the universality of the power laws, are *valid for all fluids*.

In this research programme we plan to investigate the critical point phenomenon at the most fundamental, the kinetic, level. The recent discovery of crystalline and fluid states in so-called *complex* *plasmas* has made such an attempt possible for the first time. If liquid complex plasmas have a critical point, then such investigations will provide a major leap forward in our understanding of the origins of the self-organization, ordering and scaling processes that take place in these systems. Also, if the universality principles hold — a fundamental hypothesis that also needs to be tested — then the results obtained from liquid complex plasma studies should be transferable to all other systems.

Path-finding experiments have been performed with PK-3 Plus aboard of the ISS in the last two years and the results are very promising. They show, although the lab is not perfectly suited for such research, that it is capable to investigate all kind of phase transitions in great detail. The next complex plasma laboratory, PK-4, will be launched in 2013 and is perfectly adapted to study the fluid phase, so we are expecting great progress thenceforward.

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Geophysical flow simulation

Overall driving mechanism of flow in inner Earth is convection in its gravitational buoyancy field. A lot of effort has been involved in theoretical prediction and numerical simulation of both the geodynamo, which is maintained by convection, and mantle convection which is the main cause for plate tectonics. To study specific phenomena experimentally different approaches has been observed, against the background of magneto-hydrodynamic but also on the pure hydrodynamic physics of fluids. With the experiment *GeoFlow* (Geophysical Flow Simulation) instability and transition of convection in spherical shells under the influence of central-symmetry buoyancy force field are traced for a wide range of rotation regimes within the limits between non-rotating and rapid rotating spheres. The special set-up of high voltage potential between inner and outer sphere and use of a dielectric fluid as working fluid induce an electro-hydrodynamic force, which is comparable to gravitational buoyancy force inside Earth. To reduce overall gravity in a laboratory this technique requires microgravity conditions.

Figure 2: The TT GeoFlow.

The *GeoFlow I* experiment was accomplished on the International Space Station's module COLUMBUS inside the Fluid Science Laboratory FSL from August 2008 through January 2009. For the planned second mission *GeoFlow II* (on orbit 2010) the working fluid shall be nonanol which has a temperature-dependent viscosity. Herewith, experimental modeling of mantle convection is going to spotlight.

Topical Team is set-up by Pascal Chossat (CNRS-UNSA, Université Nice), Rainer Hollerbach (University of Leeds), Laurette Tuckerman (PMMH-ESPCI, University of Paris), Innocent Mutabazi (University of Le Havre), Philippe Beltrame (University of Avignon), Fred Feudel (University of Potsdam) and Doris Breuer (DLR) with the tasks of experimental preparation and numerical simulation, interferogram evaluation, development of 3D numerical codes, bifurcation analysis methods as well as nonlinear process analysis.

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Electrochemical nucleation and growth

Many electrochemical processes are accompanied by natural convection due to the species consumption or dissolution. These flows influence the current distribution and determine the efficiency of industrial electrochemical reactors. A first aspect deals with nuclei size of crystals during electrodeposition, with bubble size during two-phase electrolysis or with pit size during corrosion. Interesting electrochemical systems include not only electrode material studies. Liquid electrolytes like aqueous solutions but also organic solvents, molten salt and ionic liquids are also interesting. The solid electrolytes (SOFC, PEMFC) or gaseous electrolytes (water vapor) are also explored electrochemical systems. The study of superimposed factors on electrochemical systems is also of interest: of course the addition of a forced convective flow (in open electrochemical cells or due to mixing) lead to a mixed flow.

But the use of external acoustics or electro-magnetics excitation should lead to interesting results. Fundamental studies on nucleation-growth in electrochemical interfacial phenomena are essential for mastering nano-structured devices tailoring, because nano-technology processing basically requires to separately control the growth process and nucleation phenomena.

Ambient conditions are to be controlled to ensure no macroscopic scale disturbances of nano-scale processes. The gravity field, because of natural convection induced during electrochemical processes, is one of the key origin of these disturbances. The possibility to eliminate the phenomena related to gravity is the most efficient way to practice and study nano-scale processes.

In all these applications it is crucial to estimate input parameters such as intrinsic reaction kinetics or material-bubbles wettability, in a pure diffusive context. Zero-gravity experiments offer this possibility. Parabolic flights or drop tower facilities enable to perform such experiments. However, they cannot give access to long time experiments which are important for electrochemical systems like batteries, fuel cells or corrosion.

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Atmosphere-space interactions monitor

The ASIM Topical Team is the scientific framework of the Atmosphere-Space Interactions Monitor, which is an instrument suite for one of the external platforms of ESA's laboratory module, Columbus. To be launched in 2014, ASIM will study thunderstorms and their interaction with the atmosphere above. The focus of the mission is two surprising phenomena that have been discovered within the last 10-20 years. One is bursts of gamma-rays, observed serendipitously from solar and astrophysics satellites when these are above thunderstorm regions, the so-called Terrestrial Gamma-ray Flashes (TGFs); the other is electric discharges of the stratosphere and mesosphere (red sprites, blue jets, and elves), also called Transient Luminous Events (TLEs). The primary objective of ASIM is to study the relationship between these independently discovered processes, to understand their physics, and to characterize their influence on the atmosphere. The instruments include an imaging X-and Gamma-ray instrument and optical cameras and photometers measuring emissions in narrow spectral bands. The ASIM payload for the ISS is the first space mission with dedicated instruments for simultaneous studies of TGFs and TLEs. ASIM is a partnership between companies and research organizations in Denmark (lead), Spain, Norway, Italy and Poland. The scientific team also includes many partners outside of ESA countries. More than 80 scientific groups from 30 countries participate in the larger ASIM Science Team.

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Figure 3: Giant jet extending from the top of a thunderstorm cloud to the ionosphere. Adapted from, and courtesy of, Su et al., National Cheng Kung University, Taiwan.

Near- and Supercritical Fluids

The objective of the topical team is to foster international cooperation in the study of fluids near their critical point and in their supercritical region. The critical point vicinity exhibit very particular properties (divergence of thermodynamic parameters and transport properties, the so-called *critical slowing down*) and universality features: all results can be put on universal, scaled master curves, one fluid is representative of all fluids.

The large compressibility of the fluid near their critical point allowed a new means to transport heat to be discovered in microgravity, the so-called *piston effect*. The diffusive thermal boundary layers at the walls compress and heat the bulk fluid that acts as a thermal short circuit.

In the supercritical region fluids, called supercritical (SC) fluids, acquire very unusual properties. For instance, SC CO_2 becomes an excellent (and non polluting) solvent of organic materials and SC water authorizes very efficient chemical reactions, as oxidation. Such *cold* combustion is very efficient to recycle organic materials and dangerous wastes like ammunitions that are transformed in mere CO_2 and water. It is likely to be the only way to authorize human long term exploration travels in space.

Two categories of experiments are currently identified, either using moderate (near ambient) temperature with SC CO_2 or SF_6 or high temperature (above 300 °C) with SC water. A dedicated facility (DECLIC, a CNES-NASA collaboration) is currently working in the ISS, studying boiling in SF6 and measuring properties of SC water (the critical temperature has been recently refined to within 1 mK thanks to this study). The investigation of oil drops diffusing in SC CO_2 is in progress for a parabolic flight. Other studies are under examination concerning jets of SC fluids. The universal behavior of the parameters of CO_2 within a few μK from its critical point and the phenomenon of enhanced salt deposition in SC water are planned with JPL and NASA. Japanese teams are interested by performing experiments of boiling.

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JEREMI

The TT JEREMI (Japanese European Research Experiment on Marangoni Instabilities) was founded in 2007 as a collaboration between Japanese and European scientist who previously have worked in the TT *Marangoni instabilities in systems with a cylindrical symmetry*.

Figure 4: The JEREMI team.

The scientific objectives of the TT are twofold. One aim is the understanding of interfacial heat transfer across moving deformable boundaries and the associated hydrodynamic oscillatory instabilities. To that end the influence of the ambient conditions on the behavior of flows at interfaces in systems with a cylindrical symmetry will be investigated. Such systems are important for the production of highest-quality crystals, semi-conductors, fibers and micro-fibers (for textiles and optics), micro-jets, and other applications. The second aim is the understanding of the formation of particle-accumulation structures (PAS), a process which represents a rapid and complete separation of the solid and liquid phases in such systems. The mechanisms and the effect of weightlessness on this unique phenomenon will be studied. A differentially heated liquid bridge exposed to an external coaxial gas stream will serve as a prototype system. The external conditions will be varied to control the flow and the particle accumulation.

To reach these goals a joint experiment will be carried out in FEPF module of KIBO supported both by ESA and JAXA. The preparation phase includes ground based experiments and theoretical studies in Europe (Belgium, Austria, Germany, Spain, and Italy) and in Japan.

Contact: Valentina Shevtsova, vshev@ulb.ac.be

Diffusion in non-metallic liquids

SODI was kicked-off at a meeting in February 2010 at ESTEC. Fourteen participants from seven countries participate in the TT which resulted from two projects submitted to AO-2009.

The scientific objectives are related to mass transport problems and, especially, diffusion and thermodiffusion in multi-component systems which are still not fully understood theoretically. Also experimental data for ternary and higher mixtures are currently not available. The prediction of heat and mass transfer in such systems greatly relies on the knowledge of diffusion and thermal diffusion coefficients, which appear in the equations describing these phenomena. The DCMIX project aims to elucidate the mechanisms of diffusion and inter-diffusion in multi-constituent mixtures and, eventually, develop predictive tools validated with the help of benchmark experimental data.

The experiment DCMIX will be performed in the facility SODI, which is already onboard the ISS. It will incorporate first set of measurements planned in the context of the original DSC project. Currently, the TT investigates the range of ternary liquid mixtures that can be suitably further studied in SODI's interferometry set-up for measurements of transport coefficients.

Contact: Valentina Shevtsova, vshev@ulb.ac.be

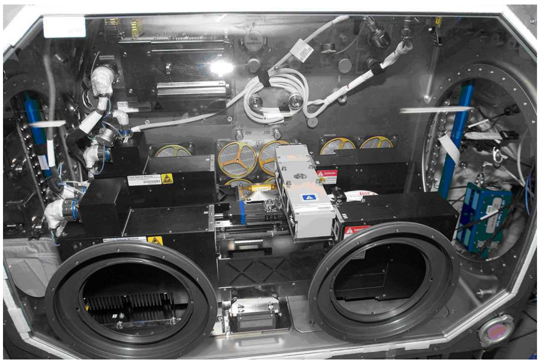

Figure 5: SODI instrument with experiment IVIDIL onboard the ISS.

Life sciences

Space radiation research

Space radiation is recognized as a limiting factor toward solar system exploration by human beings. A large research program in the field of space radiation biology has been implemented by NASA in recent years and exploits a high-energy accelerator at the Brookhaven National Laboratory to simulate space radiation. Similarly, ESA acknowledges the relevance of ground-based radiation research for human space exploration and is supporting a radiobiology program (IBER) based at GSI (Darmstadt, Germany). Besides, ESA is currently supporting different detectors and related dosimetry activities on the International Space Station. This Topical Team deals with space-radiation biology and dosimetry, proposes research topics for future activities, and co-ordinates research projects in the field of space-radiation biology and dosimetry in response to ESA announcements of opportunities. The TT covers both biology and physics, and both ground-based and flight activities.

Contact: Marco Durante, m.durante@gsi.de
www.gsi.de/forschung/bio/tteam_e.htm

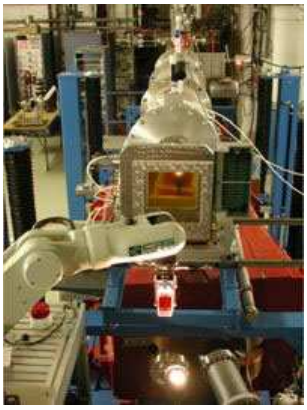

Figure 6: The experimental station at the GSI high-energy accelerator where galactic cosmic radiation can be simulated for radiobiology experiments.

Psychosocial and neuro-behavioral aspects of human spaceflight

Our ESA Research Topical Team's members are: Fabio Ferlazzo (University of Rome), Karine Weiss (University of Nimes), Berna van Baarsen (VU Medical Center in Amsterdam), Stefan Schneider (University of Cologne), Nick Kanas (UCSF), Iya Whiteley (IACE) and Gabriel G. De la Torre (University of Cadiz). We started in 2008 and our Team members have strong presence in international forums on the field such as THESEUS (ESF), ELGRA, IAA. The team members are participating in major current projects such as Mars-500. We are interested in a wide range of subtopics: Environmental issues, existential and neuro-cognitive processes, physical and mental well-being, psychosocial aspects, adaptation and new technologies in psychological assessment, treatment and countermeasures represent areas of research of current team members.

Contact: Gabriel G. De la Torre, gabriel.delatorre@uca.es

Figure 7: Some TT members during a meeting in London, 2009.

Artificial gravity

Artificial gravity has the potential to fully mitigate the physiological de-conditioning that results from long-term exposure to weightlessness. Today's approach to countering the deleterious effects of microgravity is piece-meal, whereas artificial gravity provides an integrated countermeasure affecting multiple physiological systems. Mars mission designs in the early days of the space program recommended replacing terrestrial gravity with inertial forces generated by centrifugation. Most concepts called for the use of spinning transit vehicles, which were not implemented due to technical issues associated with system complexity and cost in mass and energy. Recent studies suggest that humans can adapt to high rates of rotation at short radius. Therefore, an alternative to rotating the entire habitat is to provide a short-radius centrifuge within the habitat and deliver therapeutic doses of artificial gravity. This would result in an overall simpler and more affordable design.

There remain many unknowns as to how humans can adapt to a rotating environment and then re-adapt to a non-rotating environment (e.g., when they arrive on Mars). These human aspects were the primary focus of this Topical Team. The research needed to assess whether continuous or intermittent artificial gravity prescriptions (mostly centrifugation) can limit de-conditioning of sensory-motor, cardio-vascular, and musculo-skeletal systems has been identified. However, space research has revealed that plastic changes are induced in multiple physiological systems following exposure to weightlessness. These systems interact with each other, resulting in combined effects. Developing countermeasures for mitigating the deleterious effects of weightlessness, therefore, requires an integrative focus. Consequently, special attention was given to the interdependencies between physiological systems, including the autonomic and immune systems as well as nutritional considerations, and to the medical, psychological, and safety issues related to artificial gravity implementation.

G. Clément & A. P. Bukley (2007) Artificial Gravity. Space Technology Library. Springer, New York.

Contact: Gilles Clément, clement@isunet.edu

Space neuroscience

Discussions in this Topical Team focus on the deleterious effects of space flight on perception, sensory-motor coordination and cognitive performance. The team also tries to identify relevant research questions in space neuroscience as they relate to the current long-duration ISS missions and to the future human exploration missions. It is also taken as a given that understanding the effects of reduced gravity on the human organism is predicated on an understanding of normal physiological functioning in a one-g environment. Therefore, we also examine ground-based studies of the relevant central and peripheral systems that are compromised by exposure to reduced gravity.

Critical questions that should be investigated both in normal and altered gravity were identified for each of the four principal areas of research: gravity-sensing receptors, motor systems, spatial orientation, and cognition. Neuroscience research and technology priorities for addressing the risks to astronaut performance readiness during each of the key phases of a Mars exploration mission include the following issues: (a) motion sickness during landing on Mars and upon return to Earth; (b) dynamic range of sensory-motor responses to various gravitational environments; (c) morphological or structural changes in CNS and neuromuscular functions that may result from the decrease in afferent input to the vestibular, proprioceptive and somatosensory systems associated with long exposure to 0 g or 0.38 g; and (d) the procedures that produce rapid and complete adaptation to Mars gravity and Earth gravity after exposure to microgravity must be validated. This may be accomplished using Mars gravity simulation by executing parabolic flight maneuvers on Earth, or using a centrifuge on board the ISS or in a Moon habitat.

G. Clément & M. F. Reschke (2008) Neuroscience in Space. Springer, New York.

Contact: Gilles Clément, clement@isunet.edu

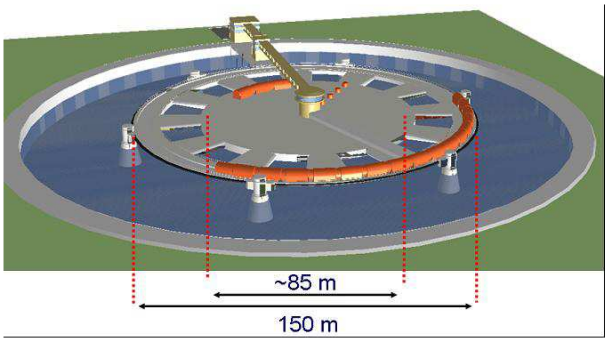

Figure 8: One of the options for a large centrifuge is a floating design. Pictured here is a 150 m diameter centrifuge with supply bridge and living modules on the rim and more to the center (Graphics courtesy of BERTE bvba, BETAQUA, and IFB GmbH).

Large Radius Human Centrifuge: The Human Hypergravity Habitat H3

Over the last decades a significant amount of knowledge has been gained on the adaptation of the human body going into near weightlessness conditions as well as for the re-adaptation to 1 g Earth after an orbital space flight. In ground-based paradigms for microgravity simulation such as head down tilted bed rest or dry-immersion studies are used. In such systems adaptations of the human body to long term immobilization and increased upper-body fluid shifts have been studied.

But could we learn something on human body adaptations to altered gravity using centrifuges? How does the body adapt to a long duration (days, weeks or longer) exposure to a hypergravity environment? And, once the body has fully adapted to a hypergravity environment, how does it re-adapt going back to a relatively hypo-gravity condition of 1 g, or even going from a hypergravity environment into a bed-rest setting? Can such transitions learn us something about the gravity transitions as a crew will experience going to Moon or Mars. Is hypergravity, therefore, a good model to study the effect of re-entry in gravitational environments after long duration space flight?

In this TT we will address these question and define a possible large radius (150–300 m) centrifuge for long duration human studies. The final outcome of the TT will be a clear answer about the feasibility of hypergravity, and if and how hypergravity studies can provide useful knowledge to support future space flight on the one hand and the medical issues in, e.g., the ageing population and on the other hand our contemporary lifestyle (osteoporosis, cardiovascular diseases, obesity, etc.).

The team consists of about 25 members from both the scientific and engineering community. Members from the USA and Japan are supported by NASA and JAXA, respectively.

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Members' section

Kayser-Threde GmbH (KT)

Kurt Kemmerle, *Kayser-Threde GmbH, Perchtingerstr. 5, D-81379 München, Germany,* kurt.kemmerle@kayser-threde.com

Over the last year, KT was active in many fields of microgravity research.

PK-3 Plus

This version of the plasma crystal facility is successfully operational on ISS in the fifth year now. In July 2010, the thirteenth experiment series was performed for French and Japanese scientists. Research topics were crystallization, melting, discharging, and agglomeration.

Figure 1: Cosmonaut Alexander Skvortsov with the PK-3 Plus Telescience Unit.

PK-4

The most recent European-Russian development is PK-4. From a technical and programmatic point of view, this is quite a different apparatus. Technically, PK-4 mainly uses high voltage DC for plasma control and possesses a rather large experimental chamber with wide gas parameter variations, particle manipulators as well as a sophisticated video observation system.

IPE

With the International Plasma Experiments Facility, ESA is preparing already the after next generation of plasma research facilities. Together with Verhaert (now QinetiQ), Kayser-Threde is preparing the phase B definition study.

MSL

The Materials Science Laboratory has passed its in orbit commissioning phase without any problems and all subsystems from KT worked perfectly.

ETD

The Eye Tracking Device for ISS is the latest one of a very successful development line from Kayser-Threde in the area of life sciences. ETD allows online evaluation of the eye movement. This project is conducted under contract to DLR. ETD is in successful operation on board the ISS since spring 2004 and has very successfully been used during each mission increment and during many taxi-missions.

EXPOSE

EXPOSE is an external payload facility on the International Space Station. Exchangeable experiments in the fields of exobiology, radiation biology, and chemical evolution can take place under ideal orbit conditions. Two units, EXP-E (ESA) and EXP-R (Russian), have already been developed and successfully flown on ISS. Currently a third issue of the instrument for ISS is under investigation.

Figure 2: EXPOSE-E in flight configuration.

TRAC

TRAC was an experiment set-up designed for measurement of astronauts' reaction times and adaptation capabilities. This German/Canadian experiment was first flown on the Shuttle and then conducted on board the ISS by Russian and US crew members in 2008. German experimenter was the Deutsche Sporthochschule Köln.

Thermolab

Thermolab is the most recent experiment which has been modified, qualified and brought to the ISS by Kayser-Threde. Thermolab measures the subject's body core temperature with a non-invasive sensor system. The first experimental sessions have successfully been performed in mid 2009. Principal investigator is the Charitée in Berlin, Prof. Gunga.

BMTC

The two biotechnological mammalian tissue culture ground demonstrators have passed the Test Readiness and Safety Review and are now undergoing the technical verification process. Afterwards, they will be delivered to the Universities of Basle and St. Etienne.

OMEGAHAB

OMEGAHAB is a German/Russian cooperation between the Universities of Erlangen and Hohenheim, and Moscow and St. Petersburg. It will fly on the Bion M1 re-entry capsule. It is an upgraded version of the successful AQUAHAB. It will comprise a multi-chamber aquarium with fish swimming chamber, fry chamber, algae reactor, plants, and crayfish areas. The movements of the fish will be recorded by a video camera, the growth of the algae by a microscope with camera set.

Swedish Space Corporation (SSC)

Christian Lockowandt, *Swedish Space Corporation, Solna strandväg 86, 17104 Solna, Sweden, christian.lockowandt@ssc.se*

The next major upcoming microgravity event for the Swedish Space Corporation (SSC) is the launch of the sounding rocket MASER 12 (for MASER 11, see fig. 1). It is scheduled for launch in November 2011 from our launch site Esrange Space Centre.

Figure 1: Launch of MASER 11, 15 May 2008.

The development of the four different experiment modules that will fly on MASER 12 is in full progress. One of the experiments is a continuation of a series of materials science experiments utilizing the in-situ X-ray diagnostic facility XRMON (for an example, see fig. 2).

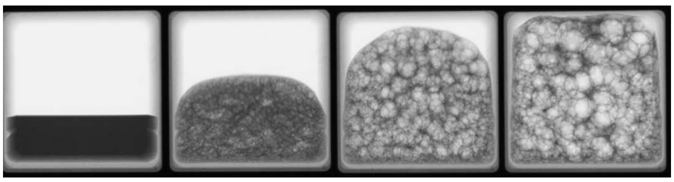

Figure 2: X-ray images of Al alloy foam generation in microgravity on sounding rocket MASER 11.

It is capable of continued X-ray imaging of samples during the experiment execution in microgravity. Images can also be down linked in real time for interactive control of experiments by scientists during flight. This facility has been developed by SSC and has been used on parabolic flights and sounding rockets for different materials science experiments with great success.

The next experiment on MASER 12, XRMON-GF, is a directional solidification experiment with Al-Cu samples by Dr. Henri Nguyen-Thi at UniversitṔaul Cźanne, Marseille, France, see fig. 3. It is interesting to notice that this type of experiment was among the first experiments we worked with in the seventies and eighties. The introduction of the in-situ X-ray diagnostics and, of course, new scientific theories and ideas have brought these experiment back again to utilizing microgravity.

Figure 3: X-ray image of dendrite growth in Al-Cu sample during ground tests with XRMON-GF experiment to be flown on MASER 12 in November 2011.

The Swedish Space Corporation has been working in close cooperation with microgravity scientists since 1976 with developing, launching and operating experiment payloads, foremost on sounding rockets. Since 1987 SSC is running the microgravity rocket program MASER offering 6–7 minutes of microgravity. The different experiment modules in the payload are developed by SSC and other companies in Europe.

ULISSE

USOCs Knowledge Integration and dissemination for Space Science Experimentation

ELGRA has been involved for two years in a European project in the framework of FP7 called ULISSE for USOCs Knowledge Integration and dissemination for Space Science Experimentation. It is a three-year project that involves 18 partners, the coordination of which is ensured by Telespazio/Mars (L. Carotenuto).

The ULISSE project is aimed at ensuring an effective exploitation of space data from physical and life science, including the archived data from previous experiments on the ISS and other platforms, as Space Shuttle, Spacelab and sounding rockets. This exploitation, although primarily for scientific purposes will also include dissemination of scientific and technical knowledge and its transfer to scientists, space agencies, industries, citizens and educational entities.

It is a matter of fact that presently an additional exploitation of the data from space experiments is difficult, if not impossible, to be performed. The main reason is that data are mostly accessible only to the Principal Investigators, i.e., to the scientific teams who submitted the experiment proposals that were selected for funding. It is, therefore, difficult to get access to a whole spectrum of all the data provided from the range of space experiments, which limits possible additional exploitation of these data. There is also a lack of exchange of data and information between different space research disciplines, limiting multidisciplinary research and making it difficult to correlate data obtained from different domains. It follows that there is a lack of visibility of space research for researchers outside the space field and a lack of visibility for European researchers from countries which are not members of the European Space Agency, in particular eastern European countries.

In order to overcome these difficulties, the ULISSE project aims to go beyond the centralized knowledge management approach by establishing, with the support of new technologies, a collaborative open network able to enhance information exchange and enable knowledge exchange. The methodology, an incremental and modular approach, is based on a semantic integration of data and applications. The implementation is based on web based interfaces.

These data could be then useful to a larger audience and it is anticipated that new knowledge will be gained from these reconsideration. For example, the coherent availability of scientific data from the ISS in the fields of the space environment, space medicine and physiology will prove fundamental in contributing to our understanding of how to design and perform future unmanned and manned space exploration missions. The knowledge gained will be useful in understanding how the human body behaves, will improve the care offered to our aging population as well as improve our understanding of the terrestrial environment.

The integration effort will generate and contribute to the standardization of knowledge representation for space science data as well as dissemination services. ULISSE will then pursue the exploitation and valorization of scientific data from previous and future space science experiments on ISS as well as data from other space platforms, promoting the involvement of specialized communities and the awareness of the general public.

ELGRA has been involved so far in collaborating to produce a questionnaire to users and sending it to representative members. A dedicated session of the next ELGRA meeting will be dedicated to the ULISSE project and to a web portal demonstrator giving access to the various services developed within the project. In addition, a special book will be published by Springer Verlag (edited by D. Beysens, L. Carotenuto, J. van Loon and M. Zell) with the contribution of many renowned scientist and experts. The book aims to show to anybody interested in space research (scientific community, space agencies, space companies, etc.) what are the main fields in life and physical science, the space infrastructures and the ULISSE project to obtain the data. It will be available by mid-2011.

Daniel Beysens, daniel.beysens@espci.fr

To register for ULISSE please visit www.ulisse-space.eu/.

ULISSE

SEVENTH FRAMEWORK PROGRAMME

Columbus and European Research with a six-member ISS Crew

More than two and a half years after the installation of the European Space Agency's Columbus Laboratory on the International Space Station (ISS), the research facilities of Columbus have been providing the European research community with valuable scientific data.

Columbus was outfitted from the beginning with the four ESA rack facilities: Biolab, the European Physiology Modules (EPM), the Fluid Science Laboratory (FSL) and the European Drawer Rack (EDR). In addition the two large external payloads SOLAR and the European Technology Exposure Facility (EuTEF) were launched together with Columbus. During 2008 NASA moved 4 research facilities from the US Destiny lab into Columbus and also mounted the MISSE payload on the Columbus External Payload Facility (CEPF). With the delivery of ESA's Materials Science Laboratory to the ISS in September 2009, and the installation of the Muscle Atrophy Research and Exercise System (MARES) in Columbus in April 2010, Europe's ISS laboratory is now fully equipped and ESA has a full spectrum of facilities on the Space Station, and committed teams of experts on ground. Add to this the presence of a permanent 6-member ISS crew since May 2009 and ESA is now in a position to undertake more extensive science activities on the ISS and achieve the majority of its Human Spaceflight research objectives.

The past 18 months have been a very exciting and busy period on the ISS with increased scientific return for ESA with the execution of more than 70 experiments across many research domains

Human Physiology

The suite of European and partner facilities in Columbus and on the ISS provide an extensive range of diagnostic and supplementary tools for undertaking a wealth of physiology research. This is augmented by the increase to a six-member ISS crew extending access to test human subjects as well as an additional diverse programme of ESA pre- and post-flight experiments.

Cardiovascular research is undoubtedly a major area of research for ESA on the ISS due to the physiological effects of weightlessness on the body and in light of future Exploration activities. In the past 18 months ESA has undertaken numerous experiments in this area looking into blood vessel wall properties (Vessel Imaging), thermoregulatory and cardiovascular adaptations (Thermolab), and cardiac output and lowered blood pressure in the face of increased activity in the sympathetic nervous system (Card). ESA has also undertaken a number of neurological/cognitive experiments (NEUROSPAT, PASSAGES, 3D-SPACE), and is continuing to look into salt retention and physiological effects with the SOLO experiment. Many additional pre-/post-flight experiments investigate a variety of medical changes for short-duration (Shuttle) and long-duration (6-months increment) crew members.

Biology

In biology, following the successful conclusion of the YEAST-B experiment in ESA's Biolab facility in October 2009 (of interest in fundamental science, industry and the medical field), ESA undertook two experiments looking into plant gravitropism processes using the model Arabidopsis plant: Waving and Coiling of Arabidopsis Roots (WAICO) in Biolab in Spring 2010 and GENARA-A in the European Modular Cultivation System in Columbus in July 2010. The WAICO samples are currently undergoing analysis looking into the effect of gravity on root spiralling, while the Genara-A samples are still preserved in a frozen state on the ISS awaiting return.

ESA has also recently extended its immune system (T-cell) research with the execution of the PADIAC experiment in the European Drawer Rack.

Radiation Dosimetry

Several experiments have been carried out in the domain of radiation research, which is of particular importance for the preparation of human long-duration spaceflight. The MATROSHKA-Kibo experiment, has been acquiring data about the accumulated radiation doses inside the Japanese Kibo Laboratory since May 2010 using a simulated human torso fitted with passive radiation sensors at vital organ sites. ESA is also carrying out area mapping of the radiation environment in the Columbus laboratory using 11 passive radiation packages distributed in Columbus (now returned for analysis) together with active radiation sensors as part of the Dose Distribution inside ISS (DOSIS) experiment. This has been supplemented recently with the start of ESA's ALTEA-Shield experiment which is looking into the light-flash phenomenon in astronauts in addition to testing the effectiveness of different shielding materials.

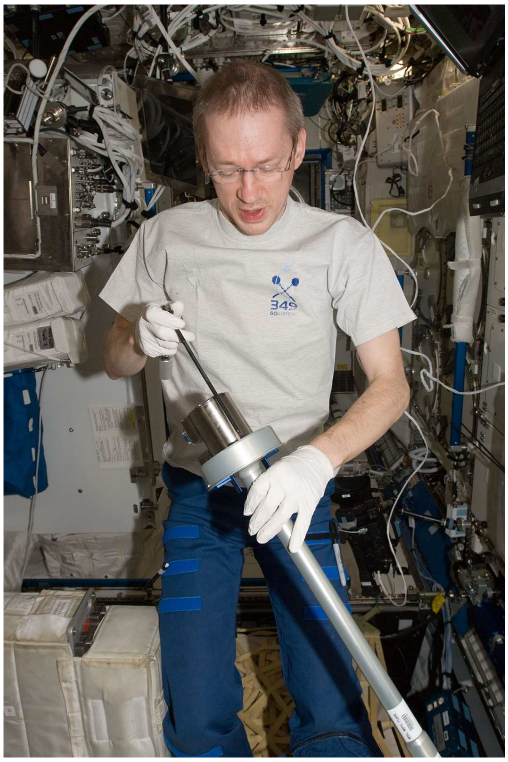

Figure 1: ESA astronaut and ISS Expedition 21 Commander Frank De Winne during Material Science Laboratory sample exchange activities in November 2009.

Fluid Science

ESA's foam research activities commenced with the Foam-S and FOCUS experiments which could have applications in the production of ultra-light and strong metallic foams in the future. One major focus for ESA's research in fluid physics in the past 18 months has been the Selectable Optical Diagnostic Instrument (SODI) and the three associated experiments IVIDIL, COLLOID and DSC which take place in the ESA-developed Microgravity Science Glovebox in Columbus.

IVIDIL (Influence of Vibrations on Diffusion in Liquids) had an exhaustive set of experiment runs from October 2009 to January 2010 with varying frequency/amplitude of vibration stimuli and varying imposed temperature gradients. The wealth of data from IVIDIL is still undergoing detailed analysis. The COLLOID experiment provided innovative research into colloidal solutions with promising applications in advanced optical components while the final SODI experiment DSC, related to improved crude oil recovery, is due to be carried out around mid 2011.

The GeoFlow-2 experiment for FSL, which will be studying geophysical phenomena is manifested to be launched on Europe's second Automated Transfer Vehicle in February 2011.

Materials Science

The delivery of ESA's Material Science Laboratory (in NASA's Materials Science Research Rack) was a major stimulus for materials research on the ISS. Scientists from the CETSOL and MICAST projects have already presented very promising preliminary scientific results stemming from analysis of the first samples to be processed in the Material Science Laboratory. CETSOL/MICAST are applied research projects which carry out research into the formation of microstructures during the solidification of metallic alloys, which will help to optimise industrial casting processes.

ESA also completed a successful $3\frac{1}{2}$ months of experimentation with the Protein Crystallization Diagnostic Facility (in ESA's European Drawer Rack facility) in July 2009 with the aim to visualize in-situ the nucleation and crystal growth environment.

External Payloads

On the external locations Columbus was originally outfitted with the SOLAR facility and European Technology Exposure Facility (EuTEF). For SOLAR an additional extension of more than 3 years to the payload's originally planned time in orbit could see its research activities extend up to 2013 and beyond in order to catch the progressive increase of 11-year Sun activity cycle. This Sun-tracking platform has been providing excellent scientific high accuracy measurements of the solar irradiance in a very large wavelength bandwidth.

The EuTEF platform with its 13 active and passive experiments was returned to ground in September 2009 after a successful mission of 1.5 years in open space since its launch with Columbus. These experiments covered a range of disciplines including material science, space physics, astrobiology, astronomy, and space technology.

ESA's astrobiology research was further increased in March 2009 with the deployment of the EXPOSE-R unit, which is operated outside the Russian ISS segment with its nine different exobiology experiments, which are complementary to experiments that took place on EuTEF and which contribute to Exploration research.

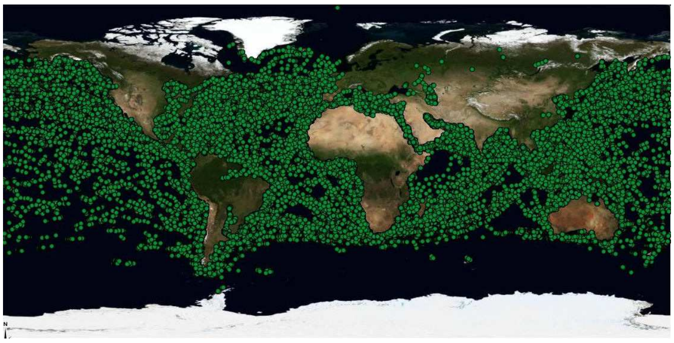

Figure 2: Plot from the Vessel identification System.

Technology Demonstrations

Technology research is becoming an extremely important and valuable area for ESA with respect to resources. One important example is the Vessel Identification System (commonly known as the Automatic Identification System, AIS) which is very successfully testing the means to track global maritime traffic from space by picking up signals from standard AIS transponders carried by all international ships over 300 tonnes, cargo vessels over 500 tonnes and all types of passenger carriers. The Vessel Identification System has successfully tested all of modes of operation with more than 90,000 messages having been received from ships during the first 14 hours of operation.

ESA's research in technology has been augmented in the past year with a test of a hands-free technology for assisting astronauts while performing on-board tasks and a high-definition 3D video camera.

Future Outlook of European Utilisation on the ISS

For future increments ESA will continue to exploit the broad spectrum of research capabilities and resources made available to European researchers on the ISS, and collaboration with ISS Partners is allowing an augmentation of the European ISS resources. The strategic research planning has now been extended beyond 2015 with clear perspectives for ISS extension until the 2020 timeframe. The latest ELIPS research project selections (68) from the AO solicitations will make full use of ESA's ISS utilisation resources for the next 5-7 years (depending on the discipline).

As a brief overview of some future ISS utilisation highlights in the near-term: further to the CETSOL/MICAST and also SETA projects, materials research will benefit in the future from the launch of the Electromagnetic Levitator (EML) for container-less processing while Fluid Science activities will see the launch of the FASES experiment for the Fluid Science Laboratory (emulsions) and FASTER experiment for sophisticated applied research in liquid adsorption. Another important areas of interest is Complex Plasma research.

Cardiovascular studies, neuroscience and metabolic studies will be predominant medical research topics, complemented by countermeasure studies. Advanced plant biology and additional cell and molecular biology research will continue in the Biolab facility, the European Modular Cultivation System and ESA's Kubik Incubators.

ESA's current radiation dosimetry research will be expanded to support the assessment of radiation risk of crews on the ISS and during human exploration missions beyond low-Earth orbit, while the phasing-out of the Space Shuttle is leading to the development by ESA of on-orbit analysis techniques to reduce download requirements, which also has exploration impacts.

Will see the launch of different major external payloads in the future including ASIM (study of high-altitude lightning and its effect on Earth's climate), ACES (ultra-precise atomic clocks) and Expose-R2 (astrobiology). ESA will further expand the utilisation of ISS with climate change studies and technology research for Exploration.

Figure 3: ESA's Solar Facility on the external surface of the Columbus laboratory in November 2009.

After $2\frac{1}{2}$ years of Columbus operations the number of ESA experiments, their scope and complexity, have significantly increased and the achievements of the last 18 months are significant. The international collaboration between the agencies is steadily increasing which simultaneously promotes joint experiments by international science teams and best use of the valuable ISS resources. An exciting era for ESA and the European scientific and industrial user community is continuing, and bodes well for a promising long-term scientific future of the ISS programme.

Dr. Martin Zell, martin.zell@esa.int
Head, ISS Utilisation Department, Directorate of Human Spaceflight, ESA/ESTEC

Award-winning student presentations

During the ELGRA Biennial Symposium 2009 in Bonn, ELGRA invited student teams (undergraduates and postgraduates) to submit their work to a special Student Session and participate in the *Student Contest*. All teams pre-selected by the ELGRA Management Committee received a free student ELGRA membership for one year and financial support – provided by the ESA Education Office – to enable their participation in the conference. A total of eleven contributions were selected, five from Life Sciences and six from Physical Sciences. Six presentation were given in the Student Oral Session (three from each of the two disciplines). Five contributions were presented as posters. All participating groups were candidates for the student award. All participants of the symposium were entitled to vote for the best student paper. As a result of the election the awards (one per discipline) were granted to the coordinators of the winning teams Camilla Pandolfi (University of Florence, Italy) in Life Sciences, and Santiago Arias (Polytechnic University of Catalonia, Spain) in Physical Sciences. The winning teams were honored during the conference dinner by handing over the award certificates. The awardees were invited to publish a summary of their paper this Newsletter.

Figure 1: Ruth Hemmersbach and Jack van Loon during the Student Award Ceremony.

Figure 2: Students who participated in the Student Competition.

Figure 3: Jack von Loon (middle) with the winners Camilla Pandolfi (left) and Santiago Arias (right).

Physiological response to temporary changes in gravity conditions on plants

C. Pandolfi*, E. Masi, S. Mugnai, E. Azzarello, L. Renna, G. Stefano and S. Mancuso, *Department of Horticulture, University of Florence, viale delle idee 30, Sesto F. no (FI), Italy,* *camilla.pandolfi@unifi.it

Gravity is the main factor that influences the direction of growth of plant organs, and has also a direct effect on the plant metabolism. When an organ, mainly roots, is turned by between 0° (vertical) and 90° (horizontal), the change of orientation is perceived by its organs producing the so-called gravitropic reaction (Perbal and Driss-Ecole, 2003), which involves a strong metabolic response.

In order to study these reaction in real microgravity conditions, some experiments have been set up during six ESA parabolic flight campaign. Oxygen concentration in the solution where roots of Zea mays were placed have been constantly monitored during normal, hyper- and microgravity conditions. An evident burst in oxygen fluxes started just 2.0 ± 0.5 s after the imposition of microgravity conditions. No significant changes were noticed neither in normal nor in hyper-gravity conditions. Moreover, oxygen bursts were detected only in the root apex zone The significance of these results is dramatic on the nature and location of the graviperception. This spike-like activation/deactivation of oxygen when growing roots were exposed to microgravity situation can be detected at each parabola with the same results, whereas the hypergravity situations, which are imposed in between, do not interfere with the microgravity-induced bursts.

Concerning the different location of the selective oxygen microelectrodes, oxygen bursts happened only in the root apex, whereas no changes in the physiological activity was never identified in the mature zone of the root, showing a clear role of the root apex region in detecting environmental changes, which is the case of microgravity conditions. Moreover, control treatments without roots showed no responses in both the micro-electrodes placed at root apex and mature region levels confirming the real and effective role of root apex. Concurrently measurements of oxygen consumption of root apex were done using oxymeters, a difference in oxygen consumption was expected during the different gravity conditions, but measurements revealed the onset of long lasting oxygen bursts appearing only during microgravity, demonstrating once again the result obtained with the oxygen electrodes.

Although the chemical nature of these oxygen bursts is sill unknown, they may implicate a strong generation of reactive oxygen species as they exactly match the microgravity situation. Thus, our data strongly suggest that the sensing mechanism is not related to a general mechanic stress, which was imposed also during hyper-gravity, but is very specific of the microgravity situation. Moreover, it is well-known that stress rapidly induces reactive oxygen bursts which are associated with oxygen influx and reactive oxygen efflux from stressed plant tissues. Thus, our data indicate that microgravity represents a stress situation for plants, especially root apices and these bursts, probably ROS, are initiating and integrating adaptive responses of plant roots which resemble other unrelated stress situations.

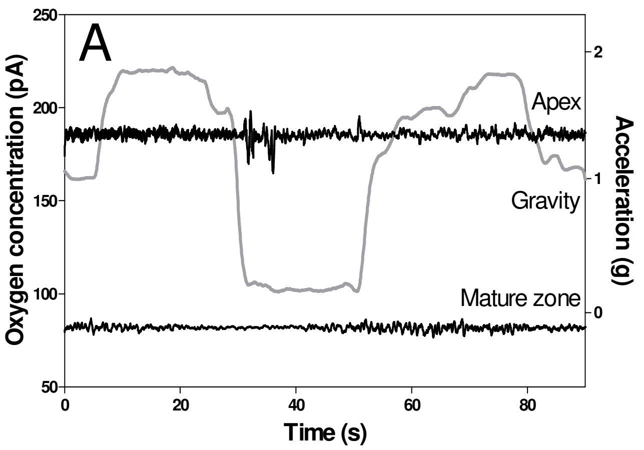

Figure 1: Oxygen spikes are detected during a microgravity event only in the apical region, whereas in the mature zone oxygen concentration remains constant.

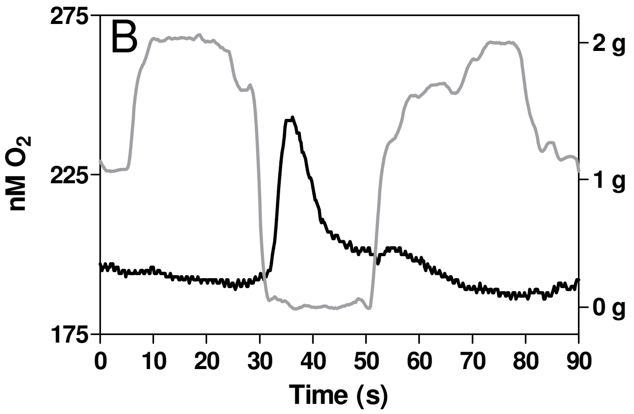

Figure 2: Oxygen consumption of six root apex in a saline medium has been measured in a close chamber, and significant oxygen bursts are recorded only during the microgravity condition

A parallel experiment has been done using the MEA (Multi-Electrode Array) System in order to examine synchronized electrical activities under temporary changes of gravity conditions. As no previous data on the use of MEA system in microgravity conditions have been ever reported in literature, one of the main goals was to check the capability of the system to optimally perform continuous monitoring of root electrical activity. Results showed a clear overall root electrical activity, with differences in rates observed both during the same flight and among different ones. Moreover, the electrical activity (namely spike rate) tended to be significant lower in microgravity in comparison with the normal conditions, while hyper-gravity conditions seemed to be less effective in decreasing the spike rate. As a conclusion, the trial was successful, with gravity changes proving to affect spike rate generated by maize root tips. Further analysis will be conducted to investigate the correlations between the changes in gravity conditions and the appearance of synchronous phenomena.

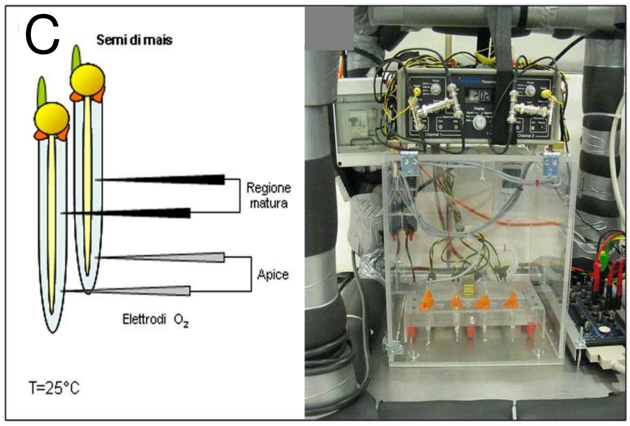

Figure 3: Scheme of oxygen electrodes positioning in the apical and mature zone of maize seedlings.

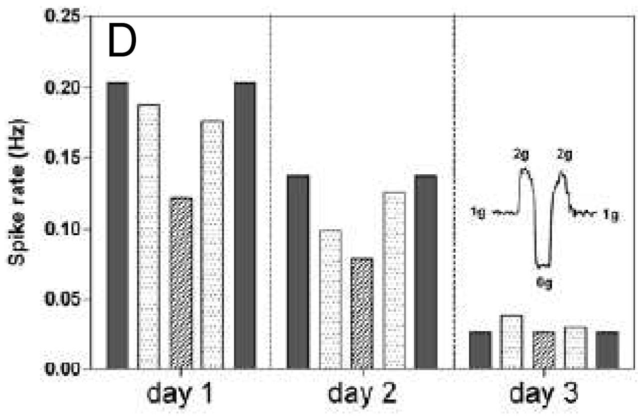

Figure 4: Average electrical activity per second (Hz) Roots showed a clear and detectable overall electrical activity during each experiment. Differences in rates were observed both during the same flight and among different ones. In the first case, differences seemed to be related to the changes in gravity conditions whereas in the latter one were probably due to different sample biological spontaneous activities. Correlations between spikes and acceleration were analyzed. Results showed that the electrical activity (namely spike rate) tended to be significant lower in μg in comparison with the normal gravity conditions.

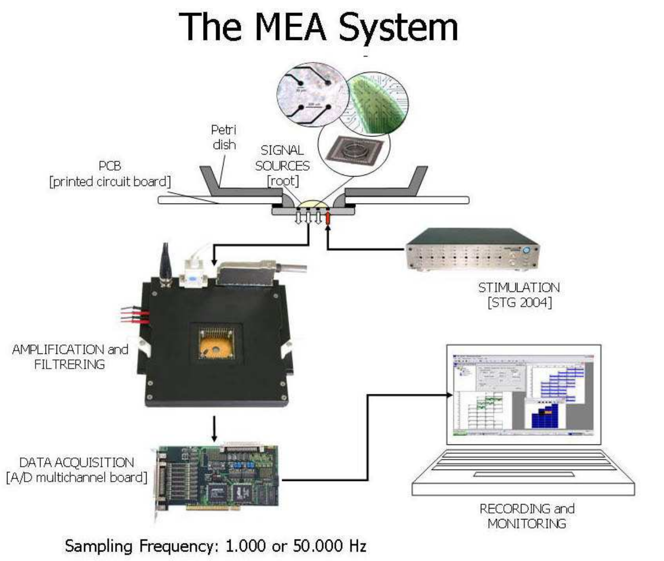

Figure 5: Root apex electrical activity detected in specific electrodes of the MEA System.

Experimental analysis of the bubble-slug transition in a mini-channel in micro-gravity conditions

Santiago Arias, *Universitat Politècnica de Catalunya, Castelldefels (Barcelona), Spain*, santiago.arias@upc.edu

Three main different flow patterns were found for two-phase gas–liquid flow in microgravity conditions: bubble, slug and annular flow [1,3]. Each of these patterns presents unique features that made it interesting for variety both scientific and technological applications. And even if several method have been proposed in the past to define the two-phase flow patterns [4,7], a better understanding of it is still required. To such end, further studies regarding the mechanisms of transition between regimes are essential.

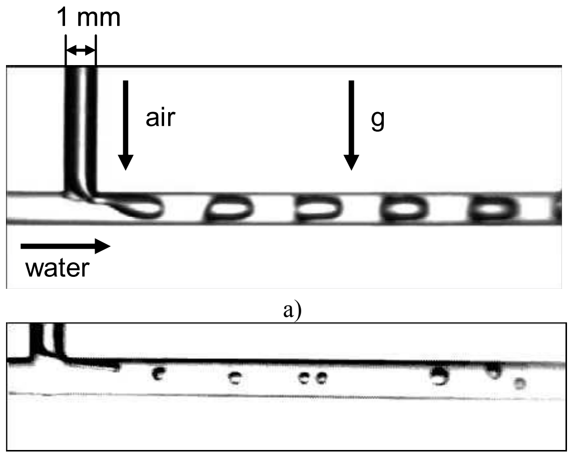

Figure 1: Representative photographs of flow patterns in the 1 mm circular diameter tube: a) slug flow; b) bubbly flow.

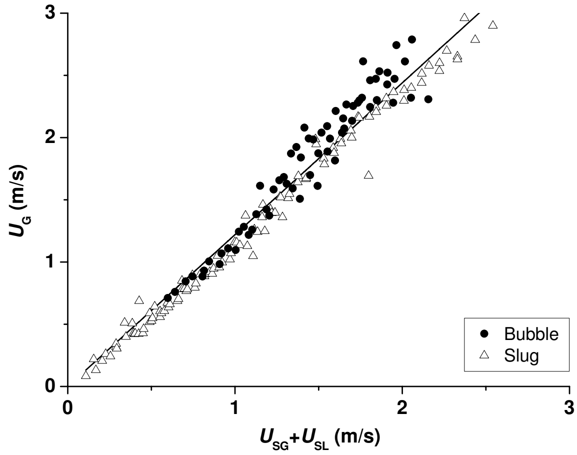

Figure 2: Gas velocity vs. mixture velocity. Symbols: experimental results, line: linear fit.

This work is focused in the experimental study of the bubble-slug transition in mini-tubes on ground and in microgravity conditions. A previously presented injector [8], where water and air are injected in a 1 mm capillary T-junction, was used. The generation and detachment of the mini-bubbles is provided by the liquid cross-flow (fig. 1a). In nominal conditions small Bond number and small Weber number are achieved for an air/water mixture flow. Therefore, capillary forces dominate over buoyancy and inertial forces [9].

We performed experiments at several water volumetric flow rates values ranging from $Q_l = 2$ up to 80 ml/min. For each value of Q_l a large number of values of air volumetric flow rates Q_g, ranging typically from 0.25 to 80 ml/min, were employed. For each chosen couple of values Q_l, Q_g images were taken by the high velocity camera. Analysis of the films permitted to measure the gas velocity, U_G, and additionally to classify the obtained flows in bubble or slug type. Churn and annular flows were also observed, but are not considered here.

The bubble-slug transition is very susceptible to the investigator subjectivity. In order to overcome this difficulty, we considered that the bubble-slug transition occurs when the mini-bubble diameter is larger than 1 capillary diameters, according with the classification proposed by Dukler et al [1]. Figure 1a and 1b show representative photographs of slug and bubbly flows. No pattern with simultaneously the characteristics of bubbly and slug flow was observed in our experiments in any case.

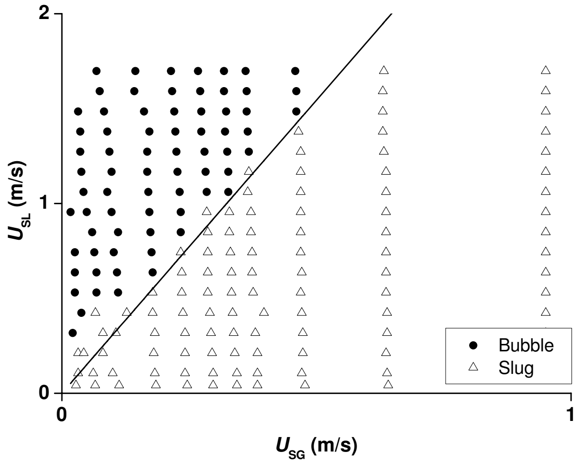

Figure 3: Bubbly and slug flow patterns. Symbols: experimental results, line: transition line corresponding to void fraction equal to 0.2.

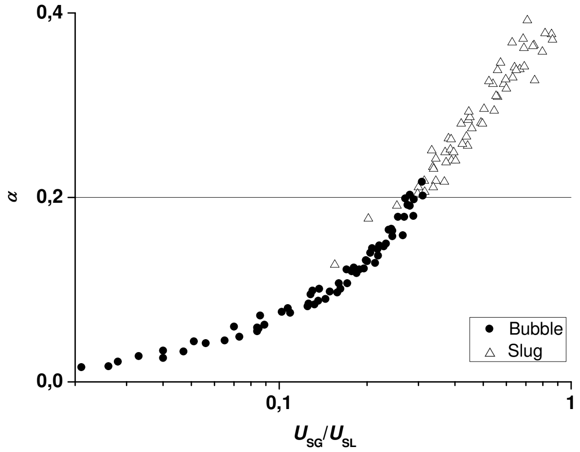

Figure 4: Void fraction vs. gas/liquid superficial velocities ratio, U_{SG}/U_{SL}. Symbols: experimental results, line: void fraction corresponding to 0.2.

Figure 2 shows the gas velocity, U_G, with respect to the mixture velocity, $U_{SG} + U_{SL}$, being U_{SG} and U_{SL} the superficial gas and liquid velocities, respectively. A simple linear relation holds in its dependence on the mixture velocity and therefore a drift-flux relationship can be assumed [3]:

$$G_G = C_0 \left(U_{SG} + U_{SL}\right) \tag{1}$$

where C_0, the distribution coefficient, fits to the value 1.22. A consequence of the previous conclusion is that the transition may be expressed as

$$U_{SL} = U_{SG} \frac{1 - C_0 \alpha_c}{C_0 \alpha_c} \tag{2}$$

being α_c the required critical value of the void fraction for the bubble-slug transition to occur. A two-phase flow bubble/slug patterns map based on the gas/liquid superficial velocities is plotted in Fig. 3 by using our experimental data. As shown, the data fit well for the bubbly and slug regions of the map for $\alpha_c = 0.2$.

Finally, with U_{SG} and U_G known, the mean void fraction can be determined as follows:

$$\epsilon = \frac{U_{SG}}{U_G} \tag{3}$$

Figure 4 shows the void fraction calculated with (3) vs. the gas/liquid superficial velocities ratio, U_{SG}/U_{SL}. Again, the data corresponding to the bubble and slug flow fit well to the plotted 0.2 void fraction line.

Acknowledgements We acknowledge financial support by Ministerio de Educación y Ciencia (Projects number ESP2006-28459-E, FIS2006-03525 and FIS2006-11452-C03-02, Spain).

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ELGRA medals

Alberto Passerone

Alberto Passerone obtained the "Laurea" in Chemical Engineering with honors from University of Genova in 1967. He received a PhD "Docteur es Sciences" with honours from the Inst. Nat. Polytech. Univ. in Grenoble in 1981. Currently, and since 1991, he is Director of Research of the Italian National Research Council working at IENI – Department of Genova Institute for Energetics and Interphases.

Alberto Passerone, has a recognized expertise in physico-chemical characterization of interfaces, with a particular reference to the measurement of surface and interfacial tensions in liquid-vapour, liquid-liquid and solid-liquid interfaces, both at room temperature and in the high temperature range. He made specific contributions to the understanding of faceting transitions in liquid-solid metallic systems and to the calculation of their interfacial tension, to the dependence of surface tension on oxygen partial pressure, and setting up new techniques and upgrading existing methodologies for surface tension and contact angle measurements for the study of liquid-vapour and solid-liquid interactions. Wettability studies are particularly devoted to the high temperature interactions in metal-ceramic systems, both from the basic point of view and for application purposes, e.g. for the optimization of joining techniques.

He is authored and co-authored numerous papers published in journals and books. He served as the Director of the CNR ICFAM institute from 1994 to 2002, and as the Deputy Director of the Genoa IENI Unit from 2002 to 2009. He was president of the Microgravity Advisory Committee of the European Space Agency and member of the Scientific Council of the Italian Space Agency. Dr. Passerone has served as the ELGRA General Secretary (1987–1992) and as the ELGRA vice-president (1993–1996). He was and still is engaged in the organization of International Conferences (High Temperature Capillarity series) and as was Chairman of many international symposia. Dr. Passerone was also responsible or coordinator in many European and national research programs, many of them dealing with research in microgravity conditions on satellites or on space stations.

Dr.-Ing. Alberto Passerone (Institute for Energetics and Interfaces - IENI CNR, Genova) has been awarded with the ELGRA Medal 2009 for his scientific achievements in the field of physics and chemistry of fluid interfaces.

Dag Linnarsson

Dag Linnarsson finished his medical studies at the Karolinska Institute in Stockholm, Sweden, in 1970. Four years later he obtained his PhD in physiology from the same institute. After his PhD he became assistant professor. After working as an associate visiting professor at the Department of Physiology at the State University of New York (SUNY) in Buffalo he returned to the Karolinska Institute and became acting professor at the Department of Medical Engineering. In 1986 he was promoted Professor for Baromedicine and became the head of the Section of Environmental Physiology. During his career Dag Linnarsson has been in various spaceflight related advisory boards such as the ESA Life Sciences Working Group, Swedish Astronaut Selection Committee, the ESA High Level Advisory Committee on Hermes Safety, the Space Station Utilization Panel and the ESF - European Space Science Committee. He is also member of the Board of Trustees of the International Academy of Astronautics and member of the ESA topical teams on Artificial Gravity and the Human Hypergravity Habitat. Currently, he is the Group Leader of the Environmental Physiology group at the Department of Physiology and Pharmacology.

Prof. Dr. Dag Linnarsson (Department of Physiology and Pharmacology of the Karolinska Institute in Stockholm) has been awarded with the ELGRA Medal 2009 for his fundamental studies on lung physiology under weightlessness. His current research is devoted to the function of pulmonary systems under different environmental conditions such as altered gravity, hypo-, and hypergravity.

Figure 1: Alberto Passerone (left) and Dag Linnarson (right) on the occasion of the ELGRA Medal Award during the ELGRA Symposium 2009 in Bonn.

ELGRA General Assembly 2009

Minutes of the General Assembly

The 2009 ELGRA General Assembly starts on September 2nd, 2009 at 18:30 at the University Club of the University of Bonn (Germany).

Agenda

1. Opening by the president / Adoption of the agenda
2. Approval of the minutes of the previous General Assembly
3. President's report
4. Election of new Management Committee members
5. Treasurer's report
6. Auditor's report
7. Discharge of the treasurer
8. Acceptance of new members
9. Election of two Auditors
10. Any other business

1. Opening by the President / Adoption of the Agenda

The ELGRA President, Jack van Loon, opens the Assembly. Approximately 40 members are present, plus several guests. Thus the required quorum for elections is fulfilled. Upon request of the President the Assembly adopts the above Agenda.

2. Approval of the minutes of the previous General Assembly

The minutes have been approved.

3. President's report

The President gave an activity report highlighting the activity of the management committee: the communications with the ELGRA members, the meetings of the Management Committee, and the organisation of the 2009 ELGRA Biennial Symposium and General Assembly in Bonn. Moreover, the activities in the framework of FyT, courses held (e.g. in Banyuls), and the ULISSE Project (coordinator of the project is Luigi Carotenuto).

Regarding the future perspectives, he explained the planned activities of the Management Committee towards a future student society. Another issue was the option of uniting the ELGRA Symposium with other ESA conferences. The president also addressed the offer of the journal Microgravity Science and Technology to ELGRA members to subscribe to the journal at a substantial discount rate.

4. Election of Management Committee Members

The election for the Management Committee has been performed using a single ballot. The following candidates were running

- Jack van Loon (president)
- Hendrik Kuhlmann (vice-president)
- Monica Monici (general secretary)
- Kurt Kemmerle (treasurer)
- Further members:
  - Daniel Beysens
  - Bob Bingham
  - Hans Fecht
  - Javier Medina
  - Ilia Roisman
  - Floris Wuyts

The evaluation of the votes (total of 43 voting ballots), performed by Hendrik Kuhlmann and Thodoris Karapantsios, gave the following result:

President:	Jack van Loon	(42 votes, elected)
Vice-President:	Hendrik Kuhlmann	(42 votes, elected)
General Secretary:	Monica Monici	(42 votes, elected)
Treasurer:	Kurt Kemmerle	(41 votes, elected)
Members:	Daniel Beysens	(25 votes, elected)
	Bob Bingham	(21 votes)
	Hans Fecht	(28 votes, elected)
	Javier Medina	(35 votes, elected)
	Ilia Roisman	(7 votes)
	Florian Wuyts	(30 votes, elected)

The President gratefully acknowledges the significant and long-term work and contributions of Thodoris Karapantsios who leaves the Management Committee.

5. Treasurer report

The Treasurer, K. Kemmerle, reports on the financial status of the Association and shows the balance of the period January 2007–July 2009. The new members were accepted by the general assembly.

6. Auditor report

As only one elected auditor, H. Dittus, is present Peter von Kampen volunteered to help checking the treasurers accounts. The two Auditors confirm the correct financial administration of the Association by the Treasurer during the aforementioned period.

7. Discharge of the treasurer

The treasurer was discharged.

9. Election of the Auditors

Peter von Kampen (ZARM, Universität Bremen) was elected as a new auditor.

10. Any other business

No other issue was brought up.

The President closes the Assembly at 19:30

The ELGRA President, The ELGRA General Secretary,

Jack van Loon Hendrik Kuhlmann

Obituaries

Bruno Berra †

Dear colleagues and friends, with deep sadness we would like to briefly remember Professor Bruno Berra, who passed away April 21, 2010.

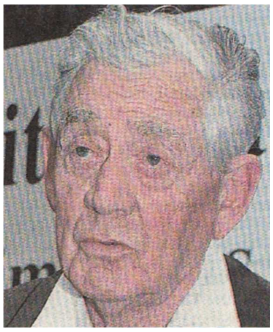
Professor Berra was born in Magenta in 1937. He completed his studies at the University of Pavia where he earned a Chemistry degree in 1961. Then he joined the Biochemistry Institute of the Faculty of Medicine of the University of Milano directed at that time by Professor Vittorio Zambotti, where he worked as Ordinary Assistant of Biochemistry until 1977. Then Berra moved to the newly formed Faculty of Pharmacy of the University of Milano where he became full Professor of Biochemistry in 1980. He held different courses of Biochemistry (General Biochemistry, Biochemistry of Nutrition, Molecular Biology, Biochemistry of the Skin) for about four decades, until few days before his death. He has been a founder of the Institute of General Physiology and Biochemistry of whom he was the chairman from 1989 to 2000. He had a key role in the scientific development of the Institute and in its movement in 1994 to the new building of via Trentacoste. Berra was a very effective leader because of his personal qualities and charisma. The success of our department owed much to these qualities.

His strong sense of community responsibility was reflected in the numerous professional activities throughout the scientific community. From 1984 to 1995 he was President of the Council of Corso di Laurea in Chemical and Pharmaceutical Technology of the Faculty of Pharmacy, from 1988-1995 Member of the Expert Committee for Biochemistry and Molecular Biology of the Italian Pharmacopeia, from 1997 to 2006 member of the Consulting Commission of the Department of Health for alimentary special products targeted to diseases. Among the large number of projects that Professor Berra was working on, in the last five years he particularly cared about the foundation and development of the University *Nostra Signora del Buon Consiglio* of Tirana.

Professor Berra's career in science spanned more than 50 years His scientific interests were broad and he did wide-ranging research in biochemistry: from the study of glicoconjugates and gangliosides in physiological and pathological conditions, mainly glicosphingolipidoses, to the field of nutrition and nutraceutics, developmental biochemistry, cancer research, cosmetology and in particular Space Biology. He has been the coordinator of many national and international research projects and in Space research the PI of many experiments selected by ESA, NASA and ASI: the ongoing space flight simulation MARS 500 and flights with different vectors, such as stratospheric balloons (1999–2001), Space Shuttle (2003 and 2009), Russian Foton satellite (2007). He has been a member of ELGRA since 2003 and was very active in microgravity research related to animal development and cell biology. His laboratory is one of the few in Italy being equipped with a regular RPM for life science experiments.

We all have many vivid recollections of Berra as a person and as a scientist. He was primed with a source of energy that permitted him to work at a vigorous pace seven days a week, and travel tirelessly from one side to the other of the world. Aside from his scientific pursuits, until few years ago he harboured a passion for skiing and he was also a gourmet. It was always good to talk to him, but he was at his best at social gatherings. It was a pleasure to listen anecdotes from his student times or from experiences with people from all walks of life. We all owe a debt of gratitude to Professor Berra, to the colleague and to the friend. We all know that he would have given much more to Space science and Biochemistry and to us if he had not suddenly and unexpectedly passed away.

Angela Maria Rizzo
University of Milano



Hans Ahlborn †

The sad news has reached us that our colleague Prof. em. Dr.-Ing. Hans Ahlborn has passed away on August 11, 2010. Hans Ahlborn was born in northern German in Katefeld. He became apprentice for *Modeling* and finished as a journeyman in 1950. Thereafter, he studied vocational pedagogy finishing in 1954 with the second state examination. During his work as vocational instructor he studied metallurgy at the Bergakademie Freiberg (later Technical University of Clausthal–Zellerfeld) and finished with a diploma in 1957. Thereafter, he became assistant of Professor Wassermann and received his Ph.D. in 1961 and, in 1965, he obtained the venia legendi for materials science. In 1969 he became professor at TU Clausthal. During the same year he took over the position of the head of the division *materials* of Battelle Frankfurt. There, Hans Ahlborn was concerned with fiber-reinforced composites, ceramic bone substitutes and surface coatings. He also worked on monotectic alloy characterization and on their use in frictional bearings by rapid solidification.

At Battelle Hans Ahlborn also became interested in materials science under zero gravity conditions. In particular, he focussed his attention on monotectic Aluminum–Led alloys whose density differences could be compensated under reduced gravity. In this field he became a well-known scientist, working as a reviewer and advisor for materials-science experiments under zero gravity. He served for various organization from government to science, including the Deutsche Forschungsgemeinschaft, DLR, ESA, and NASA. Since 1986 and up to his retirement professor Ahlborn has been a member of ELGRA.

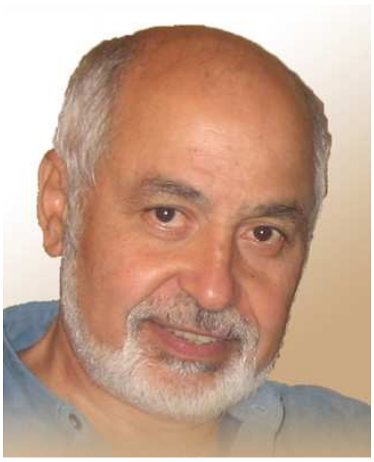
In 1973 Hans Ahlborn became professor at the University of Hamburg. The chair for Engineering Science had an emphasis on the education of vocational teachers (didactics of the commercial-technical sciences for the education of teachers). After becoming emeritus in 1994 he founded a company concerned with recycling of carbon-fiber materials.

Hans Ahlborn participated with several experiments in the TEXUS program from 1977 to 2007. He was also a key scientist during the D1 mission in 1965 (Separation of Immiscible Melts, experiment WL-IHF-01) and Euromir 95 in 1996. He also had an experiment in 1993 during D2 Mission (Separation Behavior of Monotectic Alloys, experiment WL-IHF-MONO).

Professor Ahlborn enjoyed a high reputation among his colleagues which, apart from his personal charisma, was based on his participation in microgravity experiment. He was know, appreciated, and dreaded for is strict rationale. He was able to pinpoint things and clearly present a position. Those who had the privilege to know and experience him will certainly and thankfully keep in mind his personality.

Hendrik Kuhlmann
Vienna University of Technology

H. K. gratefully acknowledges the support of W. Seyd (University of Hamburg) and I. Ahlborn, daughter of professor Ahlborn.



Abdelfattah Zebib †

With sadness we learned that Abdelfattah Zebib passed away on December 10, 2009 at the age of 63. He is survived by his three sons, Adam, Neil and Tarik.

After his doctoral and post-doctoral work at the University of Colorado, Boulder, Colorado, Professor Zebib joined Rutgers University in January 1977. He was a distinguished researcher in fluid mechanics, a field to which he made many seminal contributions. He was a true scholar and had extensive collaborations with researchers from around the world in areas such as microgravity flows, instability, and buoyancy-driven flows. He was a Fellow of APS, a distinction bestowed on only a select few. As an academic, Professor Zebib wrote and lectured extensively. He guided the research of a large number of doctoral students. Abdel also served extensively in administration. He was the Chairman of the Department from 1989 to 2000, and was the Deputy Dean of the School of Engineering from 2000-2008. In November 2009, the department dedicated the MAE Computer Laboratory for Analysis and Design (CoLAD) to Professor Abdel Zebib, in recognition of his outstanding contributions to the department and his leadership and vision over many years.

Abdel Zebib was well known in the microgravity fluid mechanics community. During his later years, in particular, he has enriched various microgravity conferences with his expertise, also the ELGRA Symposium in Florence in 2007. He was widely appreciated for his excellent scientific work and A++ sense of humor. We shall miss him very much.

Note that Department of Mechanical and Aerospace Engineering of Rutgers University has established the Abdel Zebib Memorial Fund, which will support activities relating to Abdel's scholarly interests, particularly seminars and student research. Donations to the Memorial Fund can be made through the Dean's Office, Rutgers School of Engineering.

Abridged and modified version adopted from the web site of Rutgers University.

Hendrik Kuhlmann
Vienna University of Technology

Bianca Maria Uva †

Professor Bianca Maria Uva, born on June 22, 1934 in Fiume (former Jugoslavia), passed away in Zoagli (Genua) on September 5, 2009. First of all, I would like to thank ELGRA for letting me write down these few lines in memory of Professor Bianca Maria Uva who was my scientifically sound mentor, but through the years became a more and more caring friend for me and a kind of tender grandmother for my daughters.

Bianca Maria Uva graduated in Biology in 1961 and lived all her scientific life in the University of Genua where she finally became a full professor of Comparative Anatomy and Citology in 1986 and head of the Institute devoted to that discipline. She served as the President of the Course of Biological Sciences from 1994 to 2000 and thence as the Director of the Department of Biology until 2006.

Her first publication represented the practical application of an idea of Professor Ettore Remotti, the former Director of the Institute of Comparative Anatomy, who opened a new window in the field by investigating the influence of organ extracts from adult animals on organ development in chick embryos. Immediately after, under the guidance of Professor Ghiani, who would get married to her in 1967, she began to investigate upon the functional properties of the sub-commissural organ and from then on she kept being involved in neuroscience research.

Bianca Maria Uva actively participated in several meetings, and skilfully organized some of them (e.g. two Italian Embryology Meetings in 1992 and 1998, and the Italian Conference of Histochemistry in 2003). She also greatly contributed to the success of the 24th Meeting of the European Comparative Endocrinologists (CECE) in Genua in 2008. I myself entered Professor Ghiani's group to prepare my thesis in 1981 and thus, under the guidance of Professor Uva, I had the honor of performing studies with her concerning vertebrate adaptation to extreme environments with special reference to

- skin and kidney osmoregulation in salt or fresh water (renin-angiotensin and bradykinin-kinin systems, as well as, other water-electrolyte regulating peptides),
- cardiovascular and cardiorespiratory adaption of red-blood teleosts and icefish, and
- skin and gill changes in teleosts coming from polluted environments.

Bianca Maria Uva also led a large operating unit of the Antarctica Project – as a Co/PI of Professor Luporini from the Camerino University – involving many researchers of the Biology Department of Genua University. In those years she collaborated with several internationally celebrated scientists including Professor Chieffi (Naples University) and Professor Ian Henderson (Sheffield University) with whom she got progressively tied by a close friendship. It looked like a sign of destiny when in the 90ies she first met Professor Aristide Scano and his close collaborator Professor Felice Strollo; in fact, until that moment her innate interest for space had been just smouldering under the ashes after being fostered during her childhood by her father, a Physics teacher with whom she watched the stars as often as possible.

From that moment on she got committed to microgravity research: she took advantage of her far-sighted attitude to acquire dedicated pieces of equipment, including the 3D random positioning machine, and of her scientific thrust to publish a number of papers concerning time-dependent cytoskeletal adaptation to modeled microgravity of glial and nervous cells. Soon after she started a series of cytology studies which represent a scientific inheritance that my collaborators and I feel deeply committed to respect.

Scientifically speaking she could boast more than 100 papers published on national and international journals, but just setting aside her professional skills, I need to remind all who met her of her human qualities, especially her warm-heartedness and helpfulness perfectly harmonized with her resolution and fitness while performing the demanding institutional tasks expected for the role she had in the faculty.

Professor Bianca Maria Uva, you still are unique, a kind of loving mother or a fascinating source of enthusiasm for some of us. You have been a wonderful mind as well as a cheerful, altruist, open-minded and generous soul. We always remember your elegant style: despite your great learning you never indulged in haughtiness or condescension while providing students and colleagues with your pieces of information or advice. You actually represent a human masterpiece, the nice result of an inborn determination to overcome sufferings caused by war, by an early departure from your land of birth and by your premature widowhood.

That's why, dear Mabí (the endearing nickname chosen by your friends and us), we all miss you as a person, we miss the smile we saw on your face when we referred saying nonsense to you from the other side of the desk. Despite being firm, you nourished your deeply kind-hearted flair and allowed everybody a second chance by looking for his praises, which you expected to be hidden by heavy defensive curtains, because you knew from experience that life without love is sad, empty and distressing. Thus you taught us to approach life appropriately, to accept people as they are, to better ourselves. All that explains why we miss you, our small great woman!

Despite all sorrows, anyway, I prefer to think of Mabí's funny exploits: does anybody remember when she played the mischievous little girl during a break in a space meeting in San Antonio, Texas, by fading away from her friends/colleagues and being hit immediately after that by a bicycle driving through a red light? And that's also why, rather than an obvious identity card picture, I chose one I took of her in the lab where her eyes and her attitude clearly show all I described here better than any words in the world.

Maria Angela Masini
University of Genua

ELGRA questionnaire for space research satisfaction

The ELGRA Management Committee (MC) has developed a questionnaire on your experience regarding the review, selection and de-selection for and execution of space research. The survey is intended to help ELGRA improving its services by an efficient interaction with the decision-making institutions.

Since the impact will strongly rest with a number of filled and returned questionnaires we would greatly appreciate if you take a few minutes to fill the form below. The questionnaire will also be distributed by email in an electronic form in order to facilitate filling and sending. You may fill this printed version and send it to Dr. Jack van Loon (address see page 42), before the deadline of January 31, 2011.

1. How would you describe your contact with your national space agency or representatives? Satisfying ☐ Unsatisfying ☐
2. The frequency of Announcements of Opportunities (AO's) issued by space agencies is Appropriate ☐ Not frequent enough ☐ Too frequent ☐
3. Is the review process of the proposals submitted in response to the AO's transparent? Yes ☐ No ☐
4. Are you satisfied with the reviewing process of the proposals submitted in response to the AO's? Yes ☐ No ☐

   If the answer is 'No': Why? What could be done to improve the process? ....
5. Should the proposals submitted in response to the AO's be reviewed by
   ESA/ESF only ☐
   ESA/ESF as well as by the national space agency ☐
6. What can be done to improve the re-selection/de-selection process? ....
7. The time between experiment selection and implementation/execution is Appropriate ☐ Too short ☐ Too long ☐

   If 'Too long': What can be done to shorten the delay? ....
8. An ESA Topical Team (TT) consists of a group of experts. A TT should have the following objectives:
   a) co-ordinate the activities of different research groups working on the same topic, bringing together complementary expertise ☐
   b) identify scientific problems for which series of well-defined microgravity/space experiments can generate crucial data ☐
   c) identify industries specifically interested in the research planned by the team ☐
   d) agree on the best strategy to accomplish a given research goal ☐
   e) define the required experimental programme, including microgravity/space experiments, and to adequately use the different microgravity/space platforms ESA can provide access to ☐
   f) select and define, in close co-operation with ESA, the experiment facilities needed to conduct these flight experiments ☐
   g) set up a Virtual Institute (within ESA's Virtual Campus) addressing the Topical Team's planned research ☐

   Are you sufficiently informed about ESA's topical teams (TT) and of their activities? Yes ☐ No ☐
9. Do you think the ESA Topical Teams do a good job? Yes ☐ No ☐
10. What is your field of research? Life Sci. ☐ Phys. Sci. ☐ Other ☐
11. What is you level of experience in the space research field? $<$ 5 years ☐ $>$ 5 years ☐
12. Have your experiments flown on the ISS or equivalent (not parabolic flight)? Yes ☐ No, but scheduled ☐ No ☐
13. In which country do you perform your research (to which national space agency do you submit proposals)? ....

Calender of Events

European Autonomy in Space
January 17–18, 2011
Vienna, Austria
web: www.espi.or.at
contact: ESPI
office@espi.or.at

15th ISU Annual International Symposium
February 15–17, 2011
Strasbourg, France
web: www.isunet.edu
contact: Walter Peeters
abstract deadline: October 8, 2010

2011 Next-Generation Suborbital Researchers Conference
February 28 – March 2, 2011
The University of Central Florida in Orlando, Florida.
web: www.swri.org/9what/events/confer/nsrc/2011/
contact: Cindy Conrad
cc@boulder.swri.edu
abstract deadline: November 23, 2010

20th ESA Symposium on European Rocket and Balloon Programmes and Related Research
May 22–26, 2011
Hyéres, France
web: spaceflight.esa.int/pac-symposium2011
contact: Marie-Pierre Havinga
pac@esa.int
abstract deadline: January 17, 2011

28th International symposium on Space Technology and Science (ISTS)
June 5–12, 2011
Okinawa, Japan
web: www.ists.or.jp/2011
abstract deadline: November 15, 2010

5th International Conference on Recent Advances in Space Technologies
June 9–11, 2011
Istambul, Turkey
web: www.rast.org.tr
contact: Sefer Kurnaz
rast2011@rast.org.tr
abstract deadline: December 30, 2010

ISSOL- The International Astrobiology Society and Bioastronomy (IAU C51)
July 3–8, 2011
Montpellier, France
web: www.origins2011.univ-montp2.fr
contact: Reine Bedos
origins2011@exobiologie.fr
abstract deadline: February 19, 2011

4th International Symposium on Physical Sciences in Space
July 11–15 2011
Bonn, Germany
web: www.congrex.nl/11A02
contact: ESA Conference Bureau

ELGRA Biennial Symposium and General Assembly 2011
Gravity: from μ to x!
September 6–9 , 2011
Antwerp University (Campus Drie Eiken), Antwerp, Belgium
web: www.ua.ac.be/elgra
contact: Floris Wuyts
floris.wuyts@ua.ac.be
abstract deadline: April 19, 2011

2nd International Conference on Space Technology
September 15–17, 2011
Royal Olympic Hotel, Athens, Greece
web: www.icspacetechnology.com
contact: Maria Petrou
petrou@iti.gr
abstract deadline: Janurary 30, 2011

Two-Phase Systems for Ground and Space Applications
September 25–28, 2011
Cava de' Tirreni, Italy
web: hti.ulb.ac.be
abstract deadline: February 1, 2011

AIAA SPACE 2011 Conference and Exposition
September 26–29, 2011
Long Beach Convention Center / Hyatt Regency Long Beach, Long Beach, California
web: www.aiaa.org
abstract deadline: January 25, 2011

62nd International Astronautical Congress
October 3–7, 2011
Cape Town International Convention Centre, Cape Town, South

Africa
web: www.iac2011.com
contact: IAF
enquiries@iac2011.com
abstract deadline: March 2, 2011

ASGSB combined meeting with ISGP
November 3–6, 2011
St. Claire Hotel in San Jose
web: www.asgsb.org

39th COSPAR Scientific Assembly
July 14–22, 2012
Mysore, India
web: www.cospar2012india.org
contact: COSPAR
cospar@cosparhq.cnes.fr

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European Low Gravity Research Association - ELGRA

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Additional details: …

Date and Place	Signature
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Surname :...
Professional status :...
Field of activity :...

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Main science area : … (Physical Science (PS), Life Sciences (LS), Technology (TE))
Science discipline: … e.g. material sci., fluid sci., plant physiology, cell biology, …)
Additional details: ……

Date and Place:	Signature:
...	...

Return to the President of ELGRA:

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Announcement of the

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Gravity: from μ to x!

September 6–9 , 2011

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