▲ **FIG. 1:** ESA astronaut Hans Schlegel works on the exterior of the docked Columbus module (February 2008, Credit ESA/NASA)

[PHYSICS IN SPACE]

PHYSICAL SCIENCES ONBOARD THE INTERNATIONAL SPACE STATION

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The development of virtually all living species is governed by gravity and all organisms unconsciously use or anticipate gravity effects. When gravity forces are not compensated, one talks about "free fall", and one of the features of satellites in orbit – far above the atmosphere that would otherwise slow them down by friction - is that, just like the moon, they keep free-falling around the earth. It is this particular feature of spaceflight that fuelled the interest of physicists to propose experiments in space. Many scientific experiments have already been performed that have yielded unique results and fed the natural curiosity and imagination of scientists.

When confirming the details of the European participation to the International Space Station (ISS) project in 1995, the Ministers representing the member states of the European Space Agency (ESA) acknowledged the potential of this research and emphasized the development of a vigorous European programme for both basic and industry-oriented research in space. ESA promoted the creation of teams of scientists with theoretical, computational and experimental expertise behind scientific problems to be tackled by experimenting under free fall conditions. Preparatory research on the ground helped define the specifications of the required instruments and establish databases of reference results for comparison when the experiments are performed in space. To the non-space industries involved in some of these projects, this preparation work provided further evidence of the usefulness of a clue from space!

In February 2008, the European module "Columbus" was docked to the ISS (see cover page and figure 1). In March, "Jules Verne", the first model of the Automated Transfer Vehicle (ATV), successfully docked automatically to ISS to provide fuel to the ISS and water, food, oxygen and equipment to the crew. In the mean time, the first scientific instruments were activated on Columbus. Europe thus has a laboratory in orbit to use for scientific research.

In this issue we start a series of articles on Physics in Space aiming to provide a snapshot of the programme for the scientific utilisation of the ISS in physical sciences, while making the science community aware of the availability of this tool.

The current ISS utilisation programme in physics spans a broad range of topics. Much is directed, shaped, conditioned, triggered or limited by gravity. Here are some of the topics:

Let's face it, atoms fall as well!

Recent Nobel Prize winning discoveries in cold and ultra cold atom physics have led to a new generation of high performance quantum sensors surpassing state-of-the-art instruments for accurate frequency measurements, ultra-precise monitoring of accelerations and rotations. At the same time, studies on ultra cold atoms, typically Bose-Einstein condensates are rapidly progressing, opening new exciting perspectives both for fundamental studies and for new devices based on coherent matter waves. Space is the natural environment for exploiting the high potential of these techniques. The interaction time between atoms and the probing field can be increased by several orders of magnitude, improving even further the already excellent performances of these devices, the applications of which are truly interdisciplinary. See this issue, p. 33.

Crystallising a cube of plasma!

Complex plasmas are classical plasmas in which microscopic particles are injected. These micro-particles become charged by capturing electrons and can thus interact with each other. If a comparison is made with atoms, the much larger scale and much slower dynamics of the particles make them amenable to simpler controls, stimuli and diagnostics. The reduced gravity environment that prevails in a spacecraft enables the formation and study of true three-dimensional structures and related process dynamics. The objective of this research is to generate and study phase transitions-like processes, self ordering of crystalline solids, wave formation, propagation and evolution, flow instabilities and collisions. See this issue, p. 30.

Dust! Dust everywhere!

The very early phases of the formation of a solar system and its constituents, the growth of dust particles to micrometer sizes, and the very late phase, from meter to kilometre-sized bodies, are believed to be reasonably well understood. However, the intermediate phase from micron to meter-sized bodies is not. On earth this growth cannot be reproduced. Similarly, there are many processes involved in the formation and evolution of clouds; they are intricate and have an important influence on the climate. The whole process of condensation of droplets and ice crystals is very cumbersome to study on earth because of sedimentation. Space experiments can provide quantitative data to understand the dust aggregation process or the full cycle of clouds. See this issue, p. 27.

Open your fridge and sort out your food products: emulsified and foamy products to the right and the others … well very few others as a matter of fact!

One of the most relevant problems in emulsion technology concerns the control of their stability. But the links between the physical chemistry of the droplets' interface and the collective properties of an emulsion are only qualitative, so that the criteria used in industry are mainly empirical. Investigating emulsions at different scales in space provides unique quantitative information that help develop predictive models of the stability of emulsions. Similarly, either unstable foams or "wet" foams, including metallic foams, can be investigated in space in a unique manner.

Watch a container with boiling water and think of all the phenomena going on. Now what would happen without gravity?

In fact, many superimposed physical phenomena governing the global process of heat and mass transfer in boiling are also present in many engineering fields. To develop predictive design tools, a multi-scale approach must be adopted to understand observations and theoretical modelling. Series of experiments at different scales conducted under low gravity conditions make it possible to observe effects masked under normal gravity conditions.

You will never give a pile of sand the same look again!

Granular media mechanically excited exhibit a wide range of behaviours depending on the dynamic coupling of the particles with the surrounding media and the intensity of the excitation. At low density, the solid particles can be considered as isolated bodies between collisions as in a dissipative gas. In space, in such a gas, stratification is eliminated even at high density ratios thus realising an effectively isolated gas of particles that is amenable to unique investigations.

Materials are the key!

There are strategic links between industrial processes, material structure and final properties of materials. It is important to understand how the hydrodynamic conditions affect microstructure and defect formation during the solidification process. Under low gravity one can control these hydrodynamics conditions. Benchmark samples are produced under well controlled conditions. Other experiments produce reliable and often unique thermo-physical property data.

With this issue, EPN starts the publication of a series of articles on important issues that are addressed in the programme on physical sciences in space (some specific studies were reported previously in EPN). Three consecutive issues will include a total of nine articles authored by teams of scientists involved in several different projects.

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