NEWSLetter
Excellence Cluster Universe

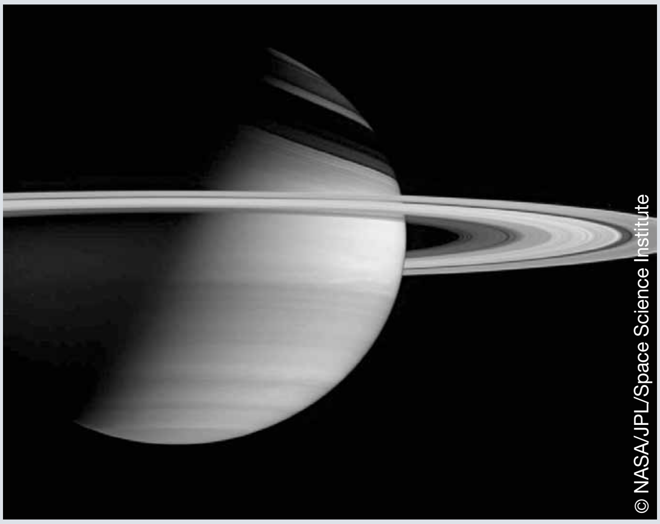
Issue 1 / 2011

Dear Readers,

it's not the first time, we report on bacteria in our newsletter. In today's issue we present a brand-new approach to extract and investigate a specific iron isotope from the Earth's crust from microfossils of magnetotactic bacteria. This chemical element was brought to us by a nearby supernova 2.8 million years ago. Talking about neighbors: Our close vicinity in the Milky Way was not always as quiet as it is now - there were quite some riots 5 million years ago... The Universe Cluster is happy to introduce some newcomers to its scientific community: while there is an ongoing discussion on quota for management positions in industry, one third of our junior professors and more than half of our research fellows are female. These numbers are encouraging enough to continue our efforts to make the workplaces in science and research still a better place for women.

Barbara Wankerl, PR Manager

PICTURE OF THE MONTH



April is the month of Saturn - the planet is now opposite to the Sun and can be seen as a bright object in the night sky. Details of the ring can be watched using a small telescope. Of course what you see from Earth cannot be compared to the Saturn view of the Cassini space mission. The image has been rotated so that north on Saturn is up; the Sun illuminates Saturn from below.

RESEARCH

Our Turbulent Neighborhood in the Milky Way

Five million years ago a gang of young and massive stars caused havoc in our immediate neighborhood in the Milky Way. They left their traces: Before the "wild" stars exploded, they produced new atomic nuclei in their interiors, which they then distributed in their vicinity of only 300 to 500 light years away from the Sun. Gamma-ray observations performed by the INTEGRAL satellite observatory of ESA, recently published by the Cluster scientist Prof. Roland Diehl and his colleagues (Diehl et al., A&A vol. 522), show the radioactive luminescence of the nuclear fusion processes. This also fits in with the discovery of exotic atomic nuclei in the deep sea, which Cluster colleagues at the TUM accelerator were able to collect and date (see article on page 2).

Dense molecular clouds in the Orion constellation, where stars are born

As spectacular as these astronomical findings at our front door may appear, they represent only the "visible" part of a long research process of theoretical model concepts, simulation and calculations: As these stars no longer exist today, scientists must apply indirect methods to obtain evidence. In this case, the unstable isotope of aluminum-26 guided them to the former stellar population. "Shortly before and during stellar explosions stars produce this radioactive aluminum isotope with a half-life of one million years which continues to glow in the interstellar space substantially longer than most of the otherwise observable astronomical phenomena", Roland Diehl explains. "As our measured gamma-radiation intensity fits in so well, we can make use of aluminum-26 as an excellent gauge of the former activity of young and massive stars." When the unstable element aluminum decays, the stable element magnesium is produced. A high-energy photon in the "color" of the gamma radiation is emitted during this process. "Today we can observe this characteristic gamma radiation directly with the spectrometer on the INTEGRAL satellite", he adds.

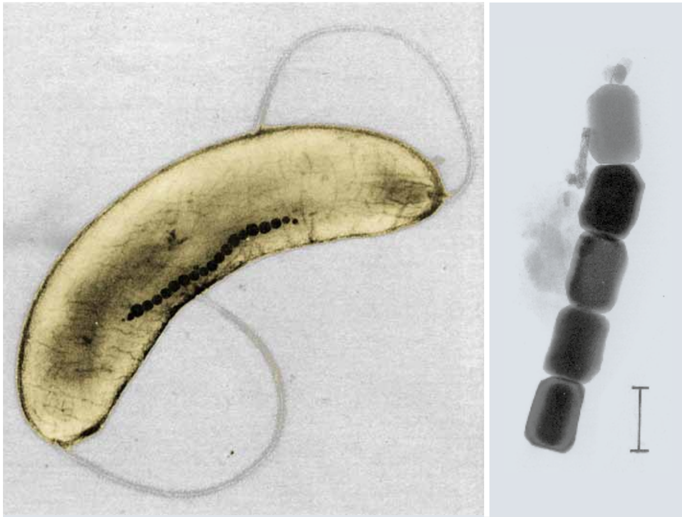
The validity of this method has been demonstrated in a study by Dr. Rasmus Voss at the Universe Cluster and MPE. Along with his colleagues Rasmus Voss set up a complex method of calculation in order to study the diversity of effects caused by a group of massive stars. In the sky region of Orion, for example, dense molecular clouds with regions where new stars are born, evolve through different stages and finally perish. This process has dramatic effects on the surrounding interstellar medium

(ISM): Massive stars and supernovae expel gigantic amounts of energy and matter, which cause the ISM to utterly buckle. In addition, they generate ionizing radiation which causes such gas shining in a colorful display in optical light. The scientists thus calculated the kinetic energy and the ultraviolet radiation – and additionally evaluated the production of radioactiv aluminum-26 and iron-60 isotopes. Their calculations yield predicted data, which they compared with real observational data and found a plausible consistency (Voss et al., A&A Vol. 520). Astronomers learn through comparisons of this kind how star formation shapes its direct cosmic neighborhood. In our neighborhood we are presented with the remaining stars of such a stellar maternity ward and see the interstellar chaos in awe-inspiring detail. The discovery of supernova ashes on the ocean floor of the Pacific Ocean reinforces this picture and suggests that our planet was directly affected by these wild young stars.

These papers were published in the scientific journal "Astronomy & Astrophysics" (Vol. 520 and 522, 2010). The journal editors listed both publications among the "Highlights" of the year.

Magnetotactic Bacteria: Tales of Iron-60 and a Past Supernova

At the Excellence Cluster Universe, Research Area G is concerned with the formation of chemical elements. In a current publication scientists present a new method of determining the terrestrial concentration of a particular iron isotope, produced in massive stars that eventually become supernovae utilizing magnetic microfossils produced by microorganisms.



Bacteria as a potential reservoir for iron-60 - left: image of the magnetotactic bacterium Spirillum with two flagellae. The magnetosome chain is clearly visible. Right: picture of fossil magnetosomes extracted from a lake sediment.

Iron plays an important role in understanding element synthesis within, and the physical mechanisms behind, supernovae explosions: Terrestrial iron is mostly comprised of iron-56 (30 neutrons and 26 protons). Scientists, however, have also found the radioactive isotope iron-60 in ferromanganese crusts acquired from the bottom of the central Pacific Ocean, 4000 meters below the ocean surface, and subsequently dated it to 2.8 million years ago.

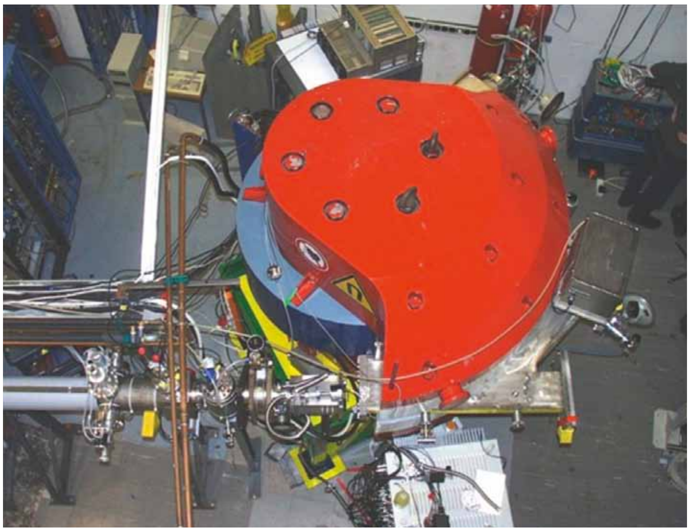
This neutron-rich radioactive isotope is formed by the slow-neutron capture process, during quiescent burning, within the carbon and oxygen burning shells of stars more than 10 times the mass of our Sun. Some fraction of the iron-60 is then transported by convection to the outer layers of the star, saving it from further destruction by subsequent neutron capture. During the wind phase of these stars, the outer layers of the star are non-explosively pushed off into space by intense radiation pressure, dispersing iron-60 into space. These same stars will eventually end their lives as core collapse supernovae. During the core collapse phase, iron-60 is further produced within the same carbon and oxygen burning shells, through a subsequent slow neutron capture process, when they are heated by the shock-wave propagating outward from the core.

The remnant of supernova N 63A in the Large Magellanic Cloud. The star that produced this supernova remnant was probably 50 times the mass of our Sun.

Iron-60 decays with a half-life of 2.6 million years, which is much younger than the age of the Earth. Thus, its discovery in a deep-sea ferromanganese crust implies that an Earth-supernova interaction occurred approximately 2.8 million years ago. That discovery resulted in an uncertain estimate of the total iron-60 flux deposited on Earth, and relatively uncertain Earth-supernova distance estimates. The uncertainty derives from the incomplete knowledge about the iron uptake efficiency of the ferromanganese crust. Estimates of this efficiency were originally 0.6 per cent, but new indications suggest it could be 100 per cent. Coeval discovery of iron-60 in a different terrestrial reservoir could help reduce the iron-60 flux uncertainty, provide an improved Earth-supernova distance estimate, and allow an additional confirmation of the initial iron-60 discovery. It would also mark the first discovery of a cosmic signature residing in the fossil record of Earth.

To clarify the Iron-60 fluence and attempt to discover it in the Earth's fossil record, Cluster scientist Prof. Shawn Bishop is now proposing along with the geophysicist Dr. Ramon Egli of the LMU, a new iron-60 reservoir: Microfossils produced by magnetotactic bacteria that use the magnetic field of the earth for orientation. These microorganisms live in ocean sediments and store iron within intracellular crystal chains (magnetosomes) composed of magnetite (Fe_3O_4). When the bacteria die, these crystal chains remain intact within the sediment and are called "magnetofossils". From the results of laboratory culture studies, the scientists assume that these bacteria prefer to absorb small nanograins of iron oxide or ferric hydroxides ("rust"), which settle on the sediment, providing the bacteria their iron pool for magnetite production. As the atomic or molecular iron released during a supernova explosion should rapidly oxidize in our atmosphere and oceans, these compounds make their way to the ocean sediments by way of the Earth's iron-cycle, and should have provided these microorganisms with the requisite iron pool for their magnetosome production.

In their search for magnetofossils, the scientists discovered them in deep-sea sediment in the Pacific Ocean: In a drill core containing sediment layers dating back to the time of the supernova, they identified a high concentration of magnetic microfossils. From specialized magnetic measurements on samples of this core, performed by Ramon Egli's group, they were able to estimate the ratio of iron-60 to stable iron and deduce a conservative value of 3.6×10^{-15}. This value falls comfortably within the sensitivity capabilities of the Maier-Leibnitz laboratory's accelerator mass spectrometry (AMS) facility at the Garching Campus., making the bacterial microfossils a potentially outstanding material for analysis for further investigation. With the support of



Picture of the magnet (central red and blue circular object) and the detector system used in the Accelerator Mass Spectrometry (AMS) at the MLL. Iron-60 atoms extracted from the microfossils would be transported to the detector by the tube entering the magnet on bottom left. The iron-60 would be swept through 135 degrees and then exit the magnet to the detector (left of center of the magnet).

Cluster PhD student Peter Ludwig the scientists hope to actually be able to extract iron-60 from the fossil microorganisms – and thus find reliable messengers from the distant past of the supernova events over 2.8 million years ago.

Original publication:
Discovery prospects for a supernova signature of biogenic origin, Bishop S., Egli R., Icarus, 212, 960 (2011); doi: 10.1016/j.icarus.2011.02.003

Excellence Cluster Universe and CTC Cambridge Sign Cooperation Agreement

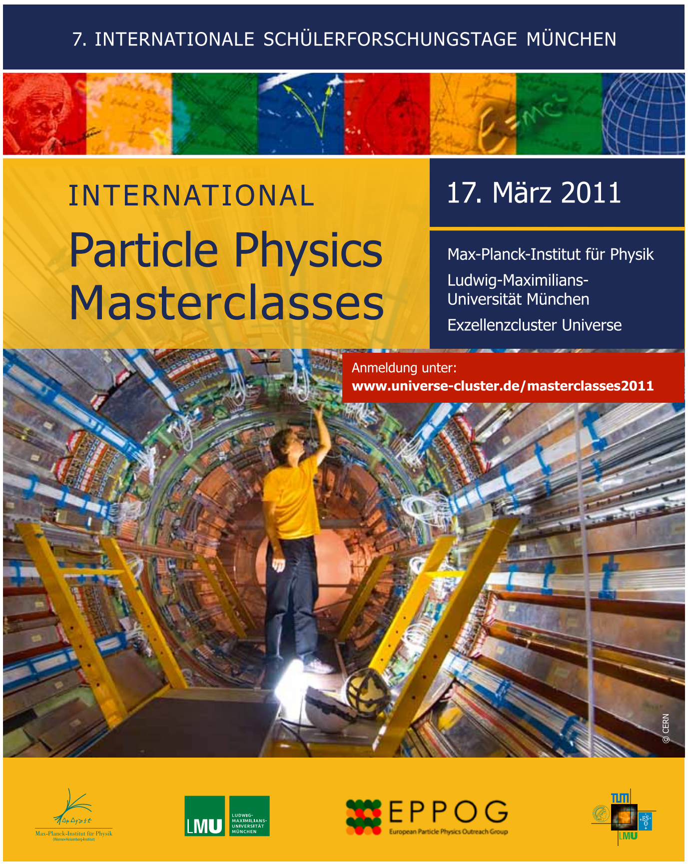
The Excellence Cluster Universe has another important international research partner: At the end of February 2011, a Cooperation Agreement was signed between the Cluster Coordinators Prof. Stephan Paul and Prof. Andreas Burkert and the Directors of the Centre for Theoretical Cosmology of the University of Cambridge, Prof. Paul Shellard and Prof. Stephen Hawking.

The agreement provides for close cooperation with regard to the development of new research projects in theoretical cosmology. These relate in particular to the development of cosmological scenarios, the investigation of Dark Matter and Dark Energy, as well as the search for knowledge to explain the fluctuations in cosmic background radiation and the large-scale structure. The cooperation partner within the Cluster will be Research Area "E", which is concerned with the study of dark matter and dark energy in the Universe. Furthermore, an exchange program is envisaged for doctoral and post-doctoral candidates of both research institutes. "Since the start of the Cluster, we have been able to enter into cooperation with many significant research institutes. We are very pleased that we are now establishing an active scientific exchange with Cambridge as well", Cluster leader Stephan Paul declares.

In addition to the Centre for Theoretical Cosmology of the University of Cambridge, the cooperation partners of the Excellence Cluster Universe include the Berkeley Center for Cosmological Physics, the Institute for the Physics and Mathematics of the Universe at the University of Tokyo, the Joint Institute for Nuclear Astrophysics, the Argonne National Laboratory and Princeton University.

EVENT

Researcher for a Day – "Hands on Particle Physics" Masterclasses at the Cluster



Following the slogan "hands on particle physics", 50 high school students aged 16 to 18 years followed the Cluster's invitation to participate in the 7th International Masterclasses on 17 March 2011. This event took place at TUM's Physics Department and was co-organized by the Max-Planck-Institut für Physik and the Physics Department of the Ludwig-Maximilians-Universität.

In this annual European-wide event, about 6000 high school students in 24 countries visit nearby universities or research institutions to experience the fascinating field of particle physics for one day. At the beginning of this year's event, Prof. Jochen Schieck, leader of the Cluster's group "Heavy Quarks" introduced the pupils to the world of particle physics. TUM-scientist Dr. Roman Gernhäuser explained the different particle detectors used in hope to unravel the mysteries of particle physics.

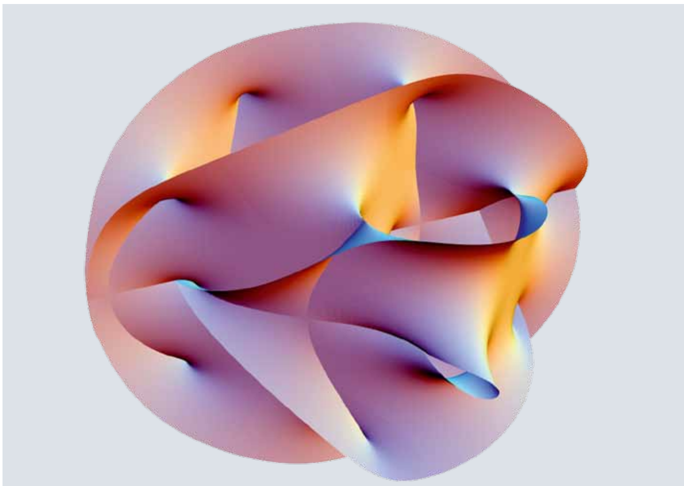
In the afternoon, the pupils faced a very special challenge: They worked on the first real data from CERN's Large Hadron Collider (LHC), collected just a few months ago. Three experiments – ATLAS, CMS, and ALICE – made data available for educational use within the program. Students could for example rediscover the Z boson or the structure of the proton, reconstruct "strange particles", or search for the elusive Higgs boson in particle tracks. At the end of the day, the pupils joined a video conference with participants in Athens, Katowice, Brookhaven, Göttingen, and scientists at CERN to combine and discuss their results.

PORTRAIT

String Theory: In Search of the Universal Formula

There are two adversaries in the Universe who don't really get on with each other, but these rivals are not called Luke Skywalker and Darth Vader ... We are referring to two basic physical principles: The General Theory of Relativity by Albert Einstein and the Quantum Field Theory, which was established by Erwin Schrödinger among other scientists. General Relativity explains the physics of the Universe, which takes place at great distances. Its most important reference system is gravitation and its effects on space-time. Quantum Field Theory becomes relevant when one is concerned with physics at the subatomic level. It describes matter and forces as particles and as a wave function. With the Quantum Theory it is possible to explain the three fundamental forces – strong, weak and electromagnetic interaction – but not gravitation. And thus we have already arrived at the problem. Both theories are ideal in order to understand specific aspects in the evolution of the Universe – but neither theory succeeds in describing the physics of the Universe as a whole.

Prof. Dr. Ilka Brunner is a scientist who refuses to be content with this division. She leads the Junior Research Group "Extra Dimensions in Particle Physics and Cosmology" at the Excellence Cluster Universe. Her field of specialization is String Theory, with which all four fundamental forces and the properties of matter can be unified on the basis of one theory. "String Theory enables us to combine gravitational theory with Quantum Theory", Ilka Brunner explains. "However, we must say farewell to the conventional idea of point-shaped particles". String Theory is based on the supposition of one-dimensional extended and vibrating objects, which is aptly illustrated by the term "string", as in a string instrument.

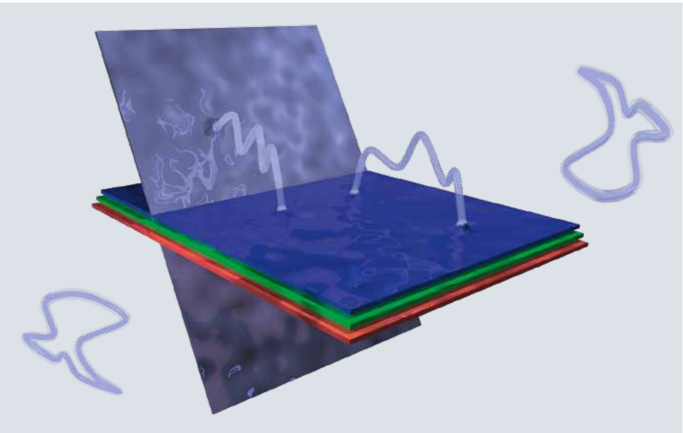


The picture shows a Calabi-Yau manifolds string theorists use to illustrate compactified dimensions in the string theory.

Strings may be either open or closed as a ring. As inconceivably small structures in the order of 10^{-35} meters, strings are to be perceived as fundamental building blocks of nature. The elementary particles, quarks and leptons, develop when the strings oscillate at different frequencies. This is analogous to how different notes are produced on the guitar depending on how high or low the tension is on the strings being plucked. Not only the named matter particles, but also the force carriers (gauge bosons) of all four interactions can be explained according to this theory. In addition to gluons (strong interaction), W and Z bosons (weak interaction) and photons (electromagnetic interaction), the String Theory provides a home for gravitation. The corresponding bosons are called gravitons.

String Theory combines what was originally impossible to unite. Nevertheless the theory also presents concrete difficulties. String Theory can only be calculated conclusively when in addition to the three known dimensions, which describe the space, one integrates six other dimensions. “Along with the time dimension, this results in a 10-dimensional Universe”, Ilka Brunner says. “The additional dimensions can be so tiny however that we would hardly notice them.” The trick these “extra dimensions” use in order to make themselves invisible: They curl up. Ilka Brunner: “This state can be well illustrated using an example with two dimensions. Imagine you are standing on a large thin woollen blanket. You can move forwards and backwards, as well as to the right or left. If you roll up the blanket lengthwise, you will lose one dimension: similar to a tightrope artist, you can only balance forwards or backwards on the thin blanket-’string’. In principle, the two dimensions are still there but one of them disappears because it is small and imperceptible for human beings. The situation on the blanket would be completely different from the perspective of an ant: It is small enough to move on the blanket roll sideways as well.”

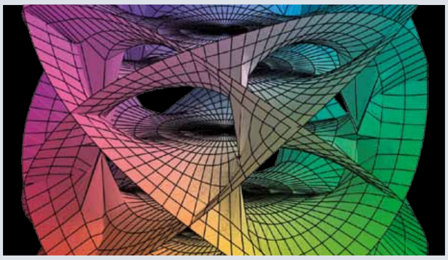
In order to represent this “compactification” of dimensions at higher levels, scientists have further developed the String Theory. In addition to the particle strings, multi-dimensional extended objects also occur. These two-dimensional structures are referred to as p-branes (brane is derived from membrane, p is the number of dimensions). These branes span the Universe like large pieces of fabric. Ilka Brunner is concerned with a special form of these p-branes, the D-branes, to which open strings attach themselves. “With the introduction of the brane worlds it is possible to provide a good description of a 10-dimensional Universe”, Ilka Brunner explains. “The three known space dimensions could be situated on one or more D-branes, whereas the bound open strings then form all elementary particles, i.e. electrons, quarks and photons. In this scenario gravitation can be introduced as a ring-shaped particle string which can move freely between the brane dimensions.”



In the string theory, fundamental interactions and particles are described by strings and branes.

In her research work Ilka Brunner analyses various ways in which consistent String Theory compactifications can be constructed with the help of D-branes. At the same time Ilka Brunner’s work is based on the idea that our world is realized on a D-brane which stretches over the uncurled three known dimensions. “As to the additional curled up dimensions there are many possibilities with regard to the behavior of the D-brane”, she explains. “If we stay with the example of the woollen blanket: The brane could either wrap itself around the rolled up dimension or simply not. If one rolls up several dimensions, initially there is a wide range of possibilities for the brane’s behavior. Our calculations have shown however that not all configurations are consistent within the framework of the String Theory. Therefore other factors must exist.”

Junior Research Group: Extra Dimensions in Particle Physics and Cosmology



Prof. Dr. Ilka Brunner has been heading the Junior Research Group “Extra Dimensions in Particle Physics and Cosmology” since October 2008. After studying physics at the University of Bonn, Ilka Brunner obtained her PhD degree from the Humboldt University in Berlin. She subsequently held a postdoctoral position at the NHETC at Rutgers University, Piscataway, USA. In 2001 she became a fellow at the Theory Division at CERN. In 2004 she started to work as a fellow at the Institut für Theoretische Physik at the ETH Zürich, where she became a professor and “EURYI award holder” (European Young Investigator) in 2006.

Research Group

Ilka Brunner’s group includes three scientists at the post doctoral level, Dr. Nils Carqueville, Dr. Andres Collinucci and Dr. Masoud Soroush as well as the PhD students Michael Kay and Daniel Plencner. In the course of 2011, Dr. Constantin Bachas of the Ecole Normale Superieure, who recently received a Humboldt award, will join her group as a guest scientist.

Research Interests and Collaborations

Ilka Brunner’s research field is string theory that offers a unified theory of all fundamental interactions (forces), thereby combining gravitation and quantum field theory. In the past years her main interests besides one-dimensional strings have focused on multi-dimensional D-branes in Calabi-Yau geometries.

She is committed to several research projects, some of them touching mathematical fields such as algebraic geometry. Depending on the project she collaborates with scientists in international institutions, e.g. Dr. Constantin Bachas, Dr. Daniel Roggenkamp (Rutgers University, USA), Prof. Michael Douglas and Prof. Leonardo Rastelli (Stony Brook, USA).

One of Ilka Brunner's main topics is the analysis of D-branes in interesting background geometries – also in the context of a supersymmetrical theory which assigns each elementary particle a supersymmetric partner. "We are hoping for a minimal supersymmetric theory in 3+1 dimensions as the result of our calculations", Ilka Brunner says. "This and other parameters set conditions for the geometry of the rolled up dimensions. As it appears, this can be summarized in the concept of so-called Calabi-Yau manifolds, whose geometries are also studied in the field of mathematics." Furthermore, Ilka Brunner is also concerned with the dependency of D-brane physics on theoretical parameters, such as, for example, the length scale which is given through the extension of the string. "My research work leads me to the exciting fringe area between mathematics and physics", she sums up. "And here D-branes play an important role in the analysis of abstract geometrical questions. The String Theory has led to predictions in certain branches of mathematics, i.e. algebraic and enumerative geometry, which were initially surprising to mathematicians. It was then possible to check these predictions mathematically."

PEOPLE

New Scientists in the Fellow Program

The Excellence Cluster Universe welcomes two new Research Fellows: Dr. Nadine Neumayer and Dr. Sinéad McGlynn. Both observational astrophysicists joined the Cluster's research area F, which focuses on the question how black holes formed and evolved.

Nadine Neumayer

Previously, Nadine Neumayer was a Research Fellow at the European Southern Observatory (ESO) in Garching and already involved in the Cluster's research network as a Junior Principal Investigator. Her research interest includes the co-evolution of black holes and galaxies, black hole mass modeling, and nuclear star clusters. For her research work, Nadine received several renowned awards. Among them is the Otto-Hahn-Medal by the Max-Planck-Gesellschaft for her outstanding PhD thesis on "The nucleus of Centaurus A".

Sinéad McGlynn

Sinéad McGlynn last held a Postdoctoral position at the Royal Institute of Technology (KTH) in Stockholm and has been a full member of the Fermi-Large Area Telescope (LAT) collaboration. She has been focusing on the data analysis and methods employed by this collaboration. Additionally, she has been involved in a number of significant papers on gamma-ray bursts (GRB), i.e. explosions of massive stars leaving behind a black hole. At the Cluster, Sinéad will remain involved in GRB research.

With the arrival of Nadine Neumayer and Sinéad McGlynn at the Cluster, the majority of the Cluster's Fellow positions have now for the first time been assigned to female researchers (five out of nine). "In our advertisements we especially encourage female scientists to apply for our Fellowship program. We are glad that in an excellent field of applicants two female researchers have accomplished those Fellowships", says the Cluster's General Manager Dr. Birgit Schaffhauser. "For this reason, we have now come a big step towards our objective to increase the number of female scientists at the Cluster."

Barbara Ercolano leads group "Theoretical Astrophysics"

Barbara Ercolano

Since December 2010 all leading positions in the ten Junior Research Groups (JRG) of the Excellence Cluster Universe have been filled. The JRG "Theoretical Astrophysics" is being led by Professor Barbara Ercolano. Born and raised in Italy, Barbara Ercolano received her PhD in 2002 from the University College London, where she developed the first 3D Monte Carlo photoionisation code (MOCASSIN) for the transfer of electromagnetic radiation in a variety of gas and dust environments from star-forming regions to supernova remnants.

The following years Barbara Ercolano held postdoctoral positions at the Harvard University and the University of Cambridge, where she further developed the MOCASSIN code. In 2009 she was awarded the five year UK Science and Technology Facility Council Advanced Fellowship for theoretical work on star and planet formation. One year later Barbara Ercolano received the Royal Astronomical Society Fowler Prize for the development and application of the MOCASSIN code.

After a short stay as lecturer at the University of Exeter (UK), Barbara Ercolano accepted the position as a professor for Theoretical Astrophysics at the Universitäts-Sternwarte at the LMU in Munich and as a Junior Group Leader at the Excellence Cluster Universe.

At the Cluster, Barbara Ercolano will continue to focus on computational astrophysics. Her research group will be part of the Cluster's research area G with emphasis on the question of how the Universe was enriched with heavy chemical elements.

IMPRINT

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