NEWSLetter
Excellence Cluster Universe

Issue 4 / 2010

Dear Readers,
I won't linger on looking back to 2010, as the New Year will be a very interesting one for the Universe Cluster - and hopefully also for you! We gladly help you organise your year 2011: You can get our attractive overview calendar by sending an e-mail to info@universe-cluster.de - don't forget to add your postal address. There will be two large conferences involving a major commitment by the Cluster in Munich: Hadron 2011 from 13-17 June and TAUP (Topics of Astroparticle and Underground Physics) from 5-9 September. The Science Week, our annual scientific event will start on 28 November 2011. Also, in 2011 we will apply for the second program phase of the German Excellence Initiative - so will be the year that decides our future in the years 2012-2017.
Of course we will keep you posted on the less highlighted activities of our Cluster. We wish you a pleasant and relaxing holiday season and a good start into the New Year!

Barbara Wankerl, PR Manager

PICTURE OF THE MONTH

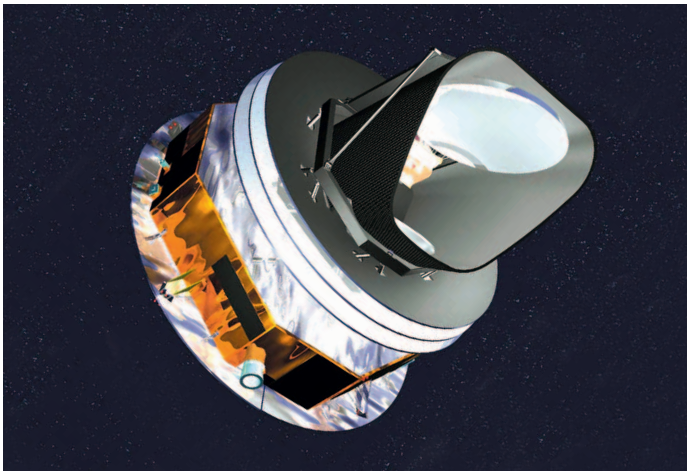
Mono Lake appears serene but some of its bacteria have caused quite a stir. In early December, NASA announced that scientists had found bacteria that were able to ingest toxic arsenic and use it as DNA building blocks instead of phosphorus, expanding the concept of "life" as we know it. In the meantime, there have been other scientists criticizing the work and the methods used as sloppy. Has good science been damaged by a rash publication?

RESEARCH

The Mystery of Inflation

The connection between particle physics and inflation has been puzzling cosmologists for over 30 years. To date, scientists are still looking for a plausible description of the first significant event in the Universe. Stefan Antusch of the Max Planck Institute for Physics (MPP), who is also involved in several research areas of the Cluster, is advancing a new model.

What do economists and cosmologists have in common? Headaches caused by the thought of inflation. Unlike economic inflation, however, whose mechanisms are largely understood, its cosmic counterpart still poses many questions.

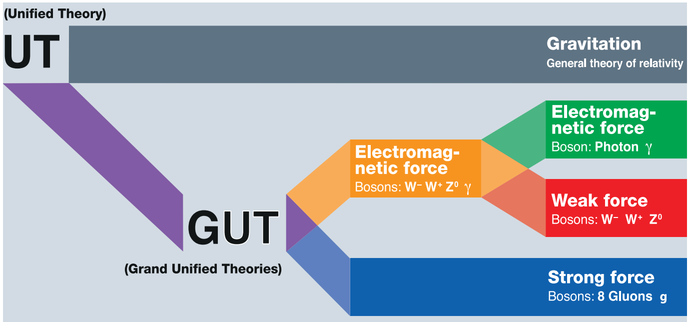


Depending on its recordings of gravitational wave signatures, the Planck satellite is expected to either confirm or overthrow the superparticle theory.

The concept of inflation was devised in the early 1980's when the Standard Model of cosmology was confronted with some serious problems: At that time no-one was able to explain why the Universe seemed to have a simple, "flat" geometry. According to Einstein's Theory of Relativity the space could also possess an inner curvature, which for example would cause beams of light to follow curved paths over long distances. The finding that matter is distributed very homogeneously in the Universe appeared no less puzzling, since this is true for regions of the Universe that are so far apart that they could not actually have "known" anything about one another after the birth of the Universe. Similar distribution of matter, however, indicates a common past.

The cosmologists Alan Guth and Andrei Linde solved these and further problems with a stroke of genius: According to their theory, the Universe was subject to a very brief phase of extremely rapid expansion directly after the Big Bang. In this expansion neighboring regions were brought "out of reach" in fractions of nanoseconds – after they had the opportunity to align their temperatures and densities. As a result of the inflation process, a region, which we perceive as being virtually flat, emerged from a Universe having an initially arbitrary curvature. The whole process took a ridiculously short time: After 10^{-33} seconds, the first "epoch" of the Universe was already history.

No matter how elegantly the inflationary model might solve fundamental problems of cosmology – cosmologists have not yet



The "evolution" of the fundamental forces in the Universe

fully understood the mechanism which sets inflation in motion and ends it again. By now the search for the driving force behind inflation has been going on for thirty years. Numerous more or less successful variants have been devised.

Together with his team at MPP and researchers from Southampton and Granada, Stefan Antusch has now proposed a new model. It is based on the theory of supersymmetry (SUSY), a widely discussed extension of the Standard Model of particle physics. This theory postulates that for each type of elementary particle a supersymmetric partner exists with related properties. A promising characteristic of SUSY is that it enables the merging of three of the fundamental forces between the elementary particles, the electromagnetic, strong and weak force, to create a single force. In a theory of this kind the different types of elementary particles and their supersymmetric partners are also described by means of a unified superparticle. In Antusch's model it is precisely this superparticle that plays the role of the inflaton, which is responsible for the sudden expansion of the Universe.

According to Stefan Antusch and his research colleagues, the unified superparticle has the properties necessary to qualify it as the driving force behind inflation. Why is that? In the epoch of the Grand Unified Theory when the three fundamental forces were still combined, a large amount of energy existed, which was stored in the form of the potential energy of the inflaton field. This so-called vacuum energy could have supplied the energy necessary to inflate the Universe in fractions of seconds from the size of a proton to a size "somewhere between a football and a football field", Antusch explains. Furthermore, after inflation all matter in the cosmos was assumed to have originated from the remnants of the inflaton. Here again the unified superparticle is the ideal inflaton candidate: In the researchers' model the vacuum energy is transferred into kinetic energy of the superparticle field after the end of inflation. The superparticle subsequently decomposes into its constituent parts, the known elementary particles and their superpartners.

The theory on which the model is based, supersymmetry (SUSY), has not yet been confirmed experimentally. The particle physicists and astrophysicists are hoping for results from the experiments at the CERN Large Hadron Collider. Sufficiently high energy levels will soon be reached at CERN and might give a first experimental hint of supersymmetry.

One possibility to either test or disprove the new model of Stefan Antusch and collaborators by means of measurements is the gravitational wave test: Cosmologists have assumed for a long time that the first structures established in the Universe during the inflationary phase were accompanied by ripples in space time, which spread like light waves throughout the whole Universe. According to the new model these gravitational waves are so weak, however, that not even the sensitive measuring apparatus of the Planck satellite can detect them. Stefan Antusch and his research colleagues will therefore be waiting in anticipation of the new data delivered by the Planck satellite in the coming months and years: Depending on whether the gravitational wave signatures appear or not, the theory will be supported or overthrown.

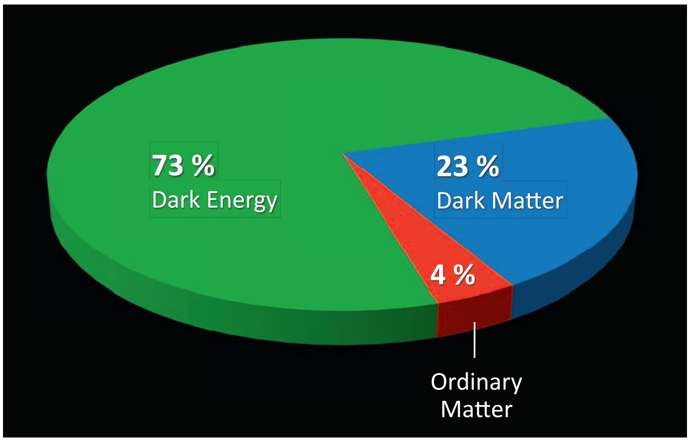
Original Publication

S. Antusch, M. Bastero-Gil, J. P. Baumann, K. Dutta, S. F. King, Ph. M. Kostka: Gauge Non-singlet Inflation in SUSY GUTs; Journal of High Energy Physics (JHEP), 2010,8,1-35; http://arxiv.org/abs/1003.3233

CRESST II : In Search of Dark Matter

It is everywhere. Here on earth, in every room, in every galaxy. Yet, to this day no-one knows what it is made of: Dark Matter. Physicists and astronomers have been trying to elicit the secret from the Dark Matter without success for decades. Although the Dark Matter makes up 23 percent of the mixture of ingredients of the Universe, it is still virtually impossible to detect. This is due to the fact that unlike ordinary matter, which is made up of atoms and forms stars and galaxies, it is invisible. This is for the simple reason that it does not take part in the electromagnetic interaction. It does not emit any light and therefore cannot be directly observed. The term WIMPs – Weakly Interacting Massive Particles has established itself among physicists as the name for the (up to now) hypothetical Dark Matter particles. It stands for the scientists' assumption that they are dealing with heavy particles which interact via the weak interaction with the environment.

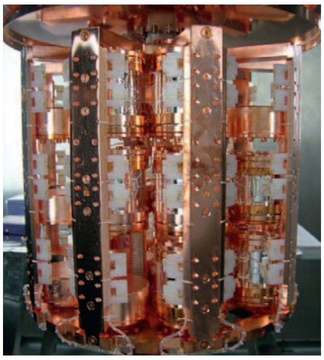
How can WIMPS be detected? In the cosmos the massive particles penetrate everything that blocks their way – usually without leaving a single trace. It is extremely seldom, however, that a collision with atomic nuclei may occur, that is to say, within the detectors on the earth as well. And this is precisely how the Dark Matter particles might reveal themselves one day. One of the projects with which scientists want to pin down the WIMPs is the



The constitutents of the Universe: Ordinary matter just plays a subordinate role.

CRESST Experiment: Cryogenic Rare Event Search with Superconducting Thermometers. The working group of Dr. Jean-Côme Lanfranchi (TUM) is participating in this research on behalf of the Excellence Cluster Universe. Furthermore, the Cluster provides funding for the development and construction of the current and future detectors.

The detectors represent the spearhead of technology currently available. The decisive factor is their ability to reliably discriminate between the WIMPs and the natural background radioactivity. According to the motto "two are better than one", the CRESST crystals simultaneously measure temperature differences and light signals, which occur as the result of a colliding particle. The measuring technology is so sensitive that CRESST can register these collisions on an event-by-event basis. The core of the WIMP "securer of evidence", which is being developed under Lanfranchi's leadership is a 300-gram crystal block of calcium tungstate ($CaWO_4$). If a WIMP collides with an atomic nucleus in the detector, the atomic structure of the crystal begins to oscillate. As the crystal is made up of three different target atoms (calcium, tungsten and oxygen), different WIMP scattering scenarios can be probed.



Detector carousel with $CaWO_4$ target crystals

Although the particles being searched for have a comparatively high mass (10 to 1000 times the mass of a proton), the energy transfer is nevertheless extremely low. In order to discover this tiny change, however, it is necessary to suppress the thermal movement of the molecules, that is, to cool the crystal down to very low temperatures. Furthermore, at temperatures barely above absolute zero at 10 milli-Kelvin, this leads to another effect: A thin film of tungsten applied on the crystal turns into a superconductor at precisely this temperature. An atomic structure oscillation, the same as is triggered after the collision of a WIMP, increases the temperature in the crystal only slightly. An electric current which is conducted through the previously superconducting film clearly changes its strength. This is because the tungsten layer quickly loses its superconducting properties due to the higher temperature of the crystal.

Furthermore, the detectors are being continually developed and tested in a new underground laboratory of the TUM in Garching, which is partly funded by the Cluster. These detectors are capable of capturing and even intensifying the weakest light signals which are generated as a result of the atomic structure oscillations in the crystal. The signal balance of the new detectors is unique in this respect: 100% of the energy that a particle brings into the crystal is recorded by the measuring apparatus.

A fundamental problem of such sensitive measurements is caused by the disturbing influence of the surroundings. Radioactive alpha, beta and gamma radiation, as well as neutrons or the particles of the cosmic radiation manage to get the atomic structure of the crystal oscillating just as the WIMPs. In contrast to the WIMPs these particles interact more strongly with their surroundings and thus with the crystal atoms as well. For this reason, the CRESST apparatus is found in an underground laboratory in the Gran Sasso massif in Italy: Approx. 1,400 meters of rock protect the apparatus from unwanted radiation.

View of the Gran Sasso, where the CRESST experiment is located

The initial measured data of 10 new detector modules is currently being analyzed. Up to now it has been possible to identify events in every single one of them, only one third of which could be explained by the influence of cosmic or radioactive background radiation. Independent of the results to come from the CRESST project, the European Research Network is already working on the extension of the experiment. The planned project called EURECA (European Underground Rare Event Calorimeter Array) is intended to detect more effectively than previously the collisions between WIMPs and atomic nuclei using absorber masses of 100 kg to one tonne. Through the use of different target materials various WIMP scenarios can be clearly proved. Perhaps it is only just a matter of time before direct evidence of Dark Matter, which has been anxiously awaited for decades, will exist.

Dark Energy under Observation

The Excellence Cluster Universe and the Ludwig-Maximilians-Universität (LMU) have joined the "Dark Energy Survey" (DES). This international observational campaign will start at the end of 2011. The understanding of Dark Energy is one of the key questions in the research of the Universe Cluster. For six astrophysicists and their research groups at the University Observatory of the LMU participation in this large-scale project will provide their research work with important impetus: The membership gives them access to all the observational data of the project and the opportunity to work collaboratively with a strong international team of scientists.

According to today's knowledge Dark Energy is considered a possible cause of this accelerating expansion of the cosmos. The aim of DES is to unravel the mystery of Dark Energy with the help of sky surveys. The scientists gathering in the DES collaboration plan to observe for 525 nights over a five-year period. During this time the highly sensitive "DECam" camera will take more than 150,000 images each of them covering more than 16 times the area of the full moon and collect data from 300 million galaxies.

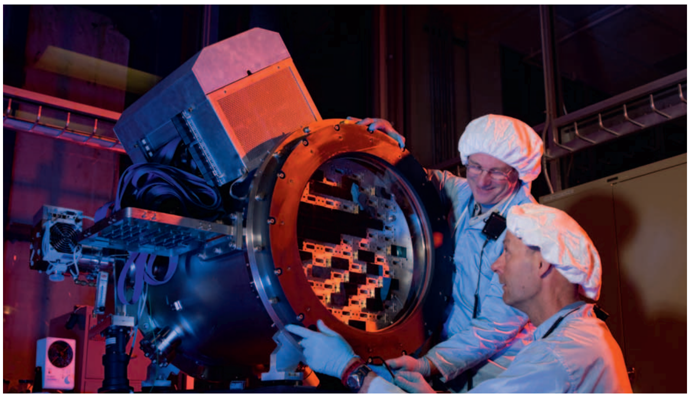
The heart of the campaign comprises a 570-megapixel digital camera (DECam), which is being mounted on the Blanco 4-meter telescope at the Cerro Tololo Observatory in the Chilean Andes together with a state of the art data management system that will use supercomputers in the US and in Germany to process the sky images into precise catalogs of the brightness and shape of each galaxy observed.

The researchers are currently discussing different forms of Dark Energy and whether Dark Energy changes with time. Compared to previous observational campaigns, DES will be the first to study the Dark Energy question using multiple independent astrophysical methods. To study Dark Energy, astrophysicists have to make a detour via Dark Matter, a further component of the Universe. The DES observations of galaxies will use gravitational lensing to enable the distribution of Dark Matter to be reconstructed; these data will in turn provide the scientists with information on the physical properties of Dark Energy. In addition, the DES will enable snapshots of the large-scale distribution of galaxies and galaxy clusters stretching back more than 10 billion years in time.

These snapshots allow the DES scientists to measure how large-scale structure is evolving in time and thereby infer the properties of the Dark Energy. “DES will deliver a combination of independent tests on the nature of the cosmic acceleration or Dark Energy, thus setting a new standard for next generation missions”, says Professor Joseph Mohr, from the University Observatory and one of the co-founders. “Upcoming observational campaigns such as Euclid, LSST and the SKA have followed in DES’s footsteps by adopting a similar multi-pronged approach to studying the nature of the Dark Energy”.

Adds his colleague Professor Jochen Weller, leader of the group “Observational Astrophysics” at the Cluster: “DES will enable us to measure the distribution and images of more than 300 million galaxies. This material will allow my research group to evaluate different models of the accelerated expansion of the Universe. Maybe we will find the answer to the question, whether or not Einstein’s theory of gravity can be applied to very large distances.”

The Blanco telescope in Chile



Scientists build a prototype of the Dark Energy Camera, which will survey about one-tenth of the sky to measure 300 million galaxies.

Other new members of DES at LMU include Professor Ralf Bender, Professor Andreas Burkert, Dr. Roberto Saglia and Dr. Stella Seitz. They will focus on gravitational lensing, on the use of new spectroscopic instruments on the Very Large Telescope (VLT) and on the production of large scale numerical simulations of structure formation in the Universe that can be directly compared to the DES measurements.

Additional information: www.darkenergysurvey.org

ERC Grant for Andrzej Buras

Andrzej Buras

Professor Dr. Andrzej J. Buras has won an ERC (European Research Council) grant to promote his studies in flavour physics. He will receive 1.6 million euros in funding from 2011 to 2016. Professor Buras is full Professor for Theoretical Elementary Particle Physics and Research Area Leader at the Excellence Cluster Universe. In addition, he has been a Carl-von-Linde Senior Fellow of the TUM Institute of Advanced Studies (IAS) since 2007. He is one of the world’s leading scientists in the area of applied quantum field theory.

The topic of his ERC-funded project is the development of a basic theory of flavour physics, one of the seven central research areas at the Universe Cluster. The characteristics of fundamental elementary particles, quarks and leptons, are studied in flavour physics. Altogether there are six quarks and leptons each with different properties with regard to electric charge and “flavours”, for example the up and down quarks.

A true understanding of the flavour structure of quarks and leptons, their masses and interactions still does not exist. The aim of Professor Buras and his team is to decode these unknown structures in order to ultimately better understand the development of the early Universe. The future results of flavour experiments at the Large Hadron Collider and the Belle II Experiment in Japan (KEK), in which the Universe Cluster is also represented, will also play a role in this project.

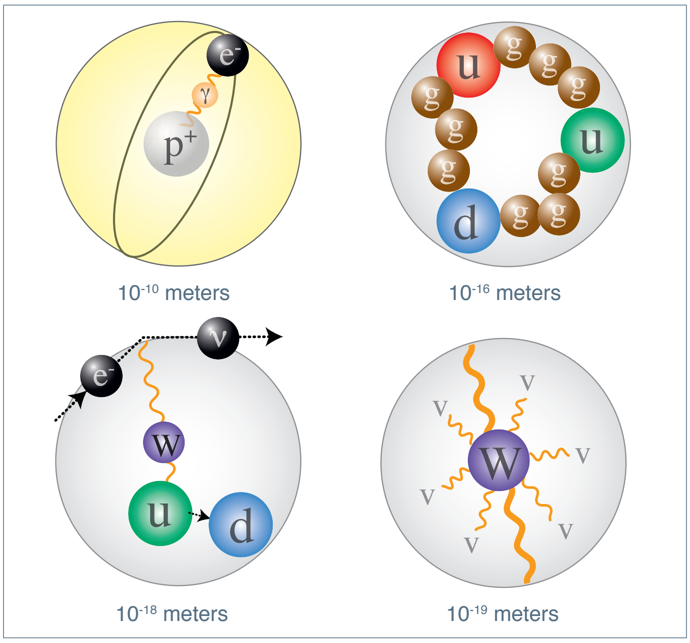
PORTRAIT

The Journey to New Physics

When physicists want to perform experiments on small objects or forces at short distances they need to invest quite a lot of energy. This becomes clear when looking at the Large Hadron Collider: To study particles and forces on very small scales, the LHC fires protons against each other at an energy of 7 tera-electronvolts, corresponding to more than 99.99 per cent of light speed. Scientists expect to find new particles under these conditions: either the Higgs particle, the last missing piece of the standard model or "new physics" beyond the standard model.

One of the scientists probing the frontiers of old and new physics is Dr. Martin Gorbahn who leads the Junior Research Group with the matching title "New Physics beyond the Standard Model". His studies focus on forces – on forces that act at small distances in the range of 10^{-19} meters, to be more precise. According to current knowledge, forces are generated by the exchange of particles. We also know that forces at very short distances are governed by highly energetic or very massive particles.

The instruments Gorbahn uses for his research are not the large collider experiments: As a theoretical particle physicist he delivers mathematical precision calculations to his colleagues in the experimental fields, using computer programs – or sometimes, quite unpretentiously – paper and pencil.

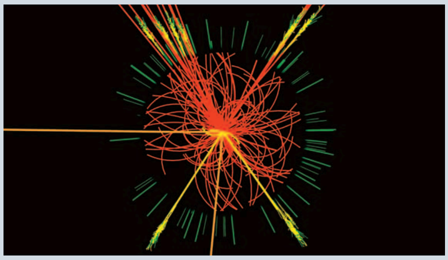


Forces in atomic and subatomic structures. At 10^{-10} meters the atom is governed by the electromagnetic force, at 10^{-16} meters the strong force predominates. The symmetry breaking of the electroweak force occurs at 10^{-19} meters.

But why do we need new physics? To explore new territories, you need new vehicles – just as you don't drive through the desert with a family car. More scientifically speaking, the standard model of particle physics serves as a good fundament for describing matter and fundamental forces. However, the further scientists drill into the innermost structure of matter and physical phenomena in the Universe, the more explanatory leaks they find. For example, the standard model fails to explain the predominance of matter over antimatter, the existence of dark matter and the special relationships between the forces and the particles they act upon.

Matter consists of atoms that can be subdivided into protons and neutrons forming the nucleus and the electrons swirling about it. According to the quantum field theory the fundamental forces in physics can also be defined as particles. The forces between matter particles are exchanged by so-called bosons. At 10^{-10} meters we are in the range of atoms. The protons and the electrons interact via the "electromagnetic force" mediated by photons (see image on the left). When examining neutrons and protons of the nuclei, we will find quarks held together by the "strong force", the interacting particles being the "gluons". If we proceed to still smaller scales we enter the regime of the "weak" force, causing the radioactive beta decay. The bosons of the weak force are the W and Z fields. These bosons are so heavy that they can only act at short distances.

Junior Research Group: Particle Physics and the Early Universe

Dr. Martin Gorbahn (37) leads the Junior Research Group "New Physics beyond the Standard Model" at the Excellence Cluster Universe. Since 2008 he has been a Carl von Linde Junior Fellow at TUM's Institute for Advanced Study. From 1994 to 2000 Martin Gorbahn studied physics at TUM, University of Glasgow and FAU Erlangen. After his dissertation at TUM, he spent two years as Research Associate at the Institute for Particle Physics Phenomenology at the University of Durham. He returned to Germany in 2005 for a position at the Institute for Theoretical Particle Physics at the University of Karlsruhe.

His group includes the post docs Dr. Joachim Brod and Dr. Christoph Bobeth, as well as the PhD students Sandro Casagrande, Emmanuel Stamou and Stefan Vickers.

Research Interests

The research of Martin Gorbahn is focused on the research of heavy particles to promote the understanding of forces acting on very short subatomic distances. With his precision calculations the theoretical particle physicist and his group complement the investigations on small scale physics performed in large collider experiments, e.g. the LHC at CERN.

Martin Gorbahn's group investigates

- the physics of K-Mesons (Kaons)
- the physics of B-Mesons
- Supersymmetry
- the Higgs field
- neutrino physics

Collaborations within the Universe Cluster:

- Prof. Dr. Jochen Weller, LMU (Observational Astrophysics)
- Prof. Dr. Jochen Schieck, LMU (Heavy Quarks)
- Prof. Dr. Andrzej Buras, TUM (Theoretical Physics)
- Prof. Dr. Alejandro Ibarra, TUM (Theoretical Elementary Particle Physics)
- Prof. Dr. Wolfgang Hollik, Max-Planck-Institut für Physik (Gauge Theories of Fundamental Forces)

"The beginning of the Universe and the formation of matter are fields with many question marks", says Martin Gorbahn. "My research revolves around the question, as to how the weak and the electromagnetic forces split from a common predecessor. This force makes the W and Z bosons heavy and leaves the photon massless. We also know it acts at distances of 10^{-19} meters – the very distance probed by the LHC". The common force is referred to as "electroweak" force. Physicists describe the splitting into two separate forces as the breaking of a former symmetry.

To make the electroweak symmetry breaking explicable, the Higgs boson was added to the standard model. Extensions of the standard model also, i.e. new physics, potentially address other phenomena, like dark matter or the matter anti-matter asymmetry in our Universe. These extensions also leave footprints on the properties of lighter particles in the standard model. For this reason, scientists use precision experiments at CERN, Fermilab (USA) and KEK (Japan) to investigate the properties of the light particles in the standard model. These experiments allow scientists to resolve distances of 10^{-19} meters and shorter.

One particle of interest is the K^+ meson and its decay. The K^+ meson is made of an anti-strange quark and an up quark: If the standard model were valid up to 10^{-22} meters, the K^+ meson would decay into a pi^+ meson and two neutrinos only every $8x10^{-11}$ times. Martin Gorbahn and his group were able to calculate this number very precisely. Yet, if there is new physics at distances larger than 10^{-22} meters this number could change significantly. Experimentalists at CERN will measure this decay precisely, which will help to discriminate various models of new physics. Martin Gorbahn resums, "The combination of our precision calculations, the direct searches at LHC, as well as cosmological findings will help us to blaze the trail for new physics. Currently we don't know where this journey will us to – and what particles or completely new theories will show up."

EVENT

Science Week 2010

The Science Week 2010 of the Excellence Cluster Universe took place from 11 to 15 October. All interested parties were again invited to this event in order to find out more about the current research work of the Cluster scientists from all seven Research Areas in a varied lecture program. In addition, the Excellence Cluster Universe welcomed the Scientific Advisory Committee with its international members and held the general meeting. The highlights of Science Week included the awarding of the Universe PhD Awards 2010 to Dr. Thomas Krühler (MPE) and Dr. Jens Jasche (formerly MPA, now University of Bonn), the highlight lecture on stellar explosions by Dr. Hans-Thomas Janka and the public lecture held by Professor Simon White in the Garching community center.

Impressions of the Science Week 2010

PEOPLE

New General Manager for the Cluster

Birgit Schaffhauser

Since a couple of months Dr. Birgit Schaffhauser has been the new General Manager of the Excellence Cluster Universe. The native-born Austrian holds a doctorate in molecular biology. Before she started at the Cluster, Birgit worked as a Research Development Officer at the Institute for Cell and Molecular Biosciences at Newcastle University in England.

The decision to manage the Cluster's administration in the future was not difficult for Birgit Schaffhauser. The natural scientist was particularly inspired by the idea behind the Cluster of promoting fundamental research by means of interdisciplinary cooperation, "To think beyond borders and see concepts as a whole; that's how I define science. I am very pleased to be part of this idea".

After a short period of becoming accustomed to her new job, Birgit Schaffhauser is now already in the middle of the preparations involved in the application for continuation of the Cluster. In 2012 the Excellence Initiative will enter the next round and decide on the continuation of the individual Excellence Clusters.

Being new in Munich, Birgit Schaffhauser is currently spending her free time exploring the city and its surroundings with her family. After several years in England, she is especially happy "to be near the mountains and good food again".

Realisation: Ulrike Ollinger (Layout) · Barbara Wankerl (Conception & Text)

Contributions: Dr. Helmut Hetznecker, Dr. Andreas Müller, Alexandra Wolfelsperger

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