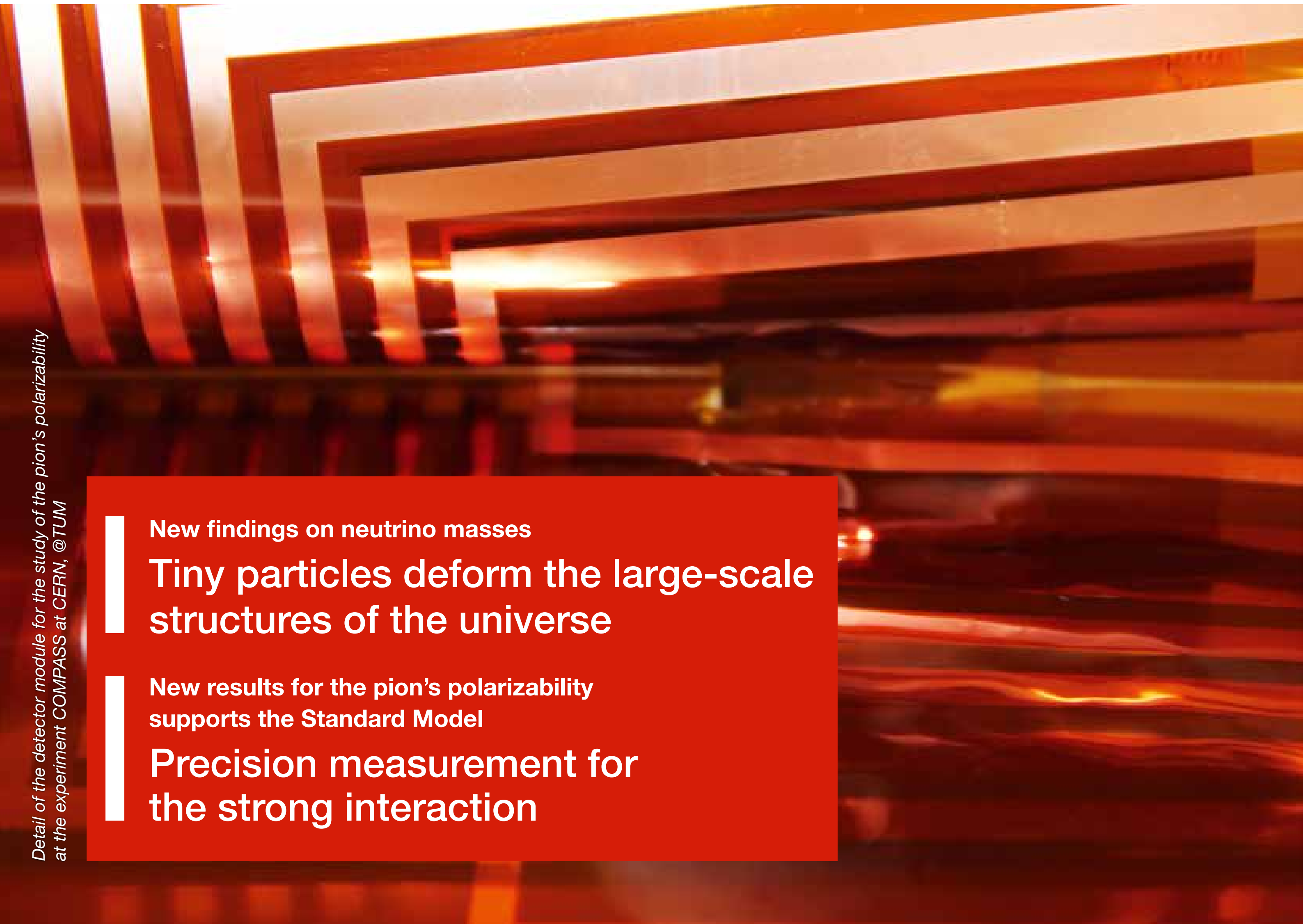
UniverseNews

Excellence Cluster Universe | Issue 1/2015



Detail of the detector module for the study of the pion's polarizability at the experiment COMPASS at CERN, @TUM

New findings on neutrino masses

Tiny particles deform the large-scale structures of the universe

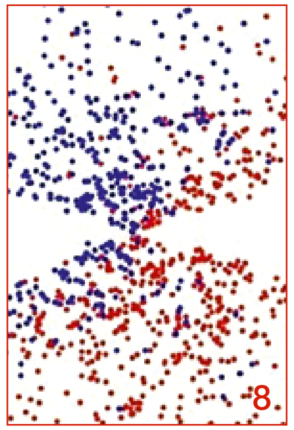
New results for the pion's polarizability supports the Standard Model

Precision measurement for the strong interaction

Dear Readers,

the limits of the Standard Model of particle physics are an issue in almost every of this issue's articles. In particular, neutrinos are subject to some unresolved puzzles in particle physics. Here, TUM Emeritus Prof. Franz von Feilitzsch gives a review on the study of neutrino oscillation and explains the role of the experiments he has initiated (page 3). Whereas the work of Prof. Hans Böhringer (MPE) shows, that also astrophysics can make important contributions to the theory of elementary particles. From the large-scale structures of the universe he was able to yield new hints for the neutrino masses (page 7). In contrast, the research group leader Dr. David M. Straub at the Excellence Cluster Universe is entirely committed to the search for new physics beyond the Standard Model (page 12).

Petra Riedel, PR Manager



Review

Science Week 2014

1 - 4 December 2014

During the Science Week 2014, the scientists of the Excellence Cluster Universe gave their annual overview of the scientific findings of the past months. Highlight was a talk given by Prof. John Ellis (CERN) (photo), a member of the scientific advisory committee of the Excellence Cluster Universe, who reported on the challenges after the discovery of the Higgs particle. In the bi-annual General Assembly, the coordinators and the research area coordinators of the Excellence Cluster were confirmed in their posts.

Music of the Spheres

25 February 2015

At this stunning evening, an audience of 500 was delighted by a "dialogue between music and cosmology" in the TUM lecture hall. Conducted by Simon Gaudenz, the Münchener Kammerorchester performed compositions by Mozart, Rameau, Schubert and Logothetis, dedicated to the topics night, moon, stars and sky. Between them, Prof. Stephan Paul (TUM) replied to children's questions such as "Why is the night sky dark?" or "What do we know about the end of the universe?". The event has been initiated by the Andrea von Braun Foundation.

Masterclasses 2015

23 March 2015

At the 11th Particle Physics Masterclasses at the Max Planck Institute for Physics (MPP), a number of 60 students were able to experience how scientists work. In the morning, they were given a brief introduction into particle physics and the world of detector technology. In the afternoon, the 10th-graders were able to analyse the original data of the CERN collisions in which the Higgs particle was discovered. The event was jointly organized by MPP, the Faculty of Physics of the LMU and the Excellence Cluster Universe.

Prof. Franz von Feilitzsch at the scientific symposium on 7 November 2014, held on the occasion of his 70th birthday.

Interview with TUM Emeritus Prof. Franz von Feilitzsch

"When I started, I didn't understand the first thing about it"

In Europe, the experimental physicist Prof. Franz von Feilitzsch is a pioneer in the field of astroparticle physics. In November 2014, on the occasion of his 70th birthday, his successor Prof. Stefan Schönert as well as Prof. Lothar Oberauer and Dr. Jean-Côme Lanfranchi organized a major scientific symposium at the TUM Institute for Advanced Study. An interview on research-based learning, academic competition, ambitious employees and constant money worries. *Interview Petra Riedel*

What were your feelings coming to the symposium?

I was very happy to be there! It was exciting to meet all the former staff scientists and to see how they have developed their profile and the success they were able to achieve.

You started studying physics in the mid-1960s. What did your first steps into science look like?

I wrote my diploma thesis in nuclear physics at the chair of Paul Kienle at the tandem accelerator, which had just started operation at that time. Many international guests, a working group with world-renowned professors – Paul Kienle and Heinz Maier-Leibnitz – and I, a complete beginner and nitwit was among them. Everybody was very cooperative and helpful. This made an incredible impression on me.

After your thesis you changed the research field and followed Rudolf Mößbauer. His interest in neutrinos started in the early 1970s, a completely new field at that time. In the mid-1970s, Mößbauer was director at the Institute Laue-Langevin (ILL) in Grenoble. Why did you change?

Paul Kienle had arranged that. He said I should have a word with Mößbauer. And so, in January of 1977, I went to Grenoble as a postdoctoral fellow. Mößbauer was good friends with the American neutrino physicist Felix Boehm, he knew him from his time at the California Institute of Technology (Caltech) in the early 1960s. Together with a group of scientists from France, the two had launched the first European experiment to search for the neutrino oscillation at the ILL. I was supposed to take over. When I first started, I didn't understand the first thing about it.

At the symposium in honour of Prof. Franz von Feilitzsch (centre), the lectures were given by (from left) Prof. Wolfgang Hillebrandt (MPA), Dr. Hans-Thomas Janka (MPA), Prof. Lothar Oberauer (TUM), Prof. Michael Wurm (Univ. Mainz), Prof. Josef Jochum (Univ. Tübingen), Dr. Thierry Lasserre (CEA Saclay), Prof. Marco Pallavicini (INFN & Univ. Genua) and Prof. Stefan Schönert (TUM).

Nevertheless, you were successful.

We weren't able to directly demonstrate that there really is neutrino oscillation, but we could set new limits on oscillation parameters. Some scientists interpreted our measurements as an indication for the existence of neutrino oscillation. In our view, that was not statistically significant. Unfortunately only afterwards we learned that the reactor's capacity was calibrated incorrectly, with an error of ten per cent. That made a difference to our results! When we learned about the mistake, it was too late for corrections or verifications: We were very efficient. Within three years, we had set up, carried out and dismantled the experiment.

In 1995, you founded a completely new and unique Collaborative Research Centre for astroparticle physics, the first one in Europe.

The idea arose in a casual conversation after a doctoral examination and came from Wolfgang Hillebrandt, who nowadays is director at the Max Planck Institute for Astrophysics. I was an associate professor at the chair held by Mößbauer at that time. I didn't know what a Collaborative Research Centre is. We developed a concept and drew-up a pre-proposal suggesting a number of projects. It was very well received by the German Research Foundation, with only a few amendments. Shortly thereafter, I received a call to Dresden, to the chair of Low Temperature Physics. The TUM didn't want to lose the positively evaluated Collaborative Research Centre, and so I was appointed full professor at the TUM. We submitted the final proposal and it went through smoothly. We were the first coordinated research group on astroparticle physics in Europe. The only other centre of excellence for astroparticle physics was located in Berkeley at that time.

The research center ran for twelve years, which is a long time.

It was the absolute maximum. The coordination always rested with our institute. This is unusual because the coordination of a Collaborative Research Centre usually rotates, but it just worked fine.

What do you attribute this success to?

Especially to the good staff! A relatively important principle was that I have never posted an open position or tried to hire people. The students used to come on their own accord. I believe that self-interest is a good indicator for an independent work style. In addition, I am firmly convinced of a second principle: No competition within the group! It is essential that all group members talk to each other, help each other and share their knowledge. Therefore, the working atmosphere in our group was always excellent. A number of outstanding scientists have emerged from my research group: a total of ten professors, four of them are women.

Which of the projects that you have initiated yielded the most important results?

Hard to say. I think that the gallium experiment Gallex and the successor GNO were most significant. Gallex was experimentally inspired by the chlorine experiment of Raymond Davis, the Homestake Chlorine solar neutrino experiment. In the early 1970s, Davis was the first to measure that the neutrino flux from the sun is about a third less than expected. No one believed him back then. Our Gallex experiment, which ran in the Gran Sasso underground laboratory starting in 1991, and the previous experiment Sage, the Soviet-American gallium experiment, confirmed the observation by Ray Davis. Our energy level was very low, and we could therefore detect the first low-energy neutrinos from the pp reaction, from which the sun derives most of its energy. After the neutrino spectrum was measured, in particular that of the pp neutrinos, it was clear that the sun's neutrino flux is much too low and not in equilibrium with the sun's radiation energy. The result confirmed that the neutrino properties differ from the Standard Model of particle physics. The scientific community was still not convinced. But in 2002, Raymond Davis finally received the Nobel Prize for his pioneering experiment.

You don't consider Borexino the most ambitious project?

Borexino could have been the crucial experiment. As a follow-up experiment of Gallex it was supposed to investigate the spectral distribution of solar neutrinos, which is sensitive to the neutrino oscillation, for the first time. Unfortunately, the construction of the experiment was delayed over and over again due to massive financial problems. Would Borexino have been built as it was planned, we probably would have been the first to show that the neutrino oscillation is responsible for the neutrino deficit, which all the previous experiments had seen.
But this success belongs to the Sudbury Neutrino Observatory in Canada. Nevertheless, the experimental design of Borexino is unique. There is no neutrino experiment in the world showing roughly the radioactive purity and sensitivity of Borexino. This is due to the innovative purification techniques of the scintillation detector.

For years, you have been advocating Lena, a giant neutrino observatory based on the technology of Borexino. What is Lena's purpose?

Astronomers learn about the universe from the observation of photons, the different wavelengths of light coming from the universe to the earth. But supernovae and other cosmic events and phenomena mainly emit particles. These particles carry interesting information. The vast majority of these particles are neutrinos, and they come from regions that are otherwise invisible to us, such as the centres of stars. Thus, neutrinos open up an additional observation window to the universe. With Lena, a large neutrino detector, we could carry out neutrino astronomy. I am firmly convinced that Lena could cover a very broad physical programme in particle physics, astrophysics and geophysics.

Why is there so little progress in realizing Lena?

A lot of European scientists from all fields, geophysics, astronomy and solar physics, are enthusiastic about Lena. The problem is funding. We have been trying for twelve years; our efforts were of no avail. It is sad. In China, where the construction of the neutrino observatory Juno has just started, the project got an "okay" within a few months. The Chinese experiment is interesting – but it has a much smaller scientific programme than it could have if it were built like Lena.

Are there any projects where you had hoped for more results?

No (laughs). In science, you can also derive information from a zero measurement.

How about CRESST? Neither CRESST nor any other experiment for the direct search for dark matter has been successful so far. Is it worth continuing?

Definitely. For several decades we know that the visible matter we are made of only accounts for a very small part of all the matter in the universe. What we have explored in physics until now refers to these five per cent. Thus, the search for dark matter should have the highest priority. By the way, I think the discovery of neutrino oscillation in particle physics is one of the most important, if not the most important result of the last years. It shows that there is physics beyond the Standard Model. The discovery of the Higgs particle, as satisfying and fundamentally it is, only completed the Standard Model.

CRESST is designed for the search of weakly interacting massive particles. Why do you focus on that?

The situation is comparable to that of 40 years ago, when we knew, through the experiment of Raymond Davis, that there is something weird about the neutrinos.

Two promising young physicists: Franz von Feilitzsch (l.) and Thomas Faestermann in 1974, as PhD students at the TUM

Very much in thoughts: Dr. Franz von Feilitzsch (r.) and Johanna Stachel, PhD student by then, at the GSI Darmstadt in 1978

But we had no idea of the scale of the neutrino masses and the frequency of the neutrino oscillation. There have been a lot of experiments at CERN and at accelerators in the United States that didn't find anything. Of course, these results provided important information, but they couldn't, as we now know, find anything because they were searching in the high-energy and not in the low-energy range. With dark matter, it is similar: We do not know where to look. Thinking of the early universe, a weakly interacting massive particle would be a promising candidate but then of course, it could be something else.

What are the most important tasks in astroparticle physics at present?
First, the particle physics issues must be addressed: Are neutrinos Majorana or Dirac particles, that is, are they identical to their antiparticles or not? The search for the neutrino-less double beta decay is the only approach known or the only approach to appear realistic to test the nature of neutrinos. I have not worked in this field, but it is a very fundamental question for elementary particle physics. And then, of course, the details of neutrino oscillation should be clarified. The next step would be to actually exploit neutrinos as information carriers.

What is more important: the low-energy or the high-energy range?
Both. Neutrinos are important in order to receive information about events in the universe, which occur at extremely high energies, such as supernova explosions. But the low energy physics in particular is very important for both, the neutrino astronomy and the particle physics issues. In my opinion, the effects of particles as light as neutrinos reveal themselves easier at low energies. Thus, I think, Lena is absolutely necessary, although the experiment will not be built in the foreseeable future.

What arguments ought to convince the funding agency?
Europe will lose its leading role in astroparticle physics if the European funding agencies do not reconsider their funding strategies. In the United States, this process is already under way. The technologies needed in neutrino physics are not only important in fundamental physics, but also in all areas of chemistry. If you like, it's about the large-scale purification of organic liquids, a technique that is also of great importance in medical engineering.

But this opinion has not yet caught on.
If a newly established research area such as astroparticle physics is not to be stalled, it has to be funded. If you compare the funding of nuclear physics, particle physics and astroparticle physics, the latter should get at least ten per cent of the budget. The request is not unreasonable, when you compare the commitment of scientists engaged in the fields. My recommendation is: ten per cent for astroparticle physics.

NEUTRINOS

Neutrinos are electrically neutral elementary particles whose properties have not been fully investigated. Therefore, neutrinos are an important research object in physics. In the Standard Model of particle physics, there are three types of neutrinos: electron neutrinos, muon neutrinos and tau neutrinos as well as their antiparticles. Contrary to the Standard Model, neutrinos have masses and can transform into each other due to quantum mechanical processes. Physicists refer to the phenomenon as neutrino oscillation. It is under discussion whether neutrinos are their own antiparticles, the so-called Majorana particles, which would provide an explanation for their masses. However, no experimental evidence has yet been found.
Neutrinos are produced in nuclear processes as they occur in the sun. Since they are only subject to the weak interaction, they only very scarcely react with matter and hence are most difficult to detect. Solar neutrinos have energies of a few eV up to 18 MeV, physicists refer to that range as low-energy. High-energy neutrinos are produced in collisions with high-energy particles, such as when particles in cosmic rays hit the earth's atmosphere (MeV to TeV). Neutrinos with even higher energies are assumed being produced outside our Milky Way and accelerated by extreme cosmic events such as black holes, neutron stars or supernovae (few TeV up to 10 PeV).

PROF. DR. FRANZ VON FEILITZSCH

studied physics from 1967 until 1973 at the Technische Universität München (TUM). In 1977, he received his doctorate for the thesis "Gamma-spectroscopic studies of high-spin states with heavy ion reactions compound and multiple Coulomb excitation" supervised by the nuclear physicist Prof. Paul Kienle (1931 – 2013). He then moved to the new field of neutrino physics. In the 1970s and 1980s he was involved in pioneering neutrino experiments, such as the gallium experiment Gallex (1991 – 1997) and the successor experiment Gallium Neutrino Observatory (GNO) (1998 – 2002) at the Gran Sasso underground laboratory. In 1987, he got his venia legendi at TUM with the habilitation treatise entitled "Search for neutrino masses". In 1991 he was appointed associate professor at the chair of Prof. Rudolf Mößbauer (1929 – 2011), in 1995 he then was appointed full professor as Mößbauer's successor. From 1995 until 2006 Prof. Franz von Feilitzsch was head of the Collaborative Research Centre (SFB) 375 "Astroparticle Physics" funded by the German Research Foundation (DFG). His research interests lie in the fields of neutrino physics and weak interaction, direct search for dark matter, low-temperature physics, detector development and superconductivity. The experiment Borexino (since 2006) in the Gran Sasso underground laboratory, primarily dedicated to the real time measurement of solar neutrinos, is largely due to his initiative, the detector technology being decisively developed by von Feilitzsch. The experiment CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) (since 1999) for the direct search for dark matter is designed to exploit the phenomenon of superconductivity to measure temperature changes in a crystal caused by recoils of potential dark matter particles. The neutrino observatory Lena (Low Energy Neutrino Astronomy), proposed by Prof. Franz von Feilitzsch, is designed to study neutrinos coming from the earth, the sun and from supernovae. In 2009, Prof. Franz von Feilitzsch became professor emeritus at TUM.

New findings on neutrino masses

Inconspicuous, tiny particles deform the large-scale structures of the universe

A systematic study of all massive galaxy clusters in the local universe provides information on the lightest elementary particles: Scientists at the Max Planck Institute for Extraterrestrial Physics conveyed from an X-ray catalogue that the universe of today shows less pronounced structures as would be expected due to the density fluctuations in the early universe, which can be derived from the cosmic microwave background. The discrepancy can be explained if the three neutrino-types together have a mass of about half an electron volts.

We are surrounded by them and they fly right through us, but we don't feel them at all – the neutrinos, the strangest among the known elementary particles. They hardly interact with other matter. Every second, Billions pass right through the earth but only a fraction of them gets stuck. They are left over in large numbers from the Big Bang, about 340 million per cubic metre on average. Together with photons – light particles – they are the most numerous elementary particles in the universe.

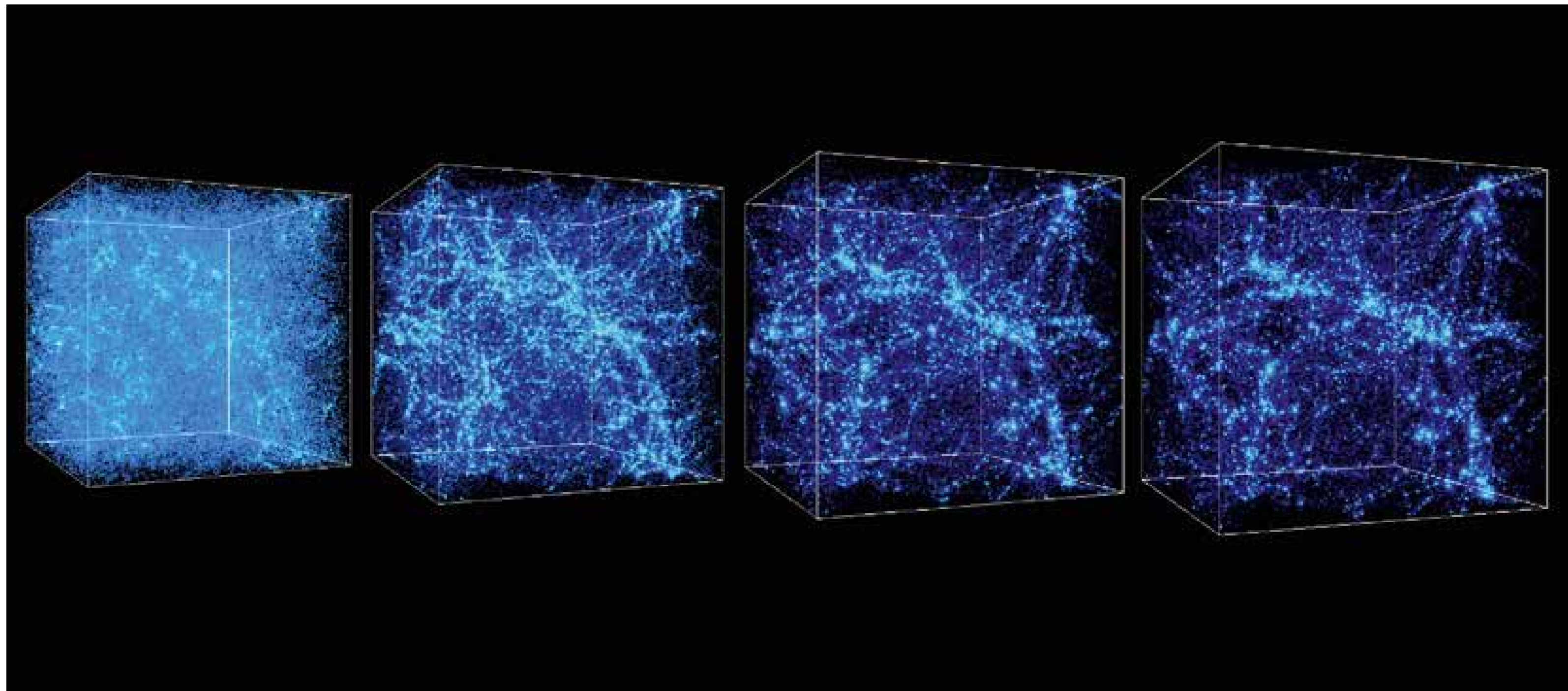
For a long time, neutrinos were thought to be massless. But now we know from observations of solar neutrinos and from terrestrial experiments that they do carry mass. But we still don't know how heavy they are. Nevertheless, due to their large number they contribute significantly to the mass density of the universe even though they are relatively light-weight.

Neutrinos are the fastest massive elementary particles left over from the Big Bang. While most other matter agglomerates due to gravitational forces over cosmic times into the large-scale structures we see today, neutrinos to some extent resist this concentration and clumping and actually hinder the growth of these structures. Their effectiveness depends on their mass: The more massive they are, the more they can impede the clumping of matter.

Astrophysics can take advantage of this damping effect by measuring it in the formation of large-scale structure. A comparison of two observations unveils this effect. On one side, we see the density fluctuations in the early universe at a time about 380,000 years after the Big Bang. This has been observed in the cosmic microwave background by the Planck satellite. With this input data, we can use accepted cosmological models to calculate quite precisely what the structure in the present day universe should look like. This allows us to predict, for example, how many clusters of galaxies with a certain mass should be found per unit volume.

Scientists at the Max Planck Institute for Extraterrestrial Physics in Garching, Prof. Hans Böhringer and Dr. Gayoung Chon, have searched for all massive galaxy clusters in the nearby universe up to a distance of more than three Billion light years. They used X-ray observations with ROSAT and compiled a complete catalogue of these objects. This compilation allows a comparison of the observations with predictions from the cosmological Standard Model.

"Observations and theoretical prediction fit surprisingly well together," asserts



Simulation of the formation of galaxy clusters in the universe: The cubes show the development of large-scale structures in a volume with an edge length of 140 Million light years from an almost uniform distribution of mass in the early universe to the very pronounced current structures.

Hans Böhringer. “But a closer look reveals that the present day structures are less pronounced than predicted – when neglecting the mass of neutrinos.”

Even though the discrepancy is only ten per cent, the precision of measurements has increased dramatically over the past years, so that the scientists take the discrepancy seriously.

Neutrinos seem one Million times lighter than electrons

“We can reconcile observation and theory if we allow for the neutrinos to have mass,” explains Gayoung Chon. “Our analysis indicates that all three neutrino-types together have a mass in the range of 0.17 to 0.73 eV.”

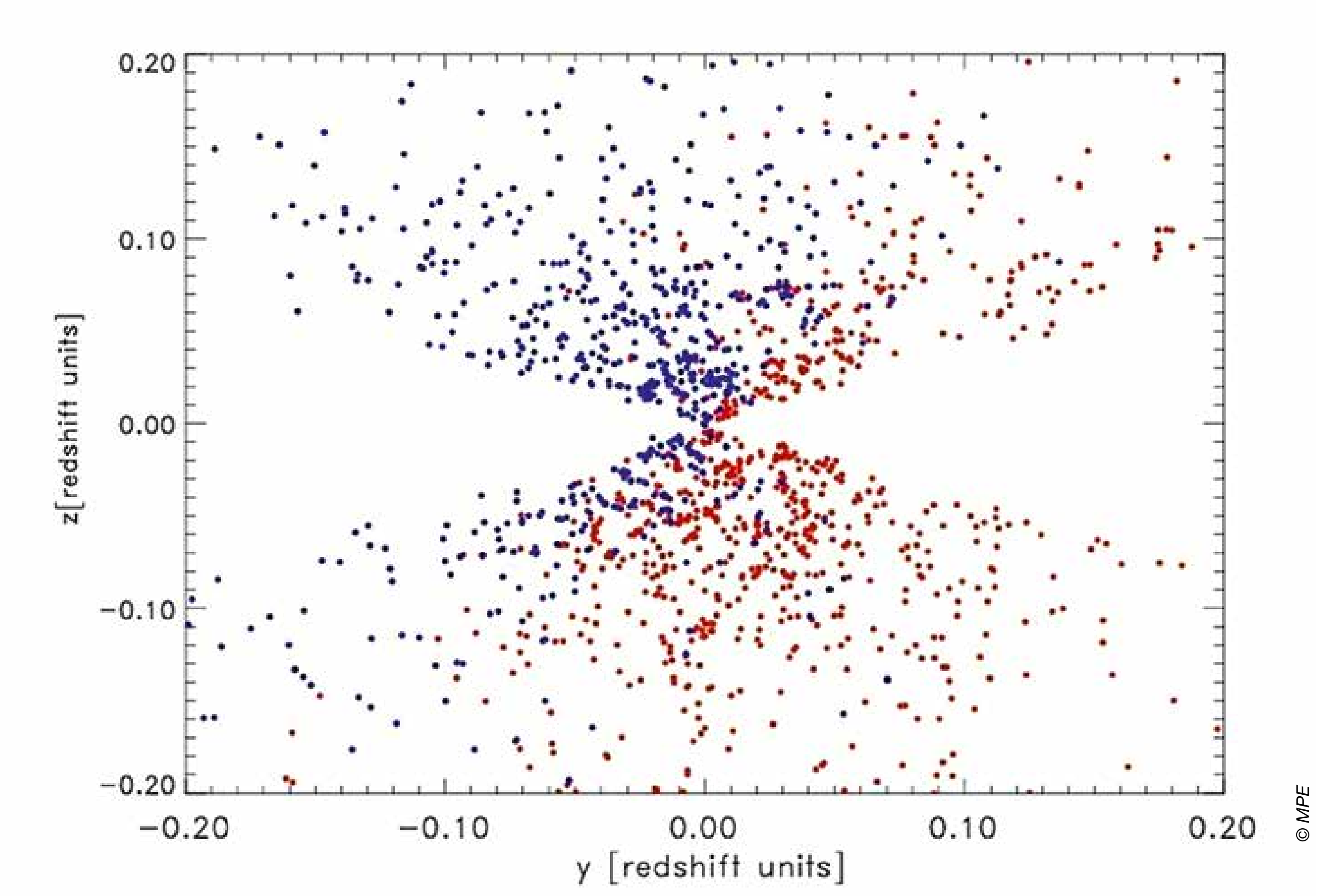
There are three neutrino families, electron, muon and tau neutrino, which can “oscillate”, i.e. change into each other. Many experiments – and also the estimate based on the large-scale structure – can only determine the mass differences or the mass of all three types combined. And this is indeed tiny: about 0.8 x 10^{-36} kg, one Million times lighter than the mass of the electron, the lightest elementary particle in ordinary matter that makes up our body.

Neutrinos therefore contribute only about one to five per cent to dark matter. But even this tiny contribution causes an effect measurable with the current, precise methods. Some other cosmological measurements, such as the study of the gravitational lensing effect of large-scale structures and the peculiar motions of galaxies, suggest a damping in the growth of the large-scale structure amplitude as well.

Other, more exotic effects could also be the cause for such a damping effect, for example the interaction of dark matter and dark energy has been suggested. “Massive neutrinos seem, however, to be the most plausible interpretation of the data at the moment,” says Hans Böhringer, who is also a principal investigator at the Excellence Cluster Universe. “This is very encouraging and we are currently improving our measurements to provide more precise results in the near future.”

The scientists are aiming at even more precise results

This is a fascinating example for how the world is interwoven on the smallest and largest levels. The largest clearly defined objects in the Universe, i.e. galaxy clusters, provide information on the lightest known elementary particles with mass. There are 48 orders of magnitude between the mass scales of the two systems. Astrophysics is providing an important contribution to elementary particle physics.



Projection of the three-dimensional distribution of galaxy clusters detected in X-rays by the ROSAT satellite: The amount of galaxy clusters with a given mass is smaller than predicted by the cosmological Standard Model based on the results from the Planck satellite. The discrepancy can be explained by a neutrino mass of 0.5 eV. (The data are shown in galactic coordinates with the galactic plane in the centre. The gap in the data is due to the “zone-of-avoidance”, an area around the galactic plane where the extinction by the galactic interstellar medium makes observations very difficult. Blue dots are in the northern sky, red dots in the southern sky.)

New result for the polarizability of pions supports Standard Model

Precision measurement for the strong interaction

Nuclear particles called pions contribute significantly to the strong interaction. This force is responsible for binding nuclei together and accounts for most of the mass of the visible matter surrounding us. Now, for the first time, physicists have succeeded in precisely determining the deformability of pions. The result, to which researchers from the Technische Universität München (TUM) contributed considerably, is in close agreement with the theoretical predictions. It also revises earlier measurements that were incompatible with the Standard Model of physics.

Everything we see in the universe is made up of tiny fundamental particles called quarks and leptons. The building blocks of the nuclei of elements, the protons and neutrons, are in turn made up of three quarks. For example, a gold nucleus consists of 79 protons and 118 neutrons. Darting between the protons and neutrons in a nucleus are pions, which mediate the strong force that binds the nucleus together.
These pions comprise a quark and an antiquark, themselves tightly bound by the strong force. The extent to which these two constituents can be removed from each other is a direct measure of the strength of the binding force between them and thus of the strong interaction.

Extremely strong electric field

To measure this deformability of the pions – physicists refer to it as polarizability – the COMPASS experiment shot a beam of pions at a nickel target. As the pions approach the nickel nuclei at an average distance of merely twice the radius of the particles themselves they experience the very strong electric field of the nickel nuclei, which causes them to deform and change their trajectory, emitting a light particle in the process. The researchers determined the polarizability by measuring this photon and the deflection of the pion for a large sample of 63,000 pions.

The tiny effect highlights the pion’s internal force

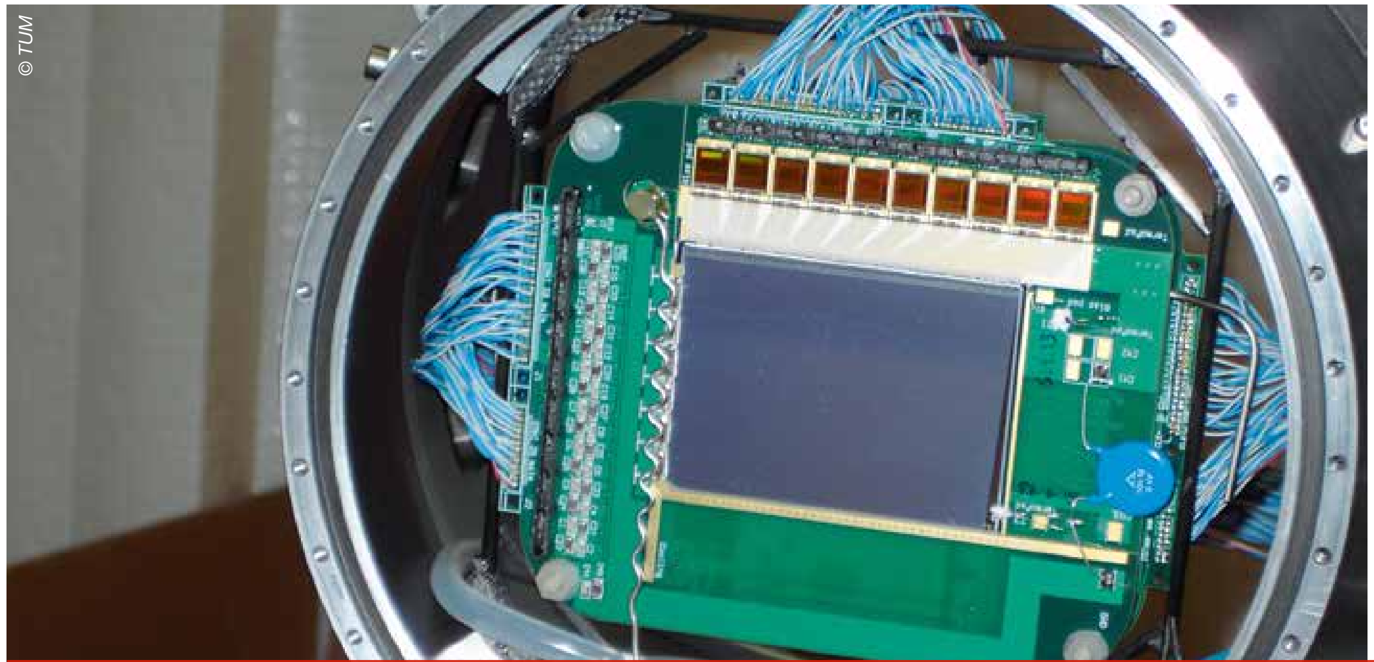
The result shows that a pion is far less deformable than one thousandth of its volume. “The experiment is – despite the high particle energies at CERN – a big challenge,” says Prof, Stephan Paul from the chair E18 of the TUM Physics Department and coordinator of the Excellence Cluster Universe. “The effect of the pion polarizability is tiny, highlighting the internal force of the pion.”

Results correct earlier measurements

The pion’s polarizability has baffled scientists since the 1980s, when first measurements appeared to be at odds with the theory. “The theory of the strong interaction is one of the cornerstones of our understanding of nature at the level of fundamental particles,” says Dr. Jan Friedrich, scientist at the TUM chair E18 and member of the Excellence Cluster Universe, who was in charge of the data analysis in the COMPASS collaboration. “The good agreement of today’s result with the theory is thus of great importance.”

TUM was in charge of the data analysis

COMPASS is standing for Common Muon an Proton Apparatus for Structure and Spectroscopy. The experiment has been running since 2002 at the Super Proton Synchrotron (SPS), the second largest accelerator at CERN. The collaboration includes about 220 physicists from 13 countries. In Germany, the universities in Bielefeld, Bochum, Bonn, Erlangen-Nürnberg, Freiburg, Mainz and Munich are involved as well as the Technische Universität München.



One of the experiment’s four detector modules. The silicon module has been developed at the TUM. It detects about 10,000 particles per second.

Astrophysicists were expecting more plutonium from supernova explosions than they could prove. Shown here is the Circinus galaxy with the supernova SN 1996cr (bottom right), one of the closest supernova events within the last 25 years.

Deep-sea crust contains less particularly heavy elements than previously thought

Unexpected findings on the production of elements

Elements of cosmic origin on the floor of the Pacific Ocean provide new insights into supernova explosions. An international research team with the participation of the Technische Universität München has analysed a deep-sea manganese crust on their content of particularly heavy elements thought to be from supernovae. It was found that the amount is much lower than expected. The researchers therefore assume that the heavy elements found may not be formed in standard supernovae. The study supported by the Excellence Cluster Universe was published in "Nature Communications".

The lifetime of a massive star ends with a supernova. The star explodes and briefly lights up as bright as a whole galaxy. In such an explosion the heavier chemical elements for example silver, tin and iodine are produced and distributed throughout the space between stars. Small amounts of debris from these distant explosions fall on earth as it travels through the galaxy and are eventually deposited on the seabed. Only a few years ago, physicists from the Technische Universität München (TUM) succeeded in detecting the stable iron isotope Fe-60 in deep-sea manganese crusts. The scientists are certain that it originates from supernovae. Now, a team of researchers from the University of Vienna, the TUM, the Australian National University, Canberra, and the Hebrew University, Israel, analysed samples from the seabed on interstellar plutonium and thereby gained a new understanding of the origin of heavy elements.

The researchers investigated deep-sea sediments from the Pacific Ocean, including a 10-inch-thick Ferrum-Manganese-Crust from a depth of 5,000 meters. This 25 Million year old deposit contained, among trace elements from the ocean, elements of interstellar dust, which were determined by a subsequent analysis at the accelerator facility Vera in Vienna. The physicists were in search for an isotope of plutonium, i.e. Pu-244, which does not occur naturally on earth, and, with a half-life of 81 Million years, is an important marker for traces of stellar explosions in recent earth history. Supernova explosions produce lead, gold and mercury. However, these elements are stable and abundant on earth and therefore not suitable as supernova tracers.

"Surprisingly, we found much less plutonium than expected," says Dr. Thomas Faestermann from the TUM, who, just like Dr. Gunther Korschinek, contributed to the new findings. Due to the frequency of supernovae, the scientists had expected much more Pu-244 in the marine sample. On average, there are about one to two supernova explosions per hundred years in our galaxy. However, the samples contained only a very small fraction of the amount of plutonium expected due to the frequency of supernovae.

Rare cosmic explosions as a solution?

The researchers conclude that the plutonium may not be formed in standard supernovae at all. They suggest that it may require more rare and more explosive events such as the merging of two neutron stars to make them.

Exhibition "Evolution of the Universe" at the Deutsches Museum

Everything up to date

After extensive updating measures, the exhibition "Evolution of the Universe" in the Astronomy Department of the Deutsches Museum offers now the latest scientific findings on the exploration of our universe. The exhibition takes visitors on a journey through time that begins 13.7 Billion years ago and ends with a glimpse at the future of the universe. En route, the visitors learn how space, time, matter and the large structures in space have formed. An excursion into today's universe describes the life cycles of stars, the structure and development of galaxies and the roles black holes play in the process.

The exhibition combines findings from astronomy, astrophysics, nuclear and particle physics in order to present the history of the development of the cosmos from different perspectives. The current level of research is clearly depicted using video and visual material.

Fascinating insights

Hands-on experiments show what we can learn from cosmic background radiation, how important dark matter is and why oxygen, iron and gold can be found on earth. The interactive "Sky Radio" is making the invisible universe visible at all wavelengths and provides startling insights into the hot and cold cosmos.

The exhibition at the Deutsches Museum was opened in 2009 – the Year of Astronomy. The exhibition was planned, financed and completed by the following five research institutes in Munich and Garching: the Excellence Cluster Universe, the European Southern Observatory (ESO) and the Max Planck Institutes for Physics (MPP), Extraterrestrial Physics (MPE) and Astrophysics (MPA). Initially conceived as a special exhibition for a period of two years, "Evolution of the Universe" has become a centrepiece of the Astronomy Department at the Deutsches Museum and is visited by around 75,000 visitors per year. In 2014, the exhibition was extensively updated and maintained.

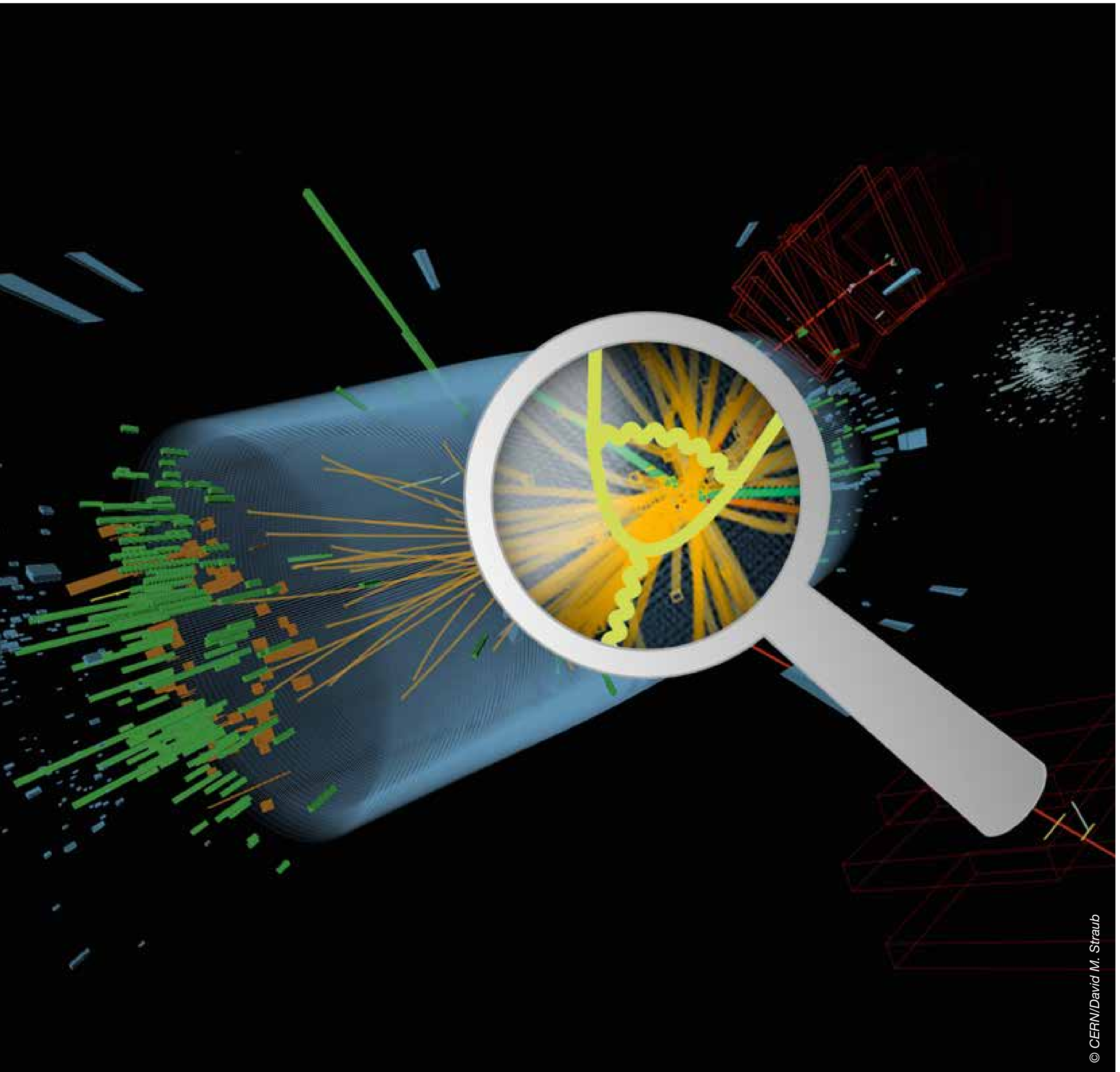
"The need for a thorough update after five years illustrates the great progress physics has made in recent years," says Prof. Andreas Burkert, co-coordinator of the Excellence Cluster Universe from the Ludwig-Maximilians-Universität Munich. "After completion of the work, we can now present new fascinating insights into our cosmos at the Deutsches Museum."

"Evolution of the Universe" at the Deutsches Museum: The exhibition takes visitors on a journey through time that begins 13.7 Billion years ago and ends with a glimpse at the future of the universe.

The junior research group leader Dr. David M. Straub explores the interplay between direct and indirect searches for new physics

Beyond familiar certainties

Dr. David M. Straub is one of those scientists who are investigating physics beyond the Standard Model. The research group leader at the Excellence Cluster Universe is doing research at the interface between theory and experiment, and he is especially interested in B mesons. According to theory, these artificially produced particles are ideal to uncover new physics phenomena. For two years now, particle physicists discuss two unexpected observations. However, it is still unclear whether they really show evidence for new physics.



© CERN/David M. Straub

In search of unknown particles and interactions:
Dr. David M. Straub explores experimental data for evidence of new physics.

The Standard Model of particle physics quite accurately describes almost all observed properties of elementary particles. But a number of phenomena remain without convincing explanation, first of all the matter-antimatter imbalance: Why is it that matter and antimatter were not completely destroyed after the Big Bang, but that a small part of matter was left from which the visible universe is made up? Furthermore, why does the visible matter only amount to 20 per cent of all mass that exists in the universe? And what is the nature of those remaining 80 per cent that is known as dark matter?

In addition, there are some unsolved puzzles around neutrinos (see pages 3 to 8). And finally, there is the problem that the Standard model of particle physics very elegantly unites three fundamental forces of physics, but the fourth, gravity, does not fit into the model at all. These phenomena are starting points for theories and hypotheses – for example, that there are probably more than the four known fundamental forces. Or the assumption, that the Standard Model is only part of a more complete theory like supersymmetry. Or the idea, that the recently discovered Higgs particle is not elementary but composed of other, as yet unidentified particles.

One can see: Theoretical physics is in motion; whereas experimental physicists systematically try to test the predictions that arise from these hypotheses.

At the interface of experiment and theory, Dr. David M. Straub is head of a junior research group exploring the interplay between direct and indirect searches for new physics at the Excellence Cluster Universe. Straub investigates the experimental data for hints of new physics and checks whether they support any of the proposed new theories, or whether they can be explained otherwise. David Straub's main interest is finding new particles and interactions, particularly by exploring B mesons.

These B mesons may be electrically neutral or charged; they are about five and a half times heavier than protons and comprise an unusual combination of anti-quark and quark: a bottom-antiquark, which must have existed at the beginning of the universe, but is no longer existing in the surrounding matter, and an up- , down, strange- or charm quark. B mesons are produced by collisions of electrons with their antiparticles, the positrons, in large particle accelerators. Their lifespan is only one trillionth of a second. Then they decay – and there are hundreds of ways on how they do this. "Because some of these decays are very rare, but most interesting for physicists, we need as many B mesons as possible," says David Straub.

The Standard Model of particle physics predicts exactly how often certain decays should occur. It also makes precise prediction as to the angles in which the decay products should fly away. For two years, a significant deviation from the prediction is under discussion. It was discovered at the LHCb experiment at the Large Hadron Collider (LHC) at CERN, currently the only active experiment in the field of B physics: A certain angular observable in the decay of a B meson into an excited Kaon, a muon and an anti- muon (B -> $K^*\mu^+\mu^-$) differs from what is predicted, reported the LHCb scientists. Could that be a sign of new physics? "Possibly yes," says David Straub, "but it may just as well be an effect not accounted for in the theoretical predictions."

Last year, the LHCb experiment published another exciting observation. Obviously, the decay rates of B mesons into a kaon, muon and anti-muon differ (B -> $K^*\mu^+\mu^-$) from that into a kaon, an electron and a positron (B -> $K^*e^+e^-$). "This is not possible in the Standard Model, where electrons and muons are identical except for their different masses which play no role in this decay," says David Straub. Both decay rates should be equal, but they are not.

"Interestingly, the two anomalies fit very nicely together if interpreted in terms of physics beyond the Standard Model," says Straub. However, it was too early to draw a firm conclusion with the deviant observable being potentially susceptible to poorly known effects and the other observation not being statistically very significant taken on its own.

Therefore, David Straub has been waiting for new results on the deviant angular observable. At the "Rencontres de Moriond" in March 2015 in Italy, one of the most important conferences in high-energy particle physics, the LHCb collaboration presented new data. David Straub had the honour to be one of the theorists to give some first interpretation of the new measurement. His analysis is based on a method he has developed together with his former PhD colleague Wolfgang Altmannshofer.

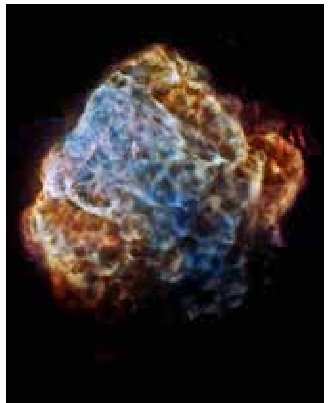
"At the moment, the situation is not yet conclusive," says David Straub. To some extent, a new physics interpretation is preferred over the Standard Model, but it is still possible that the physicists have been deceived by unexpected effects: "Both hypotheses are valid and both can have interesting implications." David Straub expects that more precise measurements will solve the puzzle in the near future. New insights are also expected from the experiment BELLE II at the Japanese KEK accelerator. A number of scientists from the Excellence Cluster Universe are involved in the BELLE II collaboration, too. The detector is to go into operation in 2016. *Petra Riedel*

DR. DAVID M. STRAUB studied physics at the University Stuttgart and at the Technische Universität München and graduated in 2007. In 2010, he received his PhD at the Excellence Cluster Universe with the thesis "Supersymmetry, the flavor puzzle and rare B decays" supervised by Prof. Andrzej Buras. After that, he was a postdoctoral researcher at the Scuola Normale Superiore and the INFN in Pisa, Italy, followed by a postdoc position at the University Mainz. Since 1st October 2013, Dr. David M. Straub is head of the junior research group "Interplay between direct and indirect searches for new physics" at the Excellence Cluster Universe.

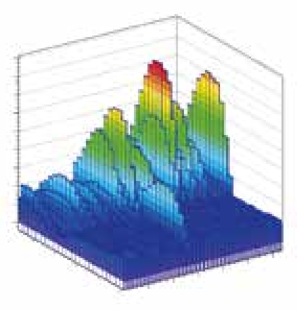
Excellence Cluster Universe awards two experimental PhD theses

Impressive achievements

The PhD Awards 2014 of the Excellence Cluster Universe go to the experimental works of Tobias Prinz and Jonathan Bortfeldt from the Ludwig-Maximilians-Universität. Jonathan Bortfeldt has refined a detector technique used in many particle physics experiments nowadays in such a way that it significantly expands the application range of the detector. The second awardee, Tobias Prinz, has explored the X-ray-emissions of supernova remnants of massive stars, gaining important new insights that generated great international interest.



The object Puppis-A in the constellation Puppis: For the first time, the measurements of Tobias Prinz give clear evidence that Puppis-A is the remnant of a stellar explosion.



Short downtimes and high efficiency: Jonathan Bortfeldt showed that when using a "floating strip" detector, cosmic muon signals are clearly visible even when the detector is irradiated with a high-rate proton beam.

About the work of Tobias Prinz

In his thesis "Exploring the End States of Massive Stars using X-ray emission of neutron stars and supernova remnants", Tobias Prinz investigated the radiation properties of supernova remnants of massive stars in the X-ray-range. The first part of his work is dedicated to the object Puppis-A in the constellation Puppis, one of the brightest spots in the sky when using an X-ray telescope. For the first time, his measurements give clear evidence that the object Puppis-A is a remnant of a stellar explosion. Tobias Prinz was also able to determine the movement speed of Puppis-A with unprecedented accuracy, and subsequently estimated its age. His result differs significantly from the values previously published and shows that Puppis-A moves much slower than previously thought.

Based on the ROSAT all-sky survey and data from XMM-Newton and Chandra, Tobias Prinz could also clearly identify two objects as supernova remnants out of a group of 200 candidates, which he examined in detail. Furthermore, he investigated the X-ray properties of pulsars and discovered a total of 18 pulsars previously not known to emit X-rays.

"Tobias Prinz' results represent a significant contribution to the research of radiation properties of supernova remnants. For his outstanding work Tobias Prinz is awarded the Universe PhD Award 2014," says Prof. Dr. Joachim Trümper.

On Jonathan Bortfeldt's thesis

In his thesis "Development of Floating Strip Micromegas Detectors" Jonathan Bortfeldt presents a new design for a Micromegas detector. These detectors are used in various particle physics experiments, because they accurately measure particle tracks even at very high rates. However, the efficiency of the detector is limited by unavoidable high voltage discharges that cause detector downtimes.

Jonathan Bortfeldt's approach combines the advantages of the traditional approach with the "resistive strip" design that significantly reduces the impact of discharges: Here, the copper strips forming the read-out structure are individually supplied with high voltage, which restricts the effects of discharge to a small area of the detector, reducing the downtime by about two orders of magnitude compared to the conventional design. Jonathan Bortfeldt has developed three types of "floating strip" detectors and has examined and in detail characterized their behaviour under different irradiation scenarios using different types of particles, radiation energies and intensities.

"For his impressive, detailed and extensive work Jonathan Bortfeldt deserves the PhD Award 2014," said laudator Prof. Dr. Konrad Kleinknecht on behalf of the PhD Award Committee at the award ceremony during the Excellence Cluster's Science Week in December 2014.

Scientific & Public Events

Preview

Within the next couple of months, the Excellence Cluster Universe will organize numerous scientific and public events. The highlighted conferences and workshops are primarily addressing experts, teacher trainings are marked with "L", all other events are aimed at the interested public.

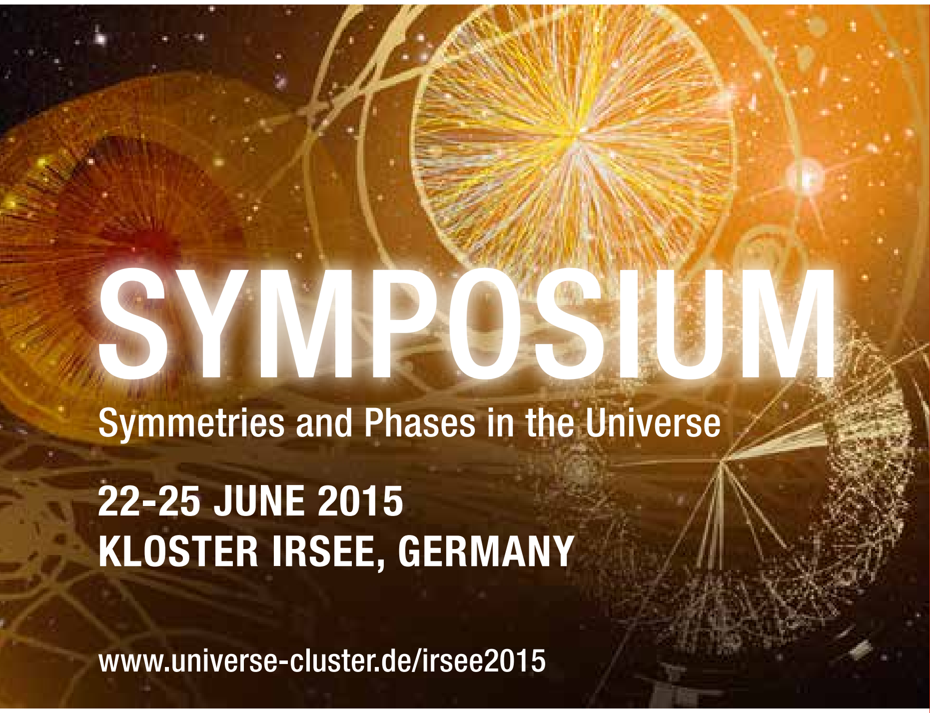
15.04.2015, 16:30	Universe Colloquium followed by wine & cheese Prof. Dragan Huterer (Univ. Michigan): "The quest for primordial non-gaussianity" for more dates see: www.universe-cluster.de	Exzellenzcluster Universe, Boltzmannstr. 2 (seminar room basement), Garching
22.04.2015, 19:00	Café & Kosmos: PD Dr. Klaus Dolag (LMU/MPA): "Galaktische Nebelhaufen – Die Könige im Universums-Zoo"	Muffatcafé, Zellstr. 4, München
04. - 29.05.2015	Munich Institute for Astro- and Particle Physics (MIAPP) Programm II/2015: The new Milky Way	MIAPP, Boltzmannstr. 2, Garching
12.05.2015, 19:00	Café & Kosmos: Peter Ludwig (TUM): "Spuren von Sternexplosionen auf dem Meeresboden" for more dates see: www.cafe-und-kosmos.de	Muffatcafé, Zellstr. 4, München
01. - 03.06.2015	MIAPP III Topical Workshop: Flavour 2015 – New Physics at High Energy and High Precision for registration: www.munich-iapp.de (until 03.05.2015)	MIAPP, Boltzmannstr. 2, Garching
01. - 26.06.2015	MIAPP III: Indirect Searches for New Physics in the LHC and Flavour Precision Era	MIAPP, Boltzmannstr. 2, Garching
16. - 19.06.2015	Workshop: "Let's group: The life cycle of galaxies in their favorite environment" for more information: letsgroup2014.wix.com/workshop	ESO, Karl-Schwarzschild-Str. 2, Garching
22. - 25.06.2015	Irsee Symposium 2015: "Symmetries and Phases in the Universe" www.universe-cluster.de/irsee2015	Kloster Irsee
27.06.2015, 17:00 - 24:00	Science Night www.forschung-garching.de	Garching-Forschungszentrum
29.06. - 03.07.2015 L	Teacher training: Astronomie, Kosmologie & Relativität www.fibs.schule.bayern.de	Lehrerakademie Dillingen
29.06. - 24.07.2015	MIAPP IV: Anticipating 14 TeV – Insights into Matter from the LHC and Beyond	MIAPP, Boltzmannstr. 2, Garching
13. - 15.07.2015	MIAPP IV Topical Workshop: Anticipating Discoveries – LHC14 and Beyond for registration: www.munich-iapp.de (until 13.06.2015)	MIAPP, Boltzmannstr. 2, Garching
27.07. - 21.08.2015	MIAPP V: The Star Formation History of the Universe	MIAPP, Boltzmannstr. 2, Garching
24.08. - 18.09.2015	MIAPP VI: The many Faces of Neutron Stars	MIAPP, Boltzmannstr. 2, Garching

Prof. Dr. Viatcheslav Mukhanov,
professor of physics at the Ludwig-Maximilians-Universität and principal investigator of the Excellence Cluster Universe is awarded the Max Planck Medal 2015 of the German Physical Society (DPG), the DPG's highest distinction for theoretical physics. Thereby, the prize committee recognizes Viatcheslav Mukhanov's fundamental contributions to cosmology and structure formation in the early universe.

Prof. Dr. Rashid Sunyaev,
director at the Max-Planck-Institute for Astrophysics (MPA) and founding member of the Excellence Cluster Universe, receives the Eddington Medal of the Royal Astronomical Society in recognition of his achievements in theoretical astrophysics. Rashid Sunyaev played a key role in exploring the cosmic background radiation, especially in characterizing the Sunyaev-Zeldovich effect that was named after him.

Dr. Martin Jung
is research fellow at the Excellence Cluster Universe since 1st October 2014. Martin Jung studied physics at the University Siegen and received his PhD in 2009 with a thesis in theoretical physics. He then worked as a postdoctoral researcher at the University Valencia, Spain, and at the TU Dortmund. His focus lies on flavour physics, CP violation and the calculation of the neutron's electric dipole moment.

Prof. Dr. Thomas Kuhr
has been appointed professor for the physics of heavy quarks at the TUM starting 1st May 2015. Thomas Kuhr received his PhD in 2002 at the University Hamburg. Since 2005, he was staff scientist at the Institute for Experimental Nuclear Physics at the Karlsruhe KIT, where he qualified as a university lecturer in 2013. Kuhr is founding member of the Belle II collaboration and the experiment's computing coordinator.



IMPRINT

Editors: Petra Riedel, Dr. Andreas Müller, Sabine Kaps

Translations: Petra Riedel, Sabine Kaps

Layout: Sabine Kwauka

Printing: flyeralarm GmbH, Alfred-Nobel-Str. 18, 97080 Würzburg

Subscribe: www.universe-cluster.de/newsletter

Unsubscribe: E-Mail to: presse@universe-cluster.de, text: “ucnews abbestellen”

The newsletter is distributed by the
Exzellenzcluster Universe,
Technische Universität München,
Boltzmannstr. 2, D-85748 Garching,
Tel. +49.89.35831-7100, Fax: +49.89.3299-4002,
E-Mail: info@universe-cluster.de
Web: www.universe-cluster.de

Coordinators: Prof. Dr. Stephan Paul (TUM), Prof. Dr. Andreas Burkert (LMU)

The Excellence Cluster Universe is supported by the German Excellence Initiative.