NEWSLetter
Excellence Cluster Universe

Issue 1 March 2009

Dear Readers,

it came close, but never threatened our planet: On 2 March an asteroid raced past the Earth at a distance of 63.000 kilometers. 2009 DD45, as NASA scientists baptized the projectile, has a diameter from 21 to about 47 meters and travels at a speed of 9 kilometers per second. Asteroids this size can cause substantial damage. In 1908, a similar object is supposed to have devasted 2000 square kilometers breaking 80 million trees in Siberia... From near misses to distant explosions: In this issue we discuss a mechanism how stars heavier than ten solar masses gain enough momentum to burst in a supernova. Further, we will take you from large scales to very small ones: Research on neutrons plays an important role at the Cluster. To examine these particles, a new source for ultracold neutrons is being built. We are happy to announce that the DFG supports this project with 2,7 million euros!

Barbara Wankerl, Public Outreach Coordinator

PICTURE OF THE MONTH

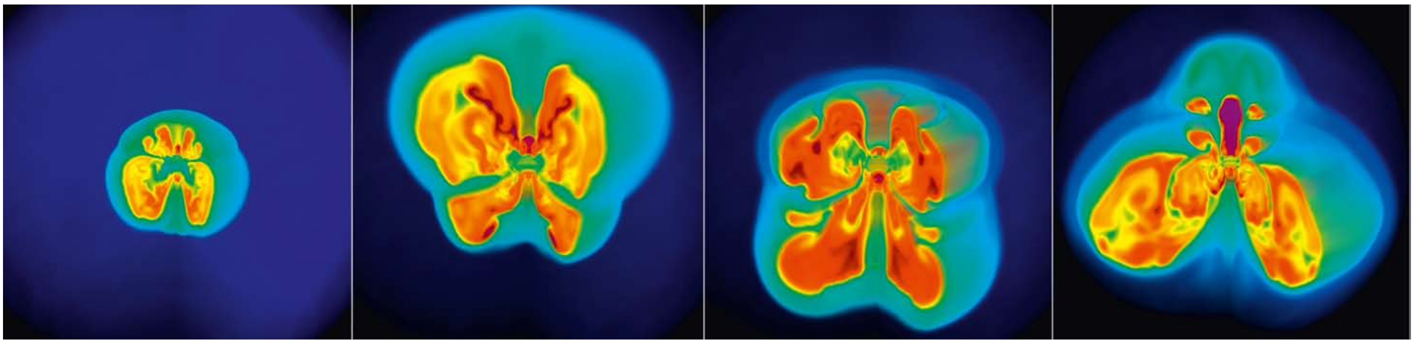
Comet Lulin

It was a quite unexpected visitor near Earth in February: Moving to its closest approach to Earth on 24 February 2009, Lulin has been visible naked-eye in some areas. To all who couldn't catch a glimpse of the comet due to cloudy skies we would like to give a second chance with a picture taken by Joseph Brimacombe.

HIGHLIGHTS

Supernova Explosions Need Second Attempt

Nowadays astrophysicists have quite a clear picture of the processes occurring in supernova explosions. However, for quite some years scientists have been puzzling about exactly how the transport of energy during a "Star Bang" happens. In a current research project scientists from the Excellence Cluster Universe have gained new insight into this question. Close supernovae are rare and hardly ever observed "live". Therefore, Andreas Marek and Hans-Thomas Janka, two researchers from the Max-Planck-Institute for Astrophysics, simulated supernova processes in a computer model. For the first time researchers succeeded in reproducing the interactions of neutrinos and matter within stars of 11 to 15 times the mass of the sun – a project which so far has used up more than ten million hours on several supercomputers. The results will be published in Astrophysical Journal (20 March 2009, v694).



The computer simulation of a supernova shows four snapshots of the explosion of a star with 15 solar masses - after 525, 610, 650 and 700 milliseconds.

Stars are the chemical factories of the universe. In the nucleus of the star, hydrogen atoms fuse to helium under inconceivable pressure and extremely high temperatures. Under suitable conditions the reaction chain continues: In other words, from the fusion of helium atoms, the heavier element carbon is produced, which in turn produces oxygen. Stars of great mass, whose mass is at least eight times the mass of our sun, continue the burning processes in the nucleus to produce even heavier elements; stars with more than ten times the mass of the sun even continue to produce iron. By contrast, the end of heavy stars is disproportionately dramatic compared to their light colleagues – after a lifespan of 100 million years at the most, they end their existence with a tremendous supernova explosion. During a supernova, it is presumed that massive stars at first implode. In their advanced state, stars resemble an onion: In the center there is a firm iron nucleus with surrounding layers containing the lighter elements up to hydrogen. With the production of iron, the burning processes responsible

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for the star's force equilibrium stop: In order to merge iron atoms it would be necessary to apply energy from outside. Thus, the star becomes the victim of gravitation and collapses. During this process, gravity compresses the nucleus more and more until the structure of the iron atoms starts to dissolve: The electrons fuse with the protons and as a result a neutron star and a large amount of neutrinos emerge.

With the star's collapse, the matter of the its outer layers crashes onto the central neutron nucleus. Because of the collision onto the compact nucleus, a shock front is formed and is reflected towards the outer shells of the collapsing star. The neutron star's intensive neutrino flow heats the matter behind the shock wave causing a major expansion. Thus, the outer layers of the star are flung away and the star bursts apart in a gigantic supernova explosion. The final relic is a small neutron star with a diameter of approximately 20 kilometers or in very rare cases a black hole.

As plausible as this model sounds – it only applies to stars with no more than ten times the mass of the sun. In the case of heavier stars the explanation has a flaw: According to computer calculations the neutrino-triggered explosion comes to a halt after approximately 100 kilometers. The reason for this is the dense material within the nucleus that decelerates the neutrinos. Moreover, in the early phase of the supernova, debris from the outer layer falls into the center and interferes with the dispersion of the shock wave. However, observations of supernovae and supernova-relics show that the shock front at a radius of 100 million kilometers finally reaches the surface of the star to demolish the star's outer layer. Therefore, it becomes clear that the explosion needs a second attempt. But what happens and what generates the necessary energy?

With their simulations of stars with 11 to 15 times the mass of the sun, scientists confirmed an assumption that had been discussed in the literature for quite a while. The simulation suggested that even the explosion of such massive stars could be powered by neutrinos. However, in contrast to smaller stars, for massive stars the crucial impetus is given by hydrodynamic instabilities. The star's layers, heated by neutrinos, are swirled by convective currents, similar to porridge boiling in a pot. During this process, the matter develops mushroom-shaped bubbles, in which hot plasma arises. However, the decisive trigger is a phenomenon called "Standing Accretion Shock Instability" (SASI) that was not taken into consideration in earlier models. This phenomenon causes the shock front to oscillate in growing amplitudes and to "bulge" more and more. Thus, the shock wave will be pushed to higher distances and the convection will increase. Consequently, a third effect applies: in the SASI model, the matter is exposed to the high energy neutrinos much longer allowing for a clearly higher transfer of energy.

"Our tests on two-dimensional computer models represent an important step forward in understanding how stars of a high mass, from ten times the mass of the sun, explode", explains Hans-Thomas Janka. "Maybe there are still other phenomena which intensify the explosion caused by neutrinos and hydrodynamic instabilities. A group of competitors claim, for example, that SASI could cause great pulsation and oscillation of the young neutron star, which then would generate sound waves like a bell. The energy of these sound waves could also contribute towards getting the explosion started. For this reason, in the future we will be concentrating on combined effect mechanisms in our simulation calculations".

Pictures and movies: *www.universe-cluster.de/press/images*
www.rzg.mpg.de/visualisation/scientificdata/rzgprojects/type-ii-supernova-simulations

The DFG Approves a Total of 2.7 Million Euros for Neutron Research in Garching

The German Research Foundation (DFG) has accepted another application for the construction of an ultracold neutron source at the Research Center Garching – a project that the Excellence Cluster Universe provides significant support to.

With a sum of 1.5 million euros, the DFG is sponsoring an apparatus for the liquefaction of helium. This liquid gas serves to generate frozen heavy hydrogen (deuterium) close to the reactor core. This enables the neutrons, which are also produced in the research reactor, to be cooled to very low energies of approx. 100 nanoelectron volts. The particles then move at a velocity of only approx. 20 kilometers per hour, so that scientists can use them for experiments – for example, in order to determine their lifetime. This value plays a central role in the examination of how the first chemical elements in the universe originated. With the current promised sum, the DFG is providing funding for experiments on ultracold neutrons for the second time within only a few months. In October 2008, the research foundation approved 1.2 million euros for the assembly of a superconducting magnetic field arrangement.

Building of the experiment for the electric dipole moment in the neutron

The production start of the ultracold neutron source in the research reactor is planned for 2011. The Garching Research Center will then house one of the world's most modern and effective production plants for these particles. The ultracold neutrons will also be used in other neutron experiments: One example is the measurement of the electric dipolmoment of the neutron. This electric charge distribution could also shed light on the symmetry breaking of matter and antimatter in the young universe. The research project is currently being realized in an international collaboration with participation of the TUM.

Mikhail Revnivtsev Receives Russian Federation President Prize in Science and Innovation

Dr. Mikhail Revnivtsev was among the awardees of a Russian Science and Innovation prize awarded for the first time. The laureates received their awards from Russia's President Dmitry Medvedev in a ceremony in the Kremlin on 9 February 2009. The prize was given to four young scientists for their outstanding results in science and technology. The awardees were endowed with a grant of approx. 70,000 US-Dollars each. Revnivtsev has been a research fellow with the Universe Cluster since August 2008. He is engaged in studying black holes and galaxy clusters, his research focusing on the origin of the galactic ridge X-ray emission, being an essential parameter for the energy of stellar and non-stellar components of our galaxy, the Milky Way.

MIXED

Showtime: the Universe Cluster Video

The Deutsche Forschungsgemeinschaft (DFG) has recently started a new website on the Excellence Initiative. The website *www.exzellenz-initiative.de* provides a video area where Germany's Excellence Clusters and Graduate Schools are shown "in action". With the film "Findings from Infinity" the Universe Cluster is one of the first projects presented in the video portal. The film is available in both German and English language.

English film: *www.excellence-initiative.com/muenchen-universe*
German film: *www.exzellenz-initiative.de/muenchen-universe*

Relaunch of www.universe-cluster.de

Merging proven functionalities with a new layout and an easy-to-manage backend – that was the goal of the relaunch of the Universe Cluster's website. Since end of January 2009 the new website has been public, providing better possibilities to present the Cluster's activities and make more contents available. For example, visitors can now view all newsletters in pdf format and register online. Another major change is the integration of a search machine for German language public talks (see next article) as well as a much more detailed sections on our institution. The project was carried through by the Munich based web agency "state of mind" that had to face the special challenge to contact legacy mysql-databases for user, jobs and publication administration to the content management system Typo3. Of course, the new website is a dynamic project that will constantly be enhanced and improved. Check it out - we're looking forward to your feedback to *info@universe-cluster.de*.

Start of Search Engine for Astronomy Topics – Over 150 Lectures for Schools, Planetariums and Museums

The Excellence Cluster Universe and the German Astronomical Society have started a new service directed at schools, planetariums, public observatories and museums: a lecture pool for astronomy topics, where over 150 lectures are listed and indexed. On the website *www.universe-cluster.de*, schools and other institutions can find suitable lecture topics by means of search words and contact the respective speakers directly and arrange a date for the talk. The search machine serves a wide variety of different questions – from the history of astronomy, the origin of galaxies, stars and planets to the development of the universe. The reason for the extension of this former database is the International Year of Astronomy 2009, in which 140 countries are participating altogether. The initiators succeeded in attracting renowned astronomers and astrophysicists for the lecture pool, who are involved in sparking the public interest for their fascinating and lively research. In simple and comprehensible lectures they explain how they explore the universe with all its unsolved questions and learn how to better understand it.

Experts and lectures at: *www.universe-cluster.de/schools/vortrags-pool*

PEOPLE

Maximo Ave Pernas is New Research Fellow at the Universe Cluster

Maximo Ave Pernas

The Excellence Cluster Universe welcomes a new Research Fellow. Maximo Ave Pernas has recently joined the Garching research community. Before, he spent six years at the University of Chicago, working for the Kavli Institute for Cosmological Physics. In his research career Ave Pernas specialized in the field of cosmic rays, studying the phenomenon with both experimental and theoretical approaches. His research works included balloon experiments as well as cosmic ray phenomenology. He was also actively involved in the building of the Pierre Auger Observatory designed to explore the high-energy end of the cosmic ray spectrum. He served the project in both the engineer phase as well as in calibration works and data analysis. At the Excellence Cluster Universe the expert in high energy astrophysics plans to expand his research to the early time of the Universe and its evolution.

Ave Pernas gained his PhD degree at the University of Santiago de Compostela, Spain. After that he was a PRARC fellow at the University of Leeds, England, focusing on the chemical composition of the Cosmic Rays with energies above 10^{17} eV.

Welcome to the Cluster!

Junior Research Group Leader: Prof. Dr. Stefan Hofmann (JRG Particle Physics and the Early Universe)

Guests: Dr. Shinya Wanajo (University of Tokyo, Japan, 07 March 2009 - 28 February 2011) ++ Dr. Martin Stringer (University of Durham, UK, 01 February - 01 April 2009) ++ Dr. Dmitry Ryabchikov (IHEP, Russia, 15 February - 29 May 2009) ++ Prof. Jeremiah Ostriker (Princeton University, USA, 09 May - 15 May 2009) ++ Arunima Banerjee (Indian Institute of Science, India, 01 May - 25 May 2009) ++ Dr. Richard Battye (Jodrell Bank Centre for Astrophysics, UK, 02 April- 07 April 2009) ++ Prof. Dr. Kenji Fukushima (Yukawa Institute, Japan, 04 April - 18 April 2009) ++ Dr. Giulia Ricciardi (Dipartimento die Scienze Fisiche, Italy, 01 May, 30 June 2009)

Postdocs: Dr. Lorant Csige (since 1 March 2009) ++ Dr. Ralf Köhler (since 1 February 2009)


Virginia Corless

Interview with Virginia Corless, new Post Doc in the Group "Theoretical Astrophysics"

Virginia Corless came to work with the Universe Cluster a couple of weeks ago. As a postdoc, she will primarily work in the field dark matter, investigating galaxy clusters. She obtained her PhD in astrophysics from the Institute of Astronomy at the University of Cambridge, UK. Virginia Corless has garnered several renowned research prizes in both the USA and Great Britain, including the Marshall Scholarship awarded by the UK parliament.

What is your research about?

Over the last fifteen years, astronomers have discovered that the myriad galaxies and stars that fill the night sky are little more than decoration. Instead, the Universe seems to absolutely full of dark matter, an unknown substance that appears to make up more than 90% of the mass of the Universe. It is called dark because it is fundamentally invisible: while it feels and creates gravity just like the normal matter that makes up the Earth and stars and human bodies, it cannot emit or absorb light. My research seeks to understand what dark matter is by studying the structures that it forms.

How do you do that?

I investigate galaxy clusters – huge structures that consist of thousands of galaxies. They are full of dark matter and therefore ideal natural laboratories in which to study its properties. However, we cannot look for dark matter directly and have to find other ways to observe it. One of the tools nature gives us is called gravitational lensing, which is an optical phenomenon predicted by Einstein's general relativity. It simply means that objects that have gravity can bend the light of other objects behind it. This means that the gravity of very large astronomical objects (such as galaxy clusters) magnifies and distorts images of other objects in space, and those distortions can be measured here on Earth. From those measurements, the mass that generates the gravity that bends the light can be mapped and measured. Thus dark matter, which has mass but no light, is revealed.

And does it work?

Yes, but we have to find ways to obtain more precise results. So far scientists have assumed galaxy clusters are perfectly round, like a football. However, we now know that the clusters are not shaped this way; instead some of them look more like a rugby ball or a pancake. Of course this affects the gravitational lensing from the cluster and and thus also our understanding of the nature of dark matter derived from those lens effects. Therefore, we develop computer models that imitate the distortion of light depending on the shape of a galaxy cluster. Then we can match our observations of the real Universe with the computer simulations and better understand how dark matter behaves, and thus what it really is.

Being an astrophysicist is not your only passion – you're also active as an actor and director in theater productions.

Yes, for as long as I've loved science, I've also loved the theater. I think a play is a unique and rich way to explore what science teaches us about the world we live in. Theater is a very emotional and visceral form of communication – and it depends on the collective imagination of the performers and audience to create its stories. And in a way this is true for science as well: the whole community of scientists works together to build a shared vision of the incredibly complex Universe we live in. Both science and theater seek to understand the world we live in – often from very different perspectives. But bringing them together can be very exciting, and perhaps offer new ways of understanding our Universe and our place in it.

Can you tell us about a project you did?

I directed the play "Dulcitius" written by a Saxon nun named Hrotsvitha of Gandersheim in the 10th century. It is a tale of buffoonish Roman soldiers battling the frightening conviction of three girls determined to be Christian martyrs. This production fused the original play with modern texts – including scientific works – to illuminate and explore its central themes, one of them being "miracles". From the sublime to the mundane, modern to ancient, science to religion – the play showed how much – and how little – has changed over the past one thousand years.

So do you think we should install a stage on the Garching campus – for your next projects?

That would be wonderful! But whether on a Garching stage or no, I'm looking forward to starting new projects here in Munich. I'm looking forward to shedding more light on the mysterious dark matter through research collaborations within the exciting scientific community in Garching, and to continuing to explore the interplay of science and theater as they both seek to understand the beautiful and overwhelming Universe we live in – and our place in it.

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

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