MUNICH INSTITUTE FOR ASTRO- AND PARTICLE PHYSICS

2014 - 2015

TUM
LMU
Excellence Cluster
Universe

MIAPP
Munich Institute for
Astro- and Particle Physics

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2014 - 2015

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Directors’ Foreword

The Munich Institute for Astro- and Particle Physics (MIAPP) provides a meeting place for physicists from all over the world. Founded in 2012, MIAPP is now one of the rare places worldwide where physicists can meet away from their turbulent daily lives and commitments, and work together on well-defined topics in their field of expertise.

Its parent institution, the Excellence Cluster “Origin and Structure of the Universe”, existing since 2006, has become one of the largest and most dynamic centres focussing on fundamental questions related to the laws of Nature at the smallest distances and to the dynamics of the Universe at large. The cluster itself links scientists from the local partner institutions, the Technical University of Munich and the Ludwig-Maximilians-University Munich, the Max Planck Institutes for Physics, Astrophysics and Extraterrestrial Physics, and the European Southern Observatory. Already the successful first funding period of the cluster demonstrated the large overlap in scientific interests and goals of astrophysicists, nuclear and particle physicists, astronomers and cosmologists. The foundation of MIAPP was driven by the idea to enhance and further increase their interaction and to promote exchange with international researchers.

With this centre embedded in the vicinity of the Technical University of Munich and the Max Planck institutes of Garching and ESO, the Universe Cluster offers a space that allows scientists from abroad, Germany and from local physics institutions to interact and collaborate and to strengthen their network in an inspiring and informal environment. In this spirit participants are asked to stay at MIAPP for at least two weeks, and are housed in a dedicated building offering office space as well as plenty of space for discussions and interaction.

Not only established scientists get a chance to meet and work at MIAPP, also young researchers like PhD students and postdocs are welcome. We hope that their stay at MIAPP enforces their scientific network and helps them substantially in their career. The cutting edge topics are selected among suggestions from scientists from around the world. We are especially grateful for the time and effort our scientific advisory board members and the programme committee invest in choosing the topics and in improving MIAPP. The generous funding by the Deutsche Forschungsgemeinschaft through the excellence initiative allows us to financially support participants from abroad.

Through their extended visits the programme participants bond with physics in Munich and Garching. Thus MIAPP largely contributes to the good reputation the local institutes enjoy in the scientific community and increases Munich’s reputation and visibility in the scientific world. We hope that the following report can convey the dedication of the participants and staff to their science and MIAPP. We are overwhelmed and honoured by our colleagues’ interest to coordinate scientific programmes at MIAPP and look forward to an exciting series of topics in the coming years.

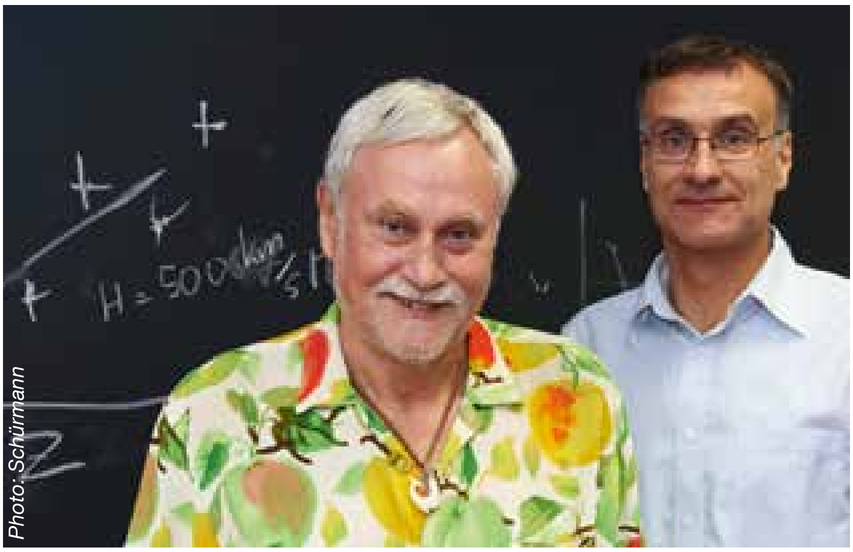


Photo: Schürmann

M. Beneke
Prof. Martin Beneke

R. P. Kudritzki
Prof. Rolf Kudritzki
(MIAPP Directors)

Physics beyond the known – promoting out-of-the-box thinking and networking at MIAPP

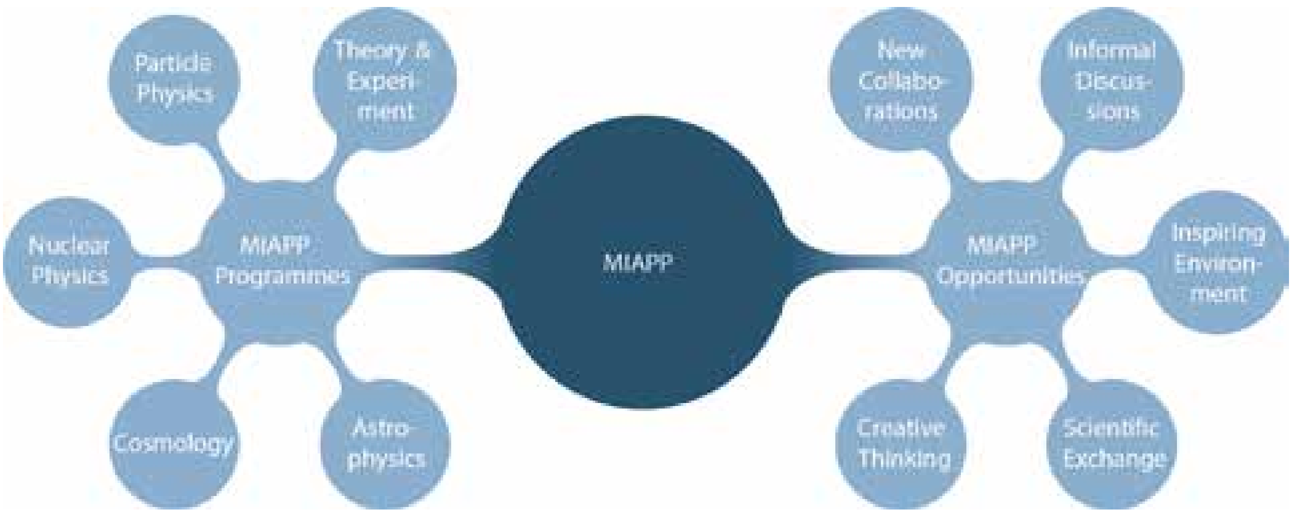
What drives the accelerated expansion of the Universe? How do you find new particles and fundamental laws of Nature in the debris of the highest-energetic particle collisions on Earth? What goes on in the interior of a neutron star? Are the mysterious neutrinos their own anti-particles?

It takes an ingenious idea, a concentrated mind unperturbed by administrative duties, and a critical colleague to talk to, to hopefully answer these questions. At MIAPP we try our best to provide a stimulating and comfortable environment for researchers in order to push the science and scientific exchange in nuclear and particle physics, astrophysics and cosmology. Since its foundation in 2012, MIAPP has become the meeting place of top physicists from around the world. Embedded in the academic environment of the physics departments of both Munich universities, the local Max Planck institutes and the European Southern Observatory (ESO), MIAPP is the ideal place to realise new ideas and to gather momentum for new developments in physics.

During the four-week programmes, local and international scientists have the opportunity to exchange and foster new ideas and projects and to open new horizons. Ideally, with only 1-2 talks per day (or even less), the participants have plenty of time for science. MIAPP thus creates a "creative bubble" in the busy everyday life of today's physicists. Here they can refrain from teaching and administrative obligations. The designated MIAPP building offers the comfort for individual work in the well-equipped offices, interaction and cooperation in small groups as well as bigger meeting areas for seminars and talks. White and black boards everywhere enable lively discussions at any time. Thus, the scientists can let their ideas flow and discuss them with their colleagues. In contrast to an ordinary conference, at MIAPP they have time to discuss and work on unsolved problems.

At MIAPP a small staff, in cooperation with the administration of the Excellence Cluster "Origin and Structure of the Universe", works behind the scenes to make this happen, and is rewarded by the enthusiasm of the participants. We look forward to another year of fruitful discussions and collaboration and hope that attendees will profit as much as possible from their stay in Garching.

Dr. Ina Haneburger
(MIAPP Programme Manager)



At MIAPP scientists from different fields of expertise benefit from the manifold opportunities offered.
Graphics: MIAPP

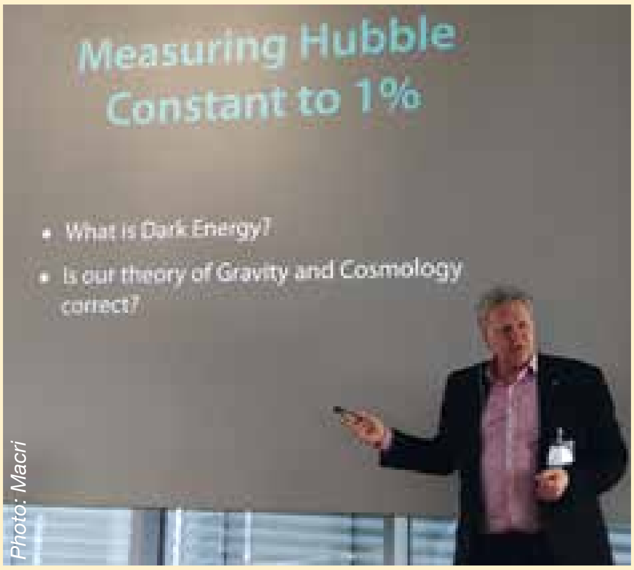
Photo: Macri

Start-up and Inauguration of MIAPP

Following the approval of the second funding period of the Excellence Cluster "Origin and Structure of the Universe" in 2012 including the Munich Institute for Astro- and Particle Physics as one of its main new initiatives, the designated directors and the cluster team set to work on making MIAPP reality.

After recruiting administrative staff, it soon became clear that the envisioned new building would not be in place. A suitable alternative was found with the building adjacent to the cluster building. To fulfil all prerequisites the MIAPP building had to undergo severe reconstruction. Walls were torn down and newly built and the infrastructure was designed to meet the needs of an environment that allowed both, communication and concentrated work of the guest scientists. Along with the infrastructure the exact modus of operation of the MIAPP programmes had to be figured out. The terms for proposal submission and selection had to be elaborated before the first programme could start in May 2014. The call for proposals went out to the scientific world already in summer 2012, and in December of the same year an international Programme Committee met in Garching for the first time to select the programmes for 2014.

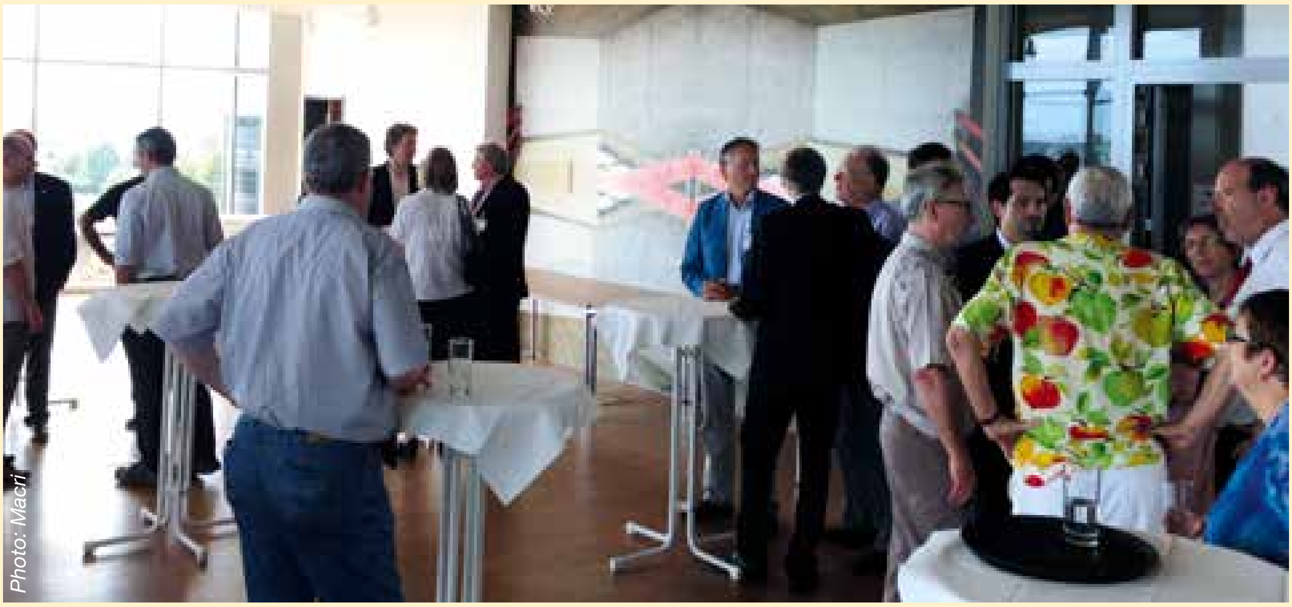
On June 11th, 2014 the official inauguration ceremony of the Munich Institute for Astro- and Particle Physics took place at the Institute of Advanced Studies on the TUM Garching campus. In walking distance from the MIAPP building, well over the roof tops of Garching, the faculty club of the Institute of Advanced Studies was the ideal place to introduce the new concept for scientific programmes brought to Munich by MIAPP and the Excellence Cluster "Universe". Leaders of the Munich universities, represent-



atives of the Bavarian Ministry for Research, friends of the Excellence Cluster, scientists of the Munich/ Garching community and the first programme participants joined the inauguration event. After welcome addresses by the Vice Presidents of the two Munich universities, Prof. Dr. Thomas Hofmann and Prof. Dr. Barbara Conradt, by the DFG Programme Director, Dr. Klaus Wehrberger, Stephan Paul (Cluster Spokesperson) and Martin Beneke (MIAPP Director) introduced the concept of MIAPP and its far reaching future perspectives.

The scientific highlight of the afternoon was the presentation by Nobel Laureate Brian Schmidt, one of the participants in the first MIAPP programme. In his talk he illustrated the arduous path of refining the precision of the Hubble constant and its impact on the current understanding of the Universe. Afterwards, all guests were invited to get together and discuss at a glass of wine and appetisers. The event with its pleasant atmosphere was the ideal opportunity to celebrate the successful start of MIAPP, to increase its local visibility and to draw attention to the large potential for the Munich/Garching science community.

To further spread the word of MIAPP a press conference was organised at the inauguration. In consequence local media but also newspapers from Berlin, Frankfurt and Switzerland as well as internet media reported on MIAPP.



Press Review

Tagesspiegel 11 June 2014
"Wachsendes Weltall"
Expanding Universe

Neue Züricher Zeitung 12 June 2014
"Wie Astrophysiker versuchen,
die Hubble-Konstante zu bändigen."
How astro-physicists try to tame
the Hubble constant

Süddeutsche Zeitung 13 June 2014
"Nobelpreisträger zu Gast"
A Visit of a Nobel Laureate

Forum – die lokale Wochenzeitung
13 June 2014
"Galaktisch gute Gesprächsatmosphäre"
A galactic conversation atmosphere

Interstellarum August 2014
"Das MIAPP: Interview mit Rolf-Peter Kudritzki"
MIAPP: Interview with Rolf-Peter Kudritzki

"Die Expansion des Universums; Interview mit
Nobelpreisträger Brian Schmidt"
The expansion of the Universe: Interview with
Nobel Laureate Brian Schmidt

CERN COURIER 19 August 2013
"New institute hosts programmes in astro- and particle-physics"

Radio – BR2: IQ – Wissenschaft und Forschung
13 June 2014
"Dunkle Energie – Suche nach einer unsichtbaren Kraft im Universum"
Dark Energy – Quest for an invisible force in the Universe

pro-physik.de 16 June 2014
"München lädt zum Forschen ein"
Munich invites to research

astronews.com 24 June 2014
"Impulse durch regelmäßige Expertentreffen"
New impulses by regular meetings of experts

Physik Journal Issue 12/2013
"Neues Gastforscherzentrum eröffnet"
Opening of a novel visiting center for scientists

Universe News Issue 1/2013
"New Science Centre for Astro- and Particle Physics"

NZZ.CH – Neue Züricher Zeitung; 12.06.2014
Süddeutsche Zeitung; Nr. 134, 13.06.2014; Sebastian Krass
http://cerncourier.com/cws/article/cern/54389; 01.08.2016
Newsletter Universe Cluster 1/2013
Quelle: http://www.oculum.de/interstellarum/video.asp?video=22, 29.7.2016

Finding a suitable and highly precise measure to determine distances to galaxies is prime to constrain physical properties of the Universe and to precisely determine its age. The participants in the first programme met at MIAPP in order to clear the path for this precision determination. *Collage: MIAPP; eso1107c: ESO and Digitized Sky Survey 2. Acknowledgement: Davide De Martin; measure: D Sharon Pruitt*

26th May - 20th June 2014

The Extragalactic Distance Scale

53 of the world's leading astronomers joined the first MIAPP programme "The Extragalactic Distance Scale", among them Adam G. Riess and Brian P. Schmidt, 2011 Nobel Laureates in Physics. The central theme of the programme, the extragalactic distance scale, always was and still is one of the most fundamental questions in astrophysics. The accurate determination of extragalactic distances enables physicists to improve their predictions about the evolution of the Universe and to relate their findings to a common basis.

COORDINATORS: LUCAS MACRI, WOLFGANG GIEREN, WOLFGANG HILLEBRANDT, ROLF-PETER KUDRITZKI

The night sky reveals billions of stars and galaxies, each of them shining at a different brightness. In order to be able to distinguish between a closer but not so bright object and a more distant but brighter object a suitable measurement is needed. This becomes especially challenging if the observed celestial bodies are extragalactic objects located at large distances outside our own galaxy. From such distant objects astronomers have detected already some hundred years ago that the Universe is expanding. The farther away a galaxy, the faster is the velocity with which it moves away from us. The expansion rate of the nearby Universe is characterised by the Hubble constant H_0, which relates distance to expansion velocity. It is also a measure for the age of the Universe. The Hubble constant is a fundamental parameter to constrain the physical properties of the Universe. Its value was first estimated by Paul Edwin Hubble in the 1920s. Since then it was heavily debated and the range of uncertainty was for a long time a factor of two. Only after the launch of the Hubble Space Telescope has it been possible to determine H_0 with an accuracy of about ten percent. However, for the physical understanding of the recently detected accelerated expansion of the Universe and the nature of the dark energy responsible for the acceleration, a measurement of H_0 with much higher precision of the order of one percent is needed.

Extragalactic distance measurements were therefore in the focus of the very first MIAPP programme. After two years of planning and preparation the programme was launched on 26th May 2014 with a welcome address by MIAPP Director Rolf-Peter Kudritzki. The programme, coordinated by four of the world leading experts in the

The spiral galaxy NGC 4921, a member of the Coma cluster of galaxies is currently estimated to be about 300 million light years away. Key stellar distance markers, known as Cepheid variable stars, were discovered with the Hubble Space Telescope within NGC 4921 and will be used for a better distance determination to one of the largest nearby clusters in the local Universe. *Photo: Hubble Legacy Archive, ESA, NASA*

field, Lucas Macri (A & M University, Texas, USA), Wolfgang Gieren (Universidad de Concepción, Chile), Wolfgang Hillebrandt (MPA) and Rolf-Peter Kudritzki (LMU and University of Hawaii), started with a first highlight: the opening lecture of Adam G. Riess, 2011 Nobel Laureate in Physics from the Space Telescope Science Institute, Baltimore, USA. After a lively discussion, a first lunch together and the

“Great experience for me. Format appeared just right and the quality of the participants was excellent.”

(Prof. Bruno Leibundgut, ESO, Germany)

allocation of office space, the scientists met again in the afternoon to listen to a second, equally high-profile lecture by Eiichiro Komatsu, director of the Max Planck Institute for Astrophysics (MPA) and a leading expert in the analysis of the cosmic microwave background radiation.

In the following four weeks, astrophysicists using different methods to determine the extragalactic distance scale discussed current research activities and prospects for a 1% determination of H_0 within ten years. Among them Brian P. Schmidt, 2011 Nobel Laureate in Physics from the Australian National University, who also gave the lecture at the official MIAPP dedication on 11th June 2014. It was intensively debated how present uncertainties in the cosmological model, like the nature of dark energy, the properties of neutrinos and the scale of departures from flat geometry, can be constrained by measurements of the Hubble constant at higher precision than was possible with the first generations of Hubble telescope instruments. Distance indicators such as classical cepheids and type Ia supernovae, are among the most precise standard candles and have enabled a calibration of the Hubble constant that is precise to about 3%. They play a starring role

THE EXTRAGALACTIC DISTANCE SCALE

107 registrations

54 participants
from 27 institutions
in 12 different countries

academic seniority:
37 faculty/staff
12 postdocs
5 PhDs

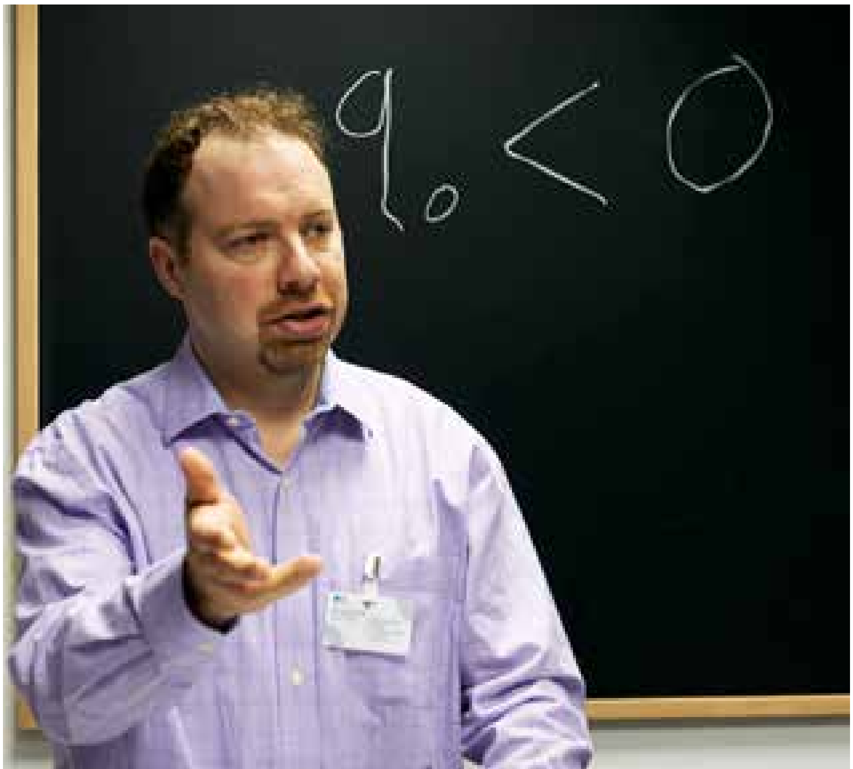
duration of stay:

in attempts to measure the scale and age of the Universe, to trace its expansion history, and to understand the dark energy that drives its current acceleration. However, tension between methodically different measurements of the Hubble constant suggests that systematic effects may be biasing our cosmic yardsticks. Diverse factors exist that limit the distance precision and accuracy (and thus, the cosmological inferences). New alternative methods to determine the Hubble constant are required, which in comparison with well-established methods allow for independent assessments of possible systematic uncertainties. With this in mind the scientists discussed the absolute calibration of primary and secondary distance indicators, like cepheid and RR Lyrae variable stars, red giant and blue supergiant stars, supernovae, galaxy surface brightness fluctuations, the Tully-Fisher relation and the fundamental plane of galaxies. Alternative routes to H_0, such as baryon acoustic oscillations, gravitational lens time-delay measurements of active galactic nuclei, and the radio megamaser emission of galaxies in the Hubble flow were broached. The signature of baryon acoustic oscillations (BAO) imprinted in the clustering of galaxies offers a robust standard ruler that can be used to measure the cosmological distance-redshift relation, probing in this way the expansion history of the Universe. Cosmographic inference from gravitational lens time-delay measurements is comple-

The relaxed atmosphere at MIAPP allows the participants to interact instead of rushing around from talk to talk. *Photo: Macri*

"It is wonderful to have such a group of excellent researchers together in an environment as provided by the MIAPP, for a time of several weeks which greatly helps to build up an atmosphere which leads to deep and fruitful discussions, and new ideas and collaborations. A truly GREAT experience!"

(Prof. Wolfgang Gieren, University of Concepción, Chile)



Nobel Laureate Prof. Adam G. Riess discussing the expansion of the Universe. *Photo: Schürmann* mentary to precision measurements of the cosmic microwave background, which cannot measure the Hubble constant directly. New and very refined analyses of time-delays have yielded first results on the Hubble constant and dark energy equation of state. Analyses of the spatially resolved motion of radio megamasers orbiting the central black holes of galaxies allow the determination of purely geometric distances and aim at the determination of the Hubble constant of high-accuracy. Finally, the astrophysicists examined the synergy between direct determinations of the Hubble constant and observations of the cosmic microwave background. New joint observational programmes for the use of the present and future large telescopes on the ground and in space were developed by the participants and successfully submitted. Presently, the first observations are being carried out and the hope is that this MIAPP initiated new collaborations will contribute to an improved measurement of the Hubble constant. This will then certainly lead to another MIAPP programme related to cosmology and the expansion of the Universe. In order to emphasize the difference of a MIAPP programme from a regular conference the coordinators implemented a special format for the talks. The scientists were summoned to present the hidden "skeleton in the closet" rather than their polished publication quality data. With this increased transparency the coordinators aimed at pushing the discussion to another level and more profound depth than usually experienced at conferences.

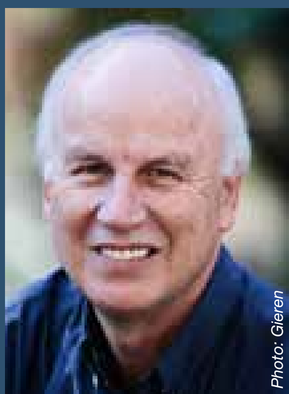
"A common theme to the workshop was highlighting the importance and feasibility of a 1% calibration of the local Hubble constant; I believe that great progress was made both in establishing the importance and validity of this goal, and in evaluating possible avenues for achieving it." *(Dr. Stefano Casertano, Space Telescope Science Institute, USA)*

COORDINATORS OF THE PROGRAMME: "EXTRAGALACTIC DISTANCE SCALE"

PROF. LUCAS MACRI

Texas A&M University, College Station, USA

- Measurement of the Hubble constant using cepheids and SNe Ia
- Searches for exoplanets and detached eclipsing binaries
- Redshift and peculiar velocity surveys



PROF. WOLFGANG GIEREN

University of Concepción, CHILE

- Extragalactic distance scale
- Cepheids and eclipsing binaries
- Galactic structure from pulsating stars

PROF. WOLFGANG HILLEBRANDT

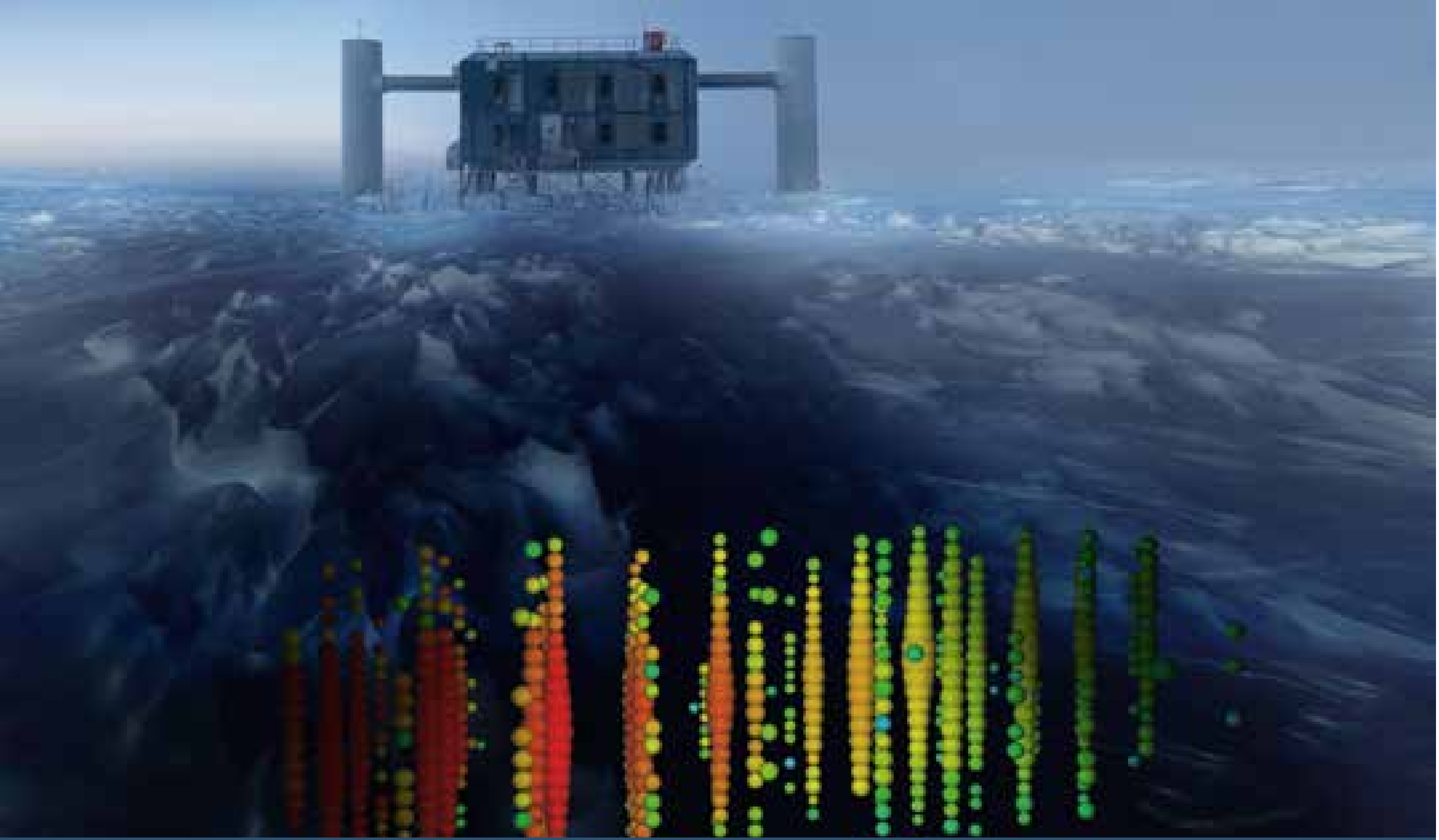
MPI for Astrophysics Garching, GERMANY

- Supernova modeling and observations
- Supernova cosmology
- Nuclear astrophysics

PROF. ROLF-PETER KUDRITZKI

Ludwig-Maximilians-University, Munich and University of Hawaii, Honolulu, USA

- Chemical evolution of galaxies
- Distances of galaxies
- Stellar physics
- Stellar spectroscopy



The IceCube Laboratory at the South Pole. Superimposed is a graphical rendering of the detection of one of the highest-energy neutrino events. The high energy of the recorded events suggests a cosmic origin of the detected neutrinos. *Credit: IceCube Collaboration*

30th June - 25th July 2014

Neutrinos in Astro- and Particle Physics

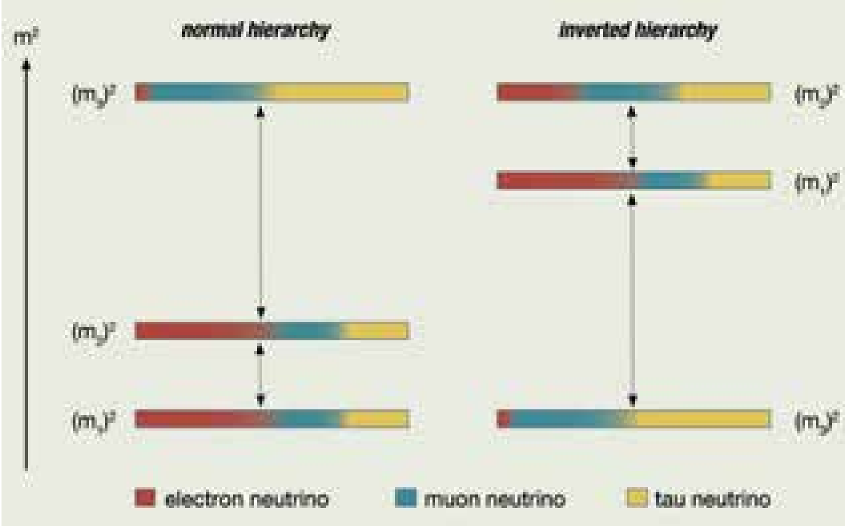
Neutrinos exist in immense numbers and are ubiquitously present throughout the Universe. They carry no charges and hardly interact with the surrounding matter. Hence, they are very difficult to study and are sometimes referred to as Nature's ghost particles. In this second MIAPP programme experts on neutrino physics from different branches of particle physics discussed the latest experimental results and theoretical ideas, and set the course for the next generation of large-scale experiments for neutrino physics.

COORDINATORS: STEFAN SCHÖNERT, GEORG G. RAFFELT, ALEXEI YU SMIRNOV, THIERRY LASSERRE

Neutrinos, subatomic particles without electric charge and colour charge, are only subject to the weak interaction and gravity. Thanks to these unique features, neutrinos hardly interact with the surrounding matter and mostly travel through it without collisions. Therefore, they are often referred to as Nature's ghost particles. Immense numbers of neutrinos exist in the Universe and every second millions of billions of neutrinos traverse every square meter of the Earth's surface without being noticed. Only in very rare cases, neutrinos come close enough to a nucleus to be refracted or converted to other particles.

Physicist Wolfgang Pauli predicted the existence of neutrinos already in the 1930s, before they were indeed discovered in the 1950s with the most sensitive experiments at the time. Over the years three different sorts ("flavours") of neutrinos were identified: the electron, the muon and the tau neutrinos. Originally predicted to be massless, two independent experiments proved at the turn of the millennium that the different neutrino flavours are interconvertible, a process called neutrino oscillation or mixing. The mixing of eigenstates is, according to quantum mechanics, only possible if neutrinos possess a mass. This further implies that neutrino flavour states are not mass eigenstates but superpositions of such states and is striking experimental evidence for the incompleteness of the Standard Model as a description of Nature. The discovery of neutrino oscillation thus represents a major milestone for elementary particle physics, for which the 2015 Nobel Prize has been awarded jointly to Takaaki Kajita from the University of Tokyo and Arthur B. McDonald of Queen's University, Kingston, Canada.

Inclusion of the tiny neutrino masses in extensions of the Standard Model requires "New Physics". Ideas of how neutrinos with masses could be integrated into the Standard Model were presented by theorists in the course of the MIAPP programme. Neutrinos could be Majorana fermions, i.e. particles that are indistinguishable from their own anti-particles. In addition, as also intensively discussed, there may be sterile neutrinos. These hypothetical particles would only be subject to gravitation and not to any of the fundamental interactions of the Standard Model, making them even more difficult to detect. Along that speculative line the plausibility of additional, so far unknown Higgs particles was in debate.



The three neutrino mass eigenstates (m_1, m_2, and m_3) are mixtures of three different neutrino flavours (electron – red, muon – blue, and tau – yellow). While the two mass differences are known, the absolute masses are not. Therefore, the ordering of their masses could be normal ($m_3 > m_2$) or inverted ($m_3 < m_1$). Deciding this fundamental question is one of the important tasks of future experiments as discussed at this programme. *(Graphics: Haneburger/ MIAPP adapted from http://www.staff.uni-mainz.de/wurmm/juno.html)*

Understanding the nature of the neutrino is still of prime importance – not only for elementary particle physics but also for astrophysics and cosmology. In a vigorous research effort experimenters currently attempt to determine the neutrino mass ordering, search for sterile neutrinos or measure the CP violating effects in the neutrino sector.

As neutrinos hardly interact with their surroundings, chances to observe them are small. In order to detect larger numbers and to further

"The density of experts was very stimulating and greatly helped many discussions."
(Prof. Sebastian Böser, Johannes Gutenberg Universität, Mainz, Germany)

Participants of the satellite topical workshop organised within the Neutrinos in Astro- and Particle Physics programme.
Photo: Schürmann

dissect the properties of neutrinos ever larger and more sophisticated experiments are being designed. At Super-Kamiokande, one of the world's largest underground neutrino detectors in Japan, 13,000 photo-multipliers detect the faint blue light emitted when a neutrino collides with an atom and generates an electron in the immense Super-Kamiokande tank filled with 50,000 tons of ultrapure water. IceCube, the cubic kilometre detector of clear Antarctic ice, located at the South Pole neutrino observatory, is a multi-purpose neutrino observatory. At IceCube, researchers learn more about neutrinos from the most violent astrophysical sources such as exploding stars, gamma-ray bursts, neutron stars and black holes. Recently, a high-energy neutrino flux from beyond the Earth's atmosphere has been observed at the IceCube observatory, and has inaugurated the era of high-energy neutrino astronomy. Until now, this observation, however, has opened more questions than it has answered, as for example the sources of this neutrino flux remain unclear. Possible interpretations of the sources were heavily discussed at this neutrino MIAPP programme.

Discussions at a MIAPP seminar. *Photo: Schürmann*

Understanding flavour conversion in the unique supernova environment is another theoretically challenging effect of neutrino-neutrino refraction. At the MIAPP programme, local experts in the topic of collective flavour conversion in the early Universe and in the supernova environment together with their colleagues from both sides of the Atlantic conferred and laid out a possible path for future action. Furthermore the question whether additional neutrinos beyond the known flavours, electron, muon and tau, exist in Nature was extensively discussed. Over the years, various anomalies in neutrino experiments have pointed in this direction. For the first time, we may live in an epoch where a number of dedicated experiments will provide definitive answers. On the other extreme, the question of

At Super-Kamiokande an international team of scientists works on revealing the properties of neutrinos. The detector, which is installed in a former mine in Gifu, Japan, consists of a stainless-steel tank, filled with 50,000 tons of ultrapure water, and is equipped with 13,000 photo-multipliers. *© Kamioka Observatory, ICRR (Institute for Cosmic Ray Research), The University of Tokyo.*

> **“I could organise the mini-workshop on charm production in the atmosphere. This was the first step towards a discussion on how high energy hadronic interactions are handled in cosmic ray physics.”**
> *(Dr. Paolo Desiati, WIPAC, University of Wisconsin Madison, USA)*

sterile neutrinos is one of cosmological significance because these “super-elusive” particles could easily contribute too much hot dark matter to the Universe. In a different incarnation, when their mass is in the keV range, they could actually represent the elusive cold dark matter of the Universe. Indeed, hints exist in this direction in the form of an unidentified 3.55 keV X-ray line observed from a variety of galaxies and galaxy clusters, which were debated in the course of the programme.

Leaving the more speculative topic of sterile neutrinos aside, the question whether the known neutrinos are identical with their own antiparticle is most fundamental. The so-called neutrinoless double beta decay can only occur if this is the case but remains unobserved as of now. At the MIAPP programme the different experimental projects and their future perspectives were discussed in great detail. In particular, the potential of future cryogenic double beta decay experiments with simultaneous heat and light detection were broached and techniques and costs of isotope enrichment were presented.

In summary, the programme was considered successful beyond expectations by both participants and coordinators as it contained the best ingredients for success: an appealing physical framework conducive to interaction and discussion, a good mix of formal and informal programme structure, and most of all, a well-chosen mix of participants from the experimental and theoretical neutrino science community.

NEUTRINOS IN ASTRO- AND PARTICLE PHYSICS

77 registrations

58 participants
from 38 institutions
in 12 different countries

academic seniority:
37 faculty/staff
16 postdocs
5 PhDs

duration of stay:

COORDINATORS OF THE PROGRAMME “NEUTRINOS IN ASTRO- AND PARTICLE PHYSICS”

PROF. STEFAN SCHÖNERT
Technical University of Munich, GERMANY

- Particle properties of neutrinos
- Neutrino astrophysics
- Dark matter search
- Detector development

DR. GEORG G. RAFFELT
Max Planck Institute for Physics, Munich, GERMANY

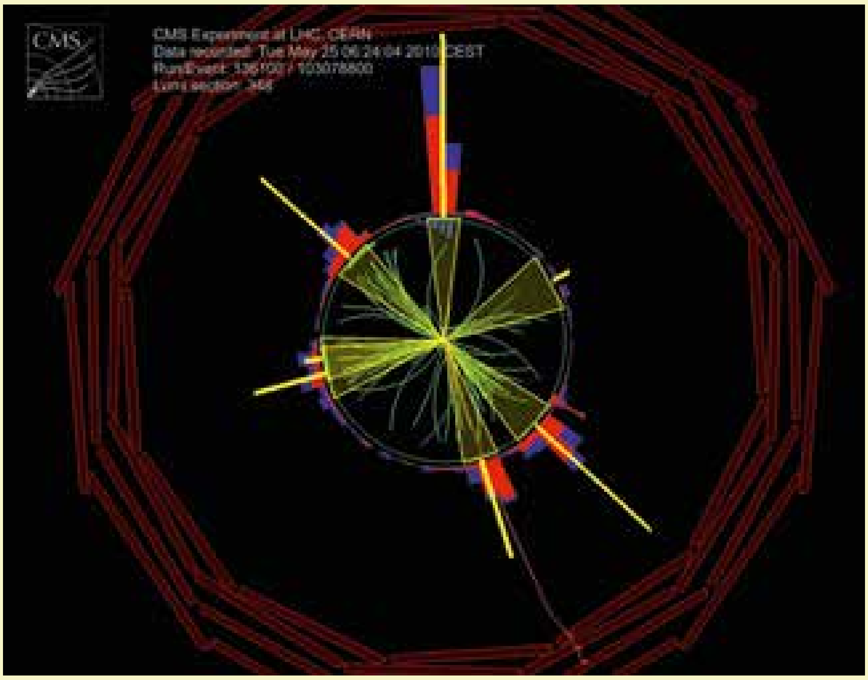
- Weakly interacting particles
- Supernova neutrinos
- Neutrino oscillations in dense media
- Axions

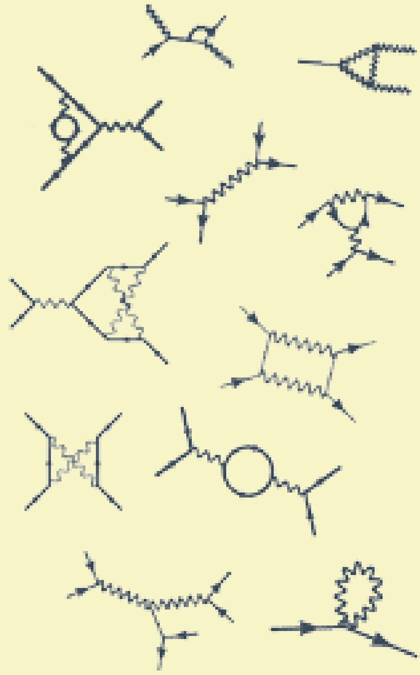
PROF. ALEXEI YU SMIRNOV
Max Planck Institute for Nuclear Physics, Heidelberg, GERMANY

- Neutrino physics and astrophysics
- Flavour physics
- Grand unification

DR. THIERRY LASSERRE
Commissariat à l’énergie atomique, Saclay, FRANCE

- Reactor neutrinos
- Light sterile neutrinos
- Neutrinos and dark matter
- Neutrinos and astrophysics
- Neutrinos and Earth sciences





A multi-jet event recorded by the LHC experiment CMS at CERN. Theorists use Feynman diagrams to illustrate the mathematical expressions from which the scattering probabilities of subatomic particles are computed.
Credit: left image © CERN, 20011-2016 CERN-EX-1107177-01; right image MIAPP.

28th July - 22nd August 2014

Challenges, Innovations and Developments in Precision Calculations for the LHC

In the first phase of operation, the Large Hadron Collider (LHC) at CERN has probed the structure of matter at the TeV scale with unprecedented breadth and precision. In 2015 the LHC resumed its operation with nearly doubled centre-of-mass energy of 13 TeV and continued the quest for New Physics. Beforehand, experts in highly accurate calculations and simulations of scattering processes met at MIAPP to pave the way for the full exploitation of the data generated at the new energy frontier.

COORDINATORS: MICHAEL KRÄMER, STEFAN DITTMAIER, NIGEL GLOVER, GUDRUN HEINRICH

The Large Hadron Collider (LHC) at the European Laboratory for Particle Physics (CERN) is the largest machine in the world. The gigantic circular particle accelerator is 27 km in circumference and is situated about 100 m below the Earth's surface at the border between Switzerland and France, close to Geneva. As the world's most powerful particle accelerator the LHC collected its first physics results in 2010, culminating in the discovery of the long-sought Higgs particle in 2012. After a long shut-down of two years, the LHC resumed operation in 2015 colliding two protons at the unprecedented collision energy of 13 TeV. Approximately 600 million times per second, particles collide within the LHC. Each collision produces particles that may decay in complex ways and hence produce a complicated final state of even more particles. But only one in every 100 billion collisions produces a Higgs particle. Hence, the search for the Higgs particle has often been compared to the search for a needle in the haystack (and what a haystack it is, weighing about ten thousand tons, to stay within the analogy!).

Achieving this goal requires theoretical predictions of signal and so-called background processes with exquisite precision. In this programme theorists from 30 institutions in ten countries gathered to take stock of their tools, and to discuss the opportunities and challenges of the upcoming LHC Run II at 13 TeV collider energy.

Soccer match “fixed order” vs “resummation” in front of the MIAPP building.
Photo: Dittmaier

> **“Stimulating, but relaxed atmosphere. Not too many official talks, lots of time for discussions and concrete work.”**
> *(Prof. Giulia Zanderighi, Oxford University, United Kingdom)*

In the late 1940s genial physicist Richard P. Feynman developed a pictorial representation, now called “Feynman diagrams”, for the mathematical expression describing a complex, quantum-mechanical scattering process. Some sixty years later it has become clear that a combination of clever insights, new theoretical techniques and an increase in computational efficiency is required to turn these expressions into precise calculations matching the demands of the Large Hadron Collider.

The MIAPP programme took place at the right time and brought together theoretical physicists working on this problem with different approaches. Next-to-leading order (NLO) calculations of scattering amplitudes are now the standard but remain challenging for complicated final states. Several groups represented at the programme pursue the automation of these computations, while the first steps towards the next order and the inclusion of subtle electroweak effects are already being undertaken. On a dedicated afternoon the subject of multi-loop Feynman diagram calculations and their benefits were introduced. In 2013 significant progress was made in the understanding of the computation of Feynman integrals using differential equations, and the ramifications of this were a hot topic. Another line of approach is all-order resummation of large quantum corrections, which are ubiquitous in complicated kinematical distributions. But which is the more useful approach, “fixed- order” or

CHALLENGES, INNOVATIONS AND DEVELOPMENTS IN PRECISION CALCULATIONS FOR THE LHC

67 registrations

54 participants from 30 institutions in 10 different countries

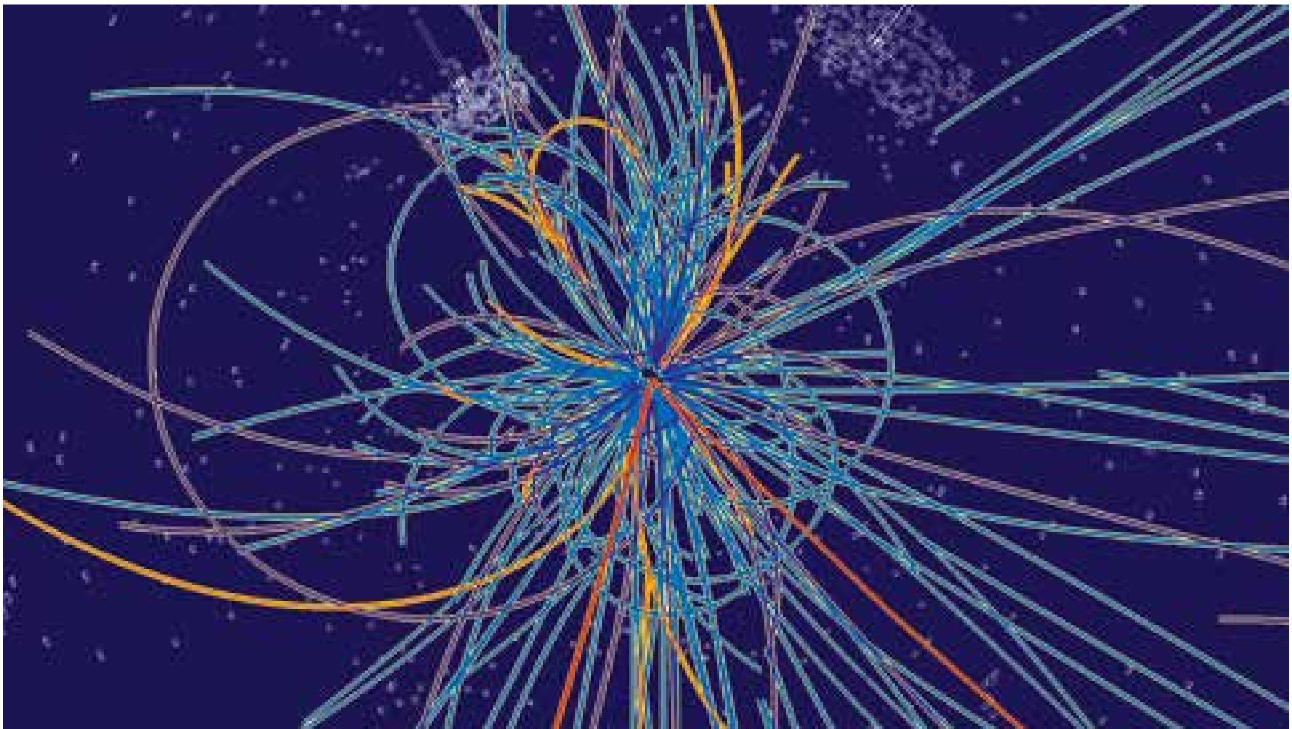
academic seniority: 27 faculty/staff, 21 postdocs, 6 PhDs

duration of stay:

2 w	3 w	4 w
32	17	5

Participants of the Top Quark Physics Day – the one-day topical workshop in week three of the programme.
Photo: Schürmann

"resummation"? The remaining controversies were fought out in a soccer match in front of the MIAPP building resulting in a crushing defeat of one of the camps. Finally, analytic computations of any sort must often be matched to Monte Carlo simulations of the scattering processes. How this can be done without loss of accuracy was another intensely discussed topic at the programme. The discussions between the various groups highlighted that the interpretation of LHC data is far from simple, requiring long calculations, detailed simulations, and close interaction with the experimenters.



Simulation of a detection of the Higgs boson in the CMS experiment. *© 2007 CERN, for the benefit of the CMS Collaboration*

The top quark, with its huge mass of about 175 proton masses while being point-like to the best of present knowledge, is one of the more enigmatic elementary particles. Its properties can now be precisely studied at the LHC for the first time. The top quark was therefore a well-chosen subject of a one-day topical workshop ("Top Quark Physics Day"), which attracted many additional participants who flew to Munich to discuss precision measurements of top quark observables, as well as the potential of the top-quark to reveal effects of "New Physics". This included experimentalists from the CERN LHC experiments CMS, ATLAS and LHCb, who reported the status of their measurements and the prospects for the next experimental run. In the aftermath of the topical workshop further discussions were triggered among the programme participants.

"The very informal gathering of such experts, and the time available to discuss are truly fruitful and beneficial. It is wonderful to realise that, when thinking of a research issue, that the world expert is just a few doors away."
(Prof. Eric Laenen, Nikhef and Universities of Amsterdam and Utrecht, Netherlands)

Aside from the intense topical workshop this programme was characterised by a rather loose and informal schedule, which was very much appreciated by the participants, who came to Garching to pursue their collaboration with colleagues from afar and the research groups in the field at the Technical University of Munich and the Max Planck Institute of Physics.

COORDINATORS OF THE PROGRAMME "CHALLENGES, INNOVATIONS AND DEVELOPMENTS IN PRECISION CALCULATIONS FOR THE LHC"

PROF. MICHAEL KRÄMER
RWTH Aachen, GERMANY

- LHC phenomenology
- Physics beyond the Standard Model, including dark matter
- Supersymmetric Higgs particles
- Perturbative loop calculations

PROF. STEFAN DITTMAIER
Albert-Ludwigs-University, Freiburg, GERMANY

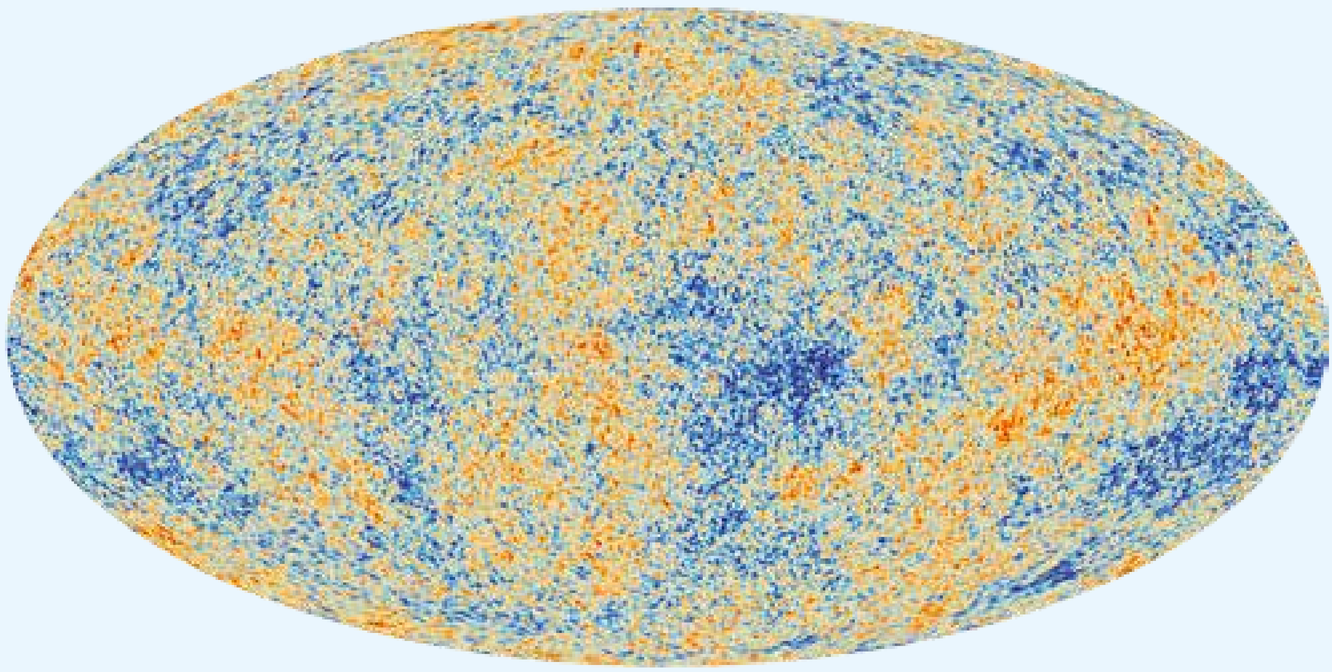
- Collider phenomenology
- Electroweak precision physics
- Physics of Higgs bosons in the Standard Model and beyond
- Electroweak and QCD radiative corrections

PROF. NIGEL GLOVER
Durham University, UNITED KINGDOM

- Collider phenomenology
- Strong and electroweak interactions
- Perturbative QCD
- Jet cross sections
- Higgs boson phenomenology

DR. GUDRUN HEINRICH
MPI for Physics, Munich, GERMANY

- Collider phenomenology
- Automation of NLO calculations for QCD, electroweak interactions and physics beyond the Standard Model
- NNLO calculations
- Numerical evaluation of multi-loop integrals



The cosmic microwave background (CMB) is a snapshot of the oldest light in the Universe. It shows tiny temperature fluctuations that correspond to regions of slightly different densities. These differences have been imprinted on the sky 13 billion years ago when the Universe was just 380,000 years old. They represent the seeds of all future structures: the stars and galaxies of today. *Photo: ESA and the Planck Collaboration*

25th August - 19th September 2014

Cosmology after Planck

Cosmologists study the origin, evolution and fate of the Universe. They want to understand the dynamics of large-scale structures and the underlying physical laws. In 2009 the European Space Agency launched the Planck mission to find answers to some of the most important cosmological questions in modern astrophysics. Analyses of the cosmic microwave background, with the highest accuracy ever achieved, were conducted to find out how the Universe begun, evolved and will continue.

COORDINATORS: NABILA AGHANIM, EIICHIRO KOMATSU, BENJAMIN WANDELT, JOCHEN WELLER

In the last eight decades, cosmologists gained important insights into the origin and structure of the Universe. Nowadays it is well perceived by most physicists that the Universe developed from a very dense, compact and hot state that expanded rapidly. This event known as the Big Bang marks the origin of matter and of time and space. Scientists try to decipher the 13.8 billion-year history of our Universe by studying celestial bodies and light that is emitted by very distant objects.

A remnant of the time when the Universe was still hot and dense and only 380,000 years old is the cosmic microwave background (CMB) a thermal left-over from the recombination period of the Universe. At that time the Universe had expanded and cooled enough to favour the formation of neutral hydrogen gas over the existence of free electrons and protons. In contrast to the earlier existing plasma of free electrons and protons cold neutral hydrogen gas is rather transparent. Therefore, the radiation from the glowing plasma could spread to every place in the Universe. As the Universe further expanded this radiation has cooled down and has been stretched to a longer wavelength. This almost perfectly isotropic radiation is detectable in the non-visible microwave region of the electromagnetic radiation spectrum and is known as cosmic microwave background.

The CMB was detected in 1964 and is one of the most important proofs of the Big Bang theory. It is

Participants of the Cosmology after Planck programme in front of the MIAPP building. *Photo: Wenzel Schürmann (TUM)*

the furthest back in time scientists can look by exploring radiation. However, the CMB radiation is not exactly isotropic. It shows very small deviations from isotropy. Imprinted in these tiny deviations are the traces of the seeds of the celestial bodies and galaxies of today.

In 2009, the European Space Agency launched the Planck satellite, a space-based telescope observing the Universe at wavelengths between 0.3 mm and 11.1 mm (corresponding to frequencies between 27 GHz and 1 THz), broadly covering the far-infrared, microwave, and high frequency radio domains of the electromagnetic spectrum. The mission's main goal was to study the cosmic microwave background across the whole sky at greater sensitivity and spatial resolution than ever before. The observations obtained with the Planck's satellite, had and have far reaching impacts on the possible cosmological models and interpretations. They allow to constrain cosmological models with unprecedented precision.

During the MIAPP programme observers and theorists discussed the Planck satellite results and their implications in the context of cosmological models and presented the newest insights. At a time when the second Planck data release was expected, revealing the complete data set of the entire mission including for the first time polarisation, MIAPP provided the ideal environment for stimulating scientific interaction and to foster new projects and publications in this area. Due to the well-understood physics of the anisotropies in temperature and polarisation of the cosmic microwave background, CMB anisotropies are an excellent probe for cosmological and astrophysical phenomena. For example the angular scale of the sound horizon of the last scattering of the CMB photons of free electrons can be used as a scale for measuring the curvature of the Universe (if the local Hubble expansion is known). This has been impressively shown by the Wilkinson Microwave Background Anisotropy Probe (WMAP), a NASA satellite launched in 2001. The Planck surveyor was anticipated to measure the CMB anisotropies to such high precision and detail, that the models of the very early Universe became testable.

"The informal nature of this workshop made it very easy to approach other researchers and start a new discussion or ask questions."

(Prof. Carlo Baccigalupi, SISSA, Trieste, Italy)

In the run-up to the MIAPP programme polarisation data from Planck, results from the BICEP2 experiment and from LOFAR were published and stimulated the discussions at the four-week programme. Influenced by the newly published data and especially the polarisation results primordial magnetic fields were highly discussed at MIAPP.

The Universe is magnetised on all scales analysed so far. These observed magnetic fields may be remnants from the early Universe, being intensified over the years. possibility of them being the seeds that generated the observed large-scale magnetic fields can be extracted from CMB data. Large-scale magnetic fields exist in cosmic structures such as galaxies and galaxy clusters. Gamma-ray observations have suggested the existence of magnetic fields even in void regions. At MIAPP the possibility of cosmological magneto-genesis was discussed and how such large-scale magnetic fields could have been generated in the early Universe. Besides limits on the magnetic fields from CMB observations, Information for investigating and constraining primordial magnetic field characteristics, understanding their origin, and exploring the potential constraints on magnetic fields from 21cm hydrogen spectral line radio observations were discussed. In addition, the possibility of circular polarisation generated in the CMB via Faraday conversion due to magnetic fields from supernovae in the epoch of re-ionisation was heavily debated. Measurements of gravitational lensing in the CMB directly probe the projected distribution of mass out to high redshifts, and thus encode a wealth of information about cosmology. Polarisation lensing

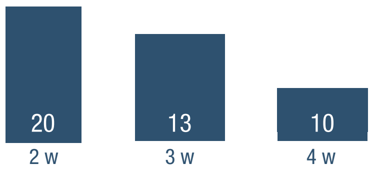
COSMOLOGY AFTER PLANCK

122 registrations

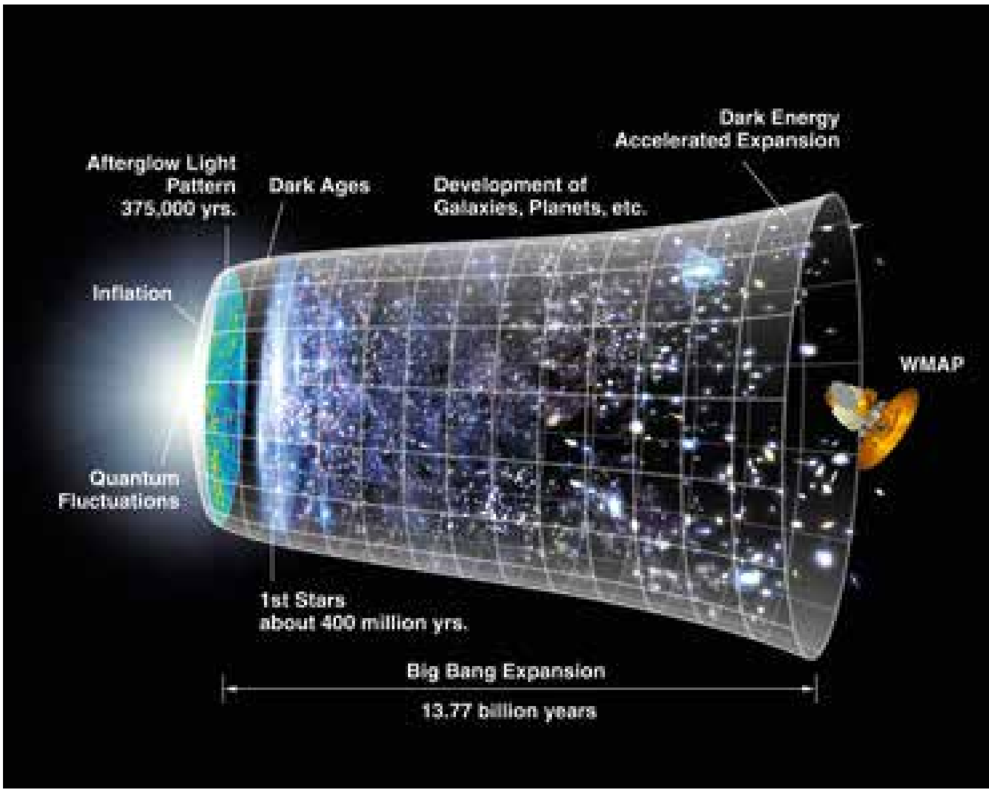
43 participants
from 31 institutions in
15 different countries

academic seniority:
24 faculty/staff
14 postdocs
5 PhDs

duration of stay:



"This was a really great workshop. I especially enjoyed the morning coffee discussions and the discussions after the talks."
(Dr. Marilena Loverde, Enrico Fermi Institute – KICP, University of Chicago, USA)



The evolution of the Universe started with a period of inflation after the Big Bang. The afterglow, or cosmic microwave background, has been extensively recorded by satellites such as WMAP and Planck, and further improves our understanding of the origin and evolution of the Universe.
Credit: NASA/ WMAP Science Team

measurements will help to improve constraints on both neutrino masses and inflationary tensor modes. By analysing the signature of inflation through CMB polarisation, ground-based lensing surveys such as the POLARBEAR and ACTPol experiments bear great potential for investigating physics that occurred at energies higher than ever achievable on Earth. As outlined at the MIAPP programme, work on the analysis of upcoming high signal-to-noise CMB polarisation lensing measurements may allow to obtain precise neutrino mass constraints. Another unforeseen discussion dealt with the tension between large-scale structure probes and the cosmic microwave anisotropies and whether it can be relaxed with massive neutrinos. Results from simulations with massive neutrinos were presented and their impact on the mass function of halos was discussed. It was stressed that neutrinos impose a scale dependent bias even on linear scales. Furthermore, new aspects of inflation were discussed, the phase after the Big Bang when the Universe expanded exponentially within a fraction of a second. Since then, the space kept expanding even though less rapid. New inflation theories were presented involving the Higgs particle in a model with enhanced friction. Other theoretical ideas involved new effective field theories, primordial black holes and new models with gauge fields. All in all, within the four weeks of the "Cosmology after Planck" programme more than 40 participants actively discussed the latest issues in cosmology. The vivid exchange of ideas amongst participants in early career stages and more established researchers fostered a buzzing environment with energetic discussions.

"My overall experience during the workshop was really good. I could discuss with many experts from different fields. I am hoping that some of the discussion lead to some effective collaborations and result in good papers in near future."

(Dr. Dhiraj Hazra, Asia Pacific Center for Theoretical Physics, Pohang, South Korea)

COORDINATORS OF THE PROGRAMME "COSMOLOGY AFTER PLANCK"

DR. NABILA AGHANIM
Astrophysicist CNRS, University Paris Sud, Orsay, FRANCE

- Planck core team member
- Cosmology
- Cosmic microwave background
- Galaxy clusters


Photo: Komatsu

DR. EIICHIRO KOMATSU
MPI for Astrophysics, Garching, GERMANY

- WMAP member
- Cosmology
- Cosmic microwave background
- Large-scale structure
- Non-gaussianity


Photo: Wandelt

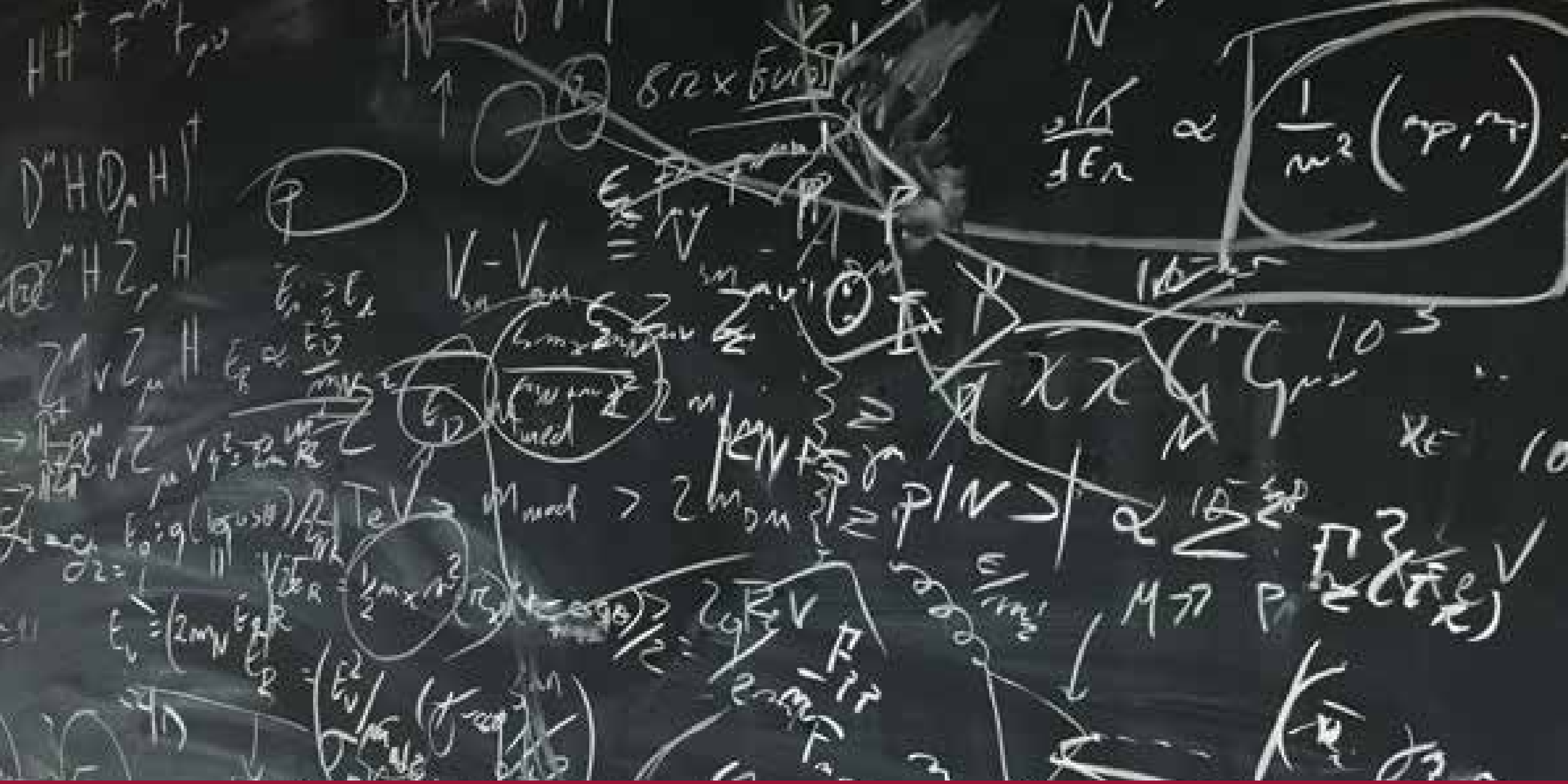
PROF. BENJAMIN WANDELT
University of Illinois, Urbana-Champaing, USA

- Planck core team member
- Cosmology
- Cosmic microwave background
- Large-scale structure
- Bayesian methods


Photo: MIAPP

PROF. JOCHEN WELLER
Ludwig-Maximilians-University, Munich, GERMANY

- Planck core team member
- Cosmology
- Galaxy clusters
- Large-scale structure
- Dark energy



The MIAPP black board after an intense afternoon of discussions. *Photo: Haneburger/MIAPP*

2nd – 27th February 2015

Dark Matter: Astrophysical Probes, Laboratory Tests and Theory Aspects

Although the concept of dark matter exists for almost a century, its true nature remains mysterious. While it is nowadays well established that only dark matter can account for various gravitational effects observed throughout the Universe, its microscopic particle properties remain practically unknown. In this MIAPP programme, researchers from several fields of dark matter physics set out to discuss theoretical and experimental questions, which arise in the different methods applied in the search for the dark matter particle.

COORDINATORS: ALEJANDRO IBARRA, JEAN-CÔME LANFRANCHI, JOSEF PRADLER, CARSTEN ROTT, JOCHEN SCHIECK

Dark matter – an unknown form of matter. In the 1930s Caltech astronomer Fritz Zwicky noted that something strange was going on in the Coma cluster of galaxies. The motion of the galaxies didn't seem to follow the laws of Newtonian mechanics and gravitation. By estimating the mass of the cluster from the light output of its stars, he concluded that there must be large amounts of unaccounted matter. This unknown matter was named "dark matter", as it consisted of yet unidentified particles that do not emit light, absorb light or directly interact with light at all (hence, "dark"). There is now ample evidence of this dark matter throughout the Universe. It leaves an imprint in the cosmic background radiation, affects the motion of stars, in particular at the edges of spiral galaxies including our own, and betrays itself by deflecting light from distant objects, resulting in gravitational lenses. Apparently, the matter we know, and which constitutes the stars, the planets, and the intergalactic gas accounts for less than 5% of the mass of the Universe. The rest is composed of around 70% dark energy and up to 25% dark matter. But the evidence for dark matter is purely gravitational, and no experiment has so far been able to detect dark matter directly and to unravel the mystery of what it is composed of. In this MIAPP programme, researchers from several fields of dark matter physics set out to discuss theoretical and experimental questions, which arise in the different searches for the dark matter particle. "Today, particle physics finds itself at a special crossroad", the coordinators explain, "the Large Hadron Collider is about to start its high-energy, high-luminosity run and the next generation of dark matter direct detection experiments are coming on-line. So it is of crucial importance to step back, take stock of the current state and to devise strategies of how to move the field forward in this critical time. The MIAPP format is ideally suited for such an agenda."

But how do you find something that is invisible? Dark matter is likely to be a ponderous substance, stable or very long-lived, not moving very fast, it must be invisible and should interact with normal matter at best very feebly. Within the Standard Model of particle physics there is not a single candidate particle that matches these features. One therefore searches for the very weak scattering of a new particle with nuclei in an ultrasensitive detector ("direct detection"), the pair annihilation of two such dark matter particles somewhere in the Universe resulting in an anomalous flux of cosmic rays ("indirect detection"), and for the production of dark matter particles at the Large Hadron Collider at CERN, where the unobserved dark matter particle would be seen as missing energy in the final state ("collider searches"). The unknown identity of the sought particle leaves much room for speculation. The experimental efforts are therefore closely tied to models invented by theoretical physicists, who then compute the consequences of a given model for the various searches.

The MIAPP programme "Dark matter: astrophysical probes, laboratory tests and theory aspects" gathered experts from these complementary fields of dark matter physics to assess the current status of the search for dark matter particles and the implications for theory, and to foster discussions among the participants that would lead to new ideas in dark matter physics and to new collaborations. In order to accomplish this goal, a daily keynote seminar was organised, while the afternoons were left to spontaneously organised "mini-workshops" such as "Dark matter and neutrinos", the "ATLAS/CMS dark matter forum", and many more.

"I gave a talk on SUSY dark matter, including work in progress, and received several very important and interesting comments, such as indirect detections (in particular the internal bremsstrahlung), LHC search, etc. In addition, I have learned a lot from other talks and discussions, such as the non-SUSY dark matter models, light mediator scenarios, and also experimental prospects for dark matter direct/indirect detections."

(Prof. Koichi Hamaguchi, Department of Physics, University of Tokyo, Japan)

Mini Workshop on dark mediators. "The relaxed environment in which the discussions took place stimulated many thoughts." (Dr. Suchita Kulkarni, HEPHY, Vienna, Austria). *Photo: Schieck*

A surprising fact is that while the total mass of dark matter in the Universe is accurately known, the mass of an individual dark matter particle is uncertain by many orders of magnitude. The most popular idea is a weakly interacting massive particle (WIMP), whose characteristics match those of dark matter perfectly. Just how severely WIMPS are already being constrained, was an important topic of discussion. Results from the Fermi and IceCube experiments were presented, and future probes such as HAWC, CTA, IceCube Gen2 and GAMMA-400 were compared.

DARK MATTER: ASTROPHYSICAL PROBES, LABORATORY TESTS, AND THEORY ASPECTS.

91 registrations

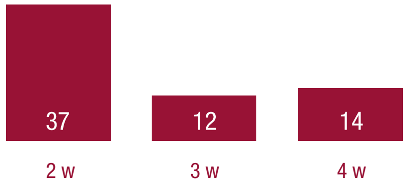
63 participants

from 35 institutions
in 16 different countries

academic seniority:

20 faculty/staff
34 postdocs
9 PhDs

duration of stay:



**"I liked best: plenty of time in the afternoon for detailed discussions. Examples:
a) concerning the improvements of a running experiment,
b) concerning theoretical dark-matter models."**
(Dr. Walter Potzel, TUM, Munich, Germany)

Multi-wavelength approaches were highlighted, and how to estimate uncertainties in cosmic ray propagation for positrons and anti-protons for the AMS-02 experiment was discussed as a prerequisite for the interpretation of the data. Very light, sub-GeV particles provide a viable alternative to WIMPs, mostly in their role as force carriers in an entire so far hidden sector of particles, but also as dark matter candidates themselves. They formed the focus of a full week of the programme. Another focus were dark matter aspects in neutrino searches and sterile neutrinos as dark matter candidates. A minimal extension of the Standard Model with only three sterile neutrinos could resolve some of the problems of the Standard Model with respect to dark matter. The observation of an anomalous 3.5 keV X-ray line in cosmic radiation was presented in the context of sterile neutrino interpretation.

With a strong participation of theoretical physicists, particle-physics model building featured strongly at this programme. The complementarity of collider searches and the traditional dark matter searches has been a particularly hot topic. Complete models often contain new particles ("mediators") in addition to dark matter particles, and it might be these, which will be observed first at the LHC. As the experimental

Detector mounting at Gran Sasso for the CRESST direct detection experiment. At CRESST searches for dark matter particles scattering on nuclei are conducted at very low temperatures. If such a scattering occurs, the minute amount of heat produced in the collision can be detected.
Credit: MPP (CRESST)

capabilities become more and more powerful, even subtle quantum effects may become relevant, increasing the demands on the theoretical calculations. Nevertheless, it became clear that without unambiguous evidence of a dark matter particle signal, the theoretical possibilities are too numerous to single out a clear candidate theory.

The relaxed working atmosphere at MIAPP and a well-balanced attendance from senior scientists, postdocs and PhD students seemed to be conducive to the goals of the programme. The various talks and discussion sessions triggered many informal conversations among the participants. “Future new projects will be started with collaborators who met for the first time during this programme”, Alejandro Ibarra from TUM says on behalf of the coordinators – and add another piece to completing what is arguably the most important puzzle in particle physics, the nature of dark matter.

“Scientific: Broad range of topics, possibilities for discussions. Non-scientific: Perfect infrastructure, good administrative support.”

(Dr. Holger Kluck, HEPHY, Vienna, Austria)

COORDINATORS OF THE PROGRAMME “DARK MATTER: ASTROPHYSICAL PROBES, LABORATORY TESTS AND THEORY ASPECTS”

PROF. ALEJANDRO IBARRA

Technical University of Munich, GERMANY

- Theoretical elementary particle physics
- Physics beyond the Standard Model
- Indirect dark matter detection

DR. JEAN-CÔME LANFRANCHI

Technical University of Munich, GERMANY

- Direct dark matter search with CRESST
- Low-temperature detector development

DR. JOSEF PRADLER

Institute of High Energy Physics, Vienna, AUSTRIA

- Dark matter theory
- Reconciliation of theory and experiment in dark matter searches
- Studies of the early Universe

PROF. CARSTEN ROTT

Sungkyunkwan University, KOREA

- Indirect searches for dark matter with neutrinos
- Astroparticle physics with IceCube

PROF. JOCHEN SCHIECK

Institute of High Energy Physics, Vienna, AUSTRIA

- Flavour physics
- Dark matter searches: What is dark matter? What are the properties?
- Detector development

The outline of our galaxy, the Milky Way, and of its neighbours, the Magellanic Clouds. This picture was constructed from the database of Gaia, a new space observatory, which is investigating the structure and formation of the Milky Way. Brighter regions indicate higher concentrations of stars, while darker regions correspond to patches of the sky where fewer stars are observed or where the stars are obscured by interstellar dust. *Photo: ESA/Gaia-CC BY-SA 3.0 IGO*

4th - 29th May 2015

The New Milky Way: Impact of Large Spectroscopic Surveys on our Understanding of the Milky Way in the Gaia Era

Observed from the earthling's point of view our galaxy appears as a glowing band at the night sky and hence was termed "Milky Way". Galileo Galilei was the first to resolve the band into individual stars. Since then our understanding of the Milky Way has increased enormously. An investigation of the structure of the Milky Way has crucial implications not only for the understanding of spiral galaxies, but also of the formation and evolution of structures in the Universe as a whole. This workshop was designed to critically analyse and compare the results obtained by the recent large surveys of the Milky Way.

COORDINATORS: ANDREAS BURKERT, SOFIA FELTZING, ACHIM WEISS, GERRY GILMORE, LUCA PASQUINI, SOFIA RANDICH

Spiral galaxies like the Milky Way possess three characteristics: the central part is called nucleus or central bulge and contains the highest density of stars. It is primarily made out of old stars, gas, and dust. The bulge is surrounded by the disk region. Within this pancake-like region mostly young stars, gas and dust are present and superimposed by the characteristic spiral arms. The third component is the so called "halo" and its precise dimension is difficult to determine. Here, only very little star formation activity resides. The halo is dominated by the presence of dark matter. A good understanding of the Milky Way is the key not only to the understanding of spiral galaxies, but also to the understanding of the formation and evolution of structures in the Universe as a whole. The structure of the Milky Way is far more complex than originally thought. It continuously swallows small neighbour galaxies. Two decades ago, in 1994, the first example of a stellar stream being directly accreted by the Milky Way was discovered when the Sagittarius dwarf galaxy was detected in a kinematic survey of the galactic bulge. Studies based on data from ESA's astrometric satellite Hipparcos and local photometric studies have revealed the solar neighbourhood to be filled with stellar streams and groups, some of dynamical origin, others genuine dissolving stellar clusters. Detailed spectral analyses allow to disentangle the field stars from the cluster stars. Subsequent studies utilising the Sloan

Digital Sky Survey have shown that also on large scales the Milky Way is not smooth in its stellar distribution. The stellar disk is asymmetric and observations show that there is a preferred plane for dwarf galaxies around both, the Milky Way and the Andromeda galaxy. Such results point to interactions between the visible components of galaxies and dark matter halos, showing how little we still know about our own stellar system.

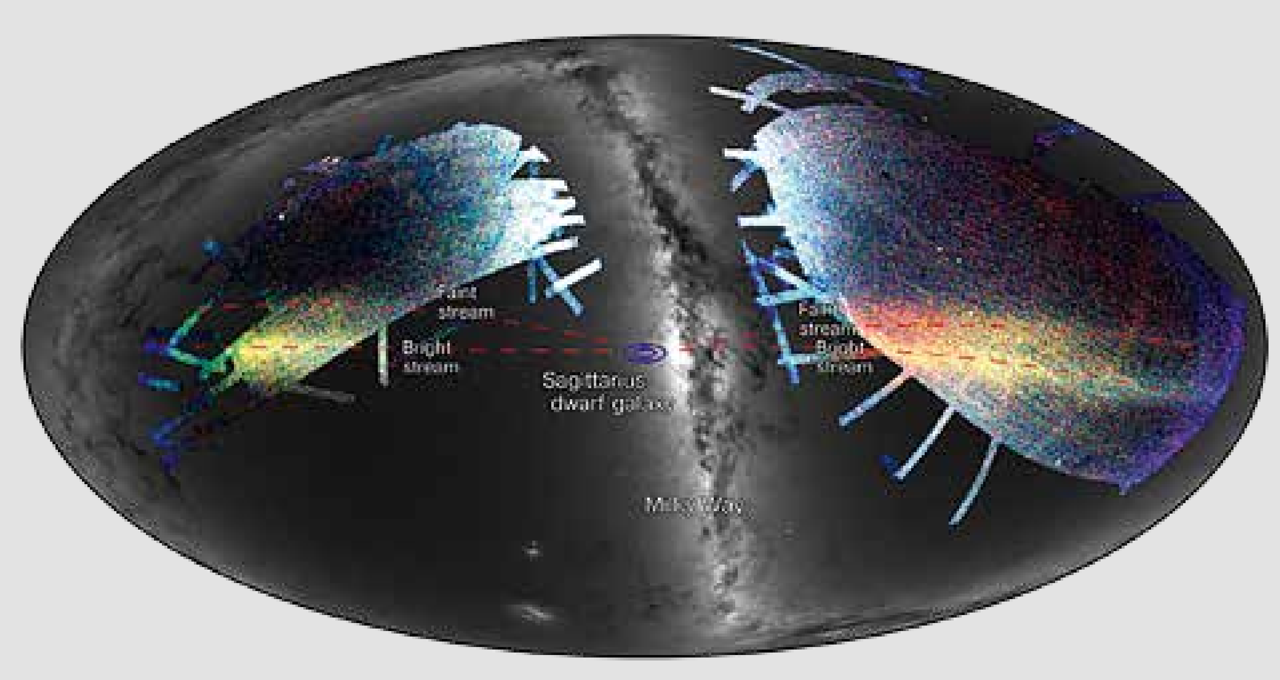
“The workshop was fantastic. Not only does it allow for general scientific discussions, it also allows for intensive collaboration.”
(Ly Duong, The Australian National University, Canberra, Australia)

In the next few years a new era of Milky Way studies is expected, thanks to the Gaia mission and complementary ground-based spectroscopic surveys. ESA’s selection and implementation of the Gaia satellite has resulted in a virtual explosion of scientific activities across Europe. Launched in December 2013, the Gaia satellite’s mission is to collect data for the largest, most precise 3D map of our galaxy, providing a crucial tool for studying the formation and evolution of the Milky Way. For this purpose Gaia is surveying the position, motion, brightness and colour of over a billion stars. Analysis of high quality data will allow to determine stellar orbits and chemical abundances. Additional ground-based spectroscopic surveys and the follow-up analyses will complement Gaia’s data to complete the view of the Milky Way and to unravel its evolution.

The Gaia-ESO Survey is one of the largest spectroscopic surveys ever, comprising 300 nights of observation of all galactic stellar populations, using the FLAMES spectrograph at the Very Large Telescope in Paranal, Chile. Precise radial velocities, stellar parameters, and chemical element abundances for 100,000 stars belonging to all stellar populations in the Milky Way are collected in the course of the survey. The APO Galactic Evolution Experiment (APOGEE), another large spectroscopic survey, examines 100,000 red giant stars across the full range of the galactic bulge, bar, disk, and halo. For this purpose it employs high-resolution, high signal-to-noise infrared spectroscopy to penetrate the dust that obscures significant fractions of the disk and bulge of our galaxy. With the help of APOGEE and the Australian GALactic Archaeology with

To facilitate and encourage scientific exchange and collaboration, a brief description of the scientists’ main interest was mounted on each door. *Photo: Haneburger/MIAPP*

Lively scientific discussion at a wine & cheese gathering in the MIAPP kitchen. *Photo: Haneburger/MIAPP*



A map of the sky showing the location of the Sagittarius dwarf galaxy in relation to the Milky Way. The strong tidal forces resulted in a disruption of the dwarf galaxy and in four protruding streams of stars orbiting the Milky Way (red dashed lines). The different colours indicate the distance of the stars (blue areas: stars are closer; red areas: stars farther away). *Credit: S. Koposov and the SDSS-III collaboration.*

"I found this experience to be very motivating for my own research. Being able to speak directly with colleagues on a regular basis over a couple of weeks meant more productive and less intense conversations than can usually happen at week long conferences. Having a desk space as well to work at when needed, and everyone mainly in the same building gave the `pseudo-institute´ a coherent feel."

(Dr. Clare Worley, Institute of Astronomy, University of Cambridge, United Kingdom)

HERMES (GALAH) survey precise radial velocities and detailed chemical abundances are obtained and will provide insights into the dynamical structure and chemical history of the galaxy.

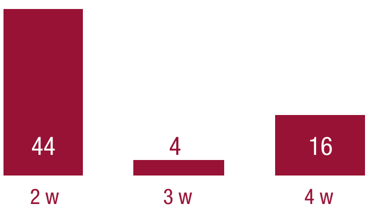
THE NEW MILKY WAY

105 registrations

64 participants
from 31 institutions
in 12 different countries

academic seniority:
38 faculty/staff
16 postdocs
10 PhDs

duration of stay:



The interpretation of the spectroscopic results needs to involve detailed stellar structure calculations and the physical processes of the stellar interiors. Element abundances may not always faithfully reflect the chemical composition of the gas cloud out of which a star formed. Internal processes such as gravitational settling and diffusion may play an important role and must be taken into account in the analysis of the stellar data. Also, a detailed understanding of stellar evolution is needed to derive reliable stellar ages, which, in turn, are fundamental in the context of galaxy formation and evolution. The spectroscopically determined stellar parameters (temperature, mass, radius) need to be assessed with respect to systematic errors to establish their concordance with stellar interior models. Finally, the observational data of all ongoing surveys need to be combined with accurate theoretical stellar models to reconstruct the history of our galaxy. To accomplish these goals the New Milky Way programme was designed to bring together scientists who are deeply involved in on-going and future large scale spectroscopic surveys. In a scientifically lively atmosphere the current understanding of the Milky Way and its constituents were discussed.

Along these lines talks and discussion sessions covered the different flavours of galactic archaeology, such as chemical studies and observations of radial migration of stars within the Milky Way and dwarf spheroidal galaxies. Great progress was made towards a better understanding of the complex chemo-dynamic processes leading to the observed structure of our home galaxy.

COORDINATORS OF THE PROGRAMME "THE NEW MILKY WAY: IMPACT OF LARGE SPECTROSCOPIC SURVEYS ON OUR UNDERSTANDING OF THE MILKY WAY IN THE GAIA-ERA"

PROF. ANDREAS BURKERT

Ludwig-Maximilians-University,
Munich, GERMANY

- Structure and formation of dark matter halos
- Formation and evolution of galaxies
- Structure of the multi-phase, turbulent interstellar medium
- Formation of stars and stellar clusters.

PROF. SOFIA FELTZING

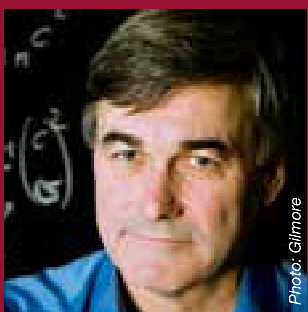
Lund Observatory, SWEDEN

- The Milky Way as a galaxy
- Near field cosmology
- Elemental abundance analysis of late type stars
- Massive spectroscopic surveys with WEAVE and 4MOST
- Gaia-ESO Survey

PROF. ACHIM WEISS

Max Planck Institute for Astrophysics,
Garching, GERMANY

- Stellar evolution of low- and intermediate-mass stars
- Population synthesis: stellar models as input, AGB stars: evolutionary state and colours
- Asteroseismology as a tool for determining the physics of stars



PROF. GERRY GILMORE

University of Cambridge, UK

- GAIA: the origins of the galaxy
- Galactic and galactic chemical evolution: the histories of star dust
- Dark mass distribution in galaxies: searching for the nature of matter
- Stellar luminosity function: how much mass is understood?

DR. LUCA PASQUINI

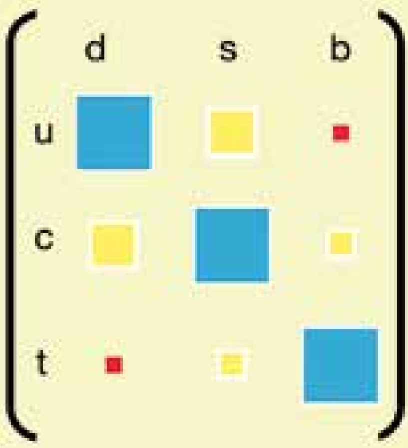
European Southern Observatory,
Garching, GERMANY

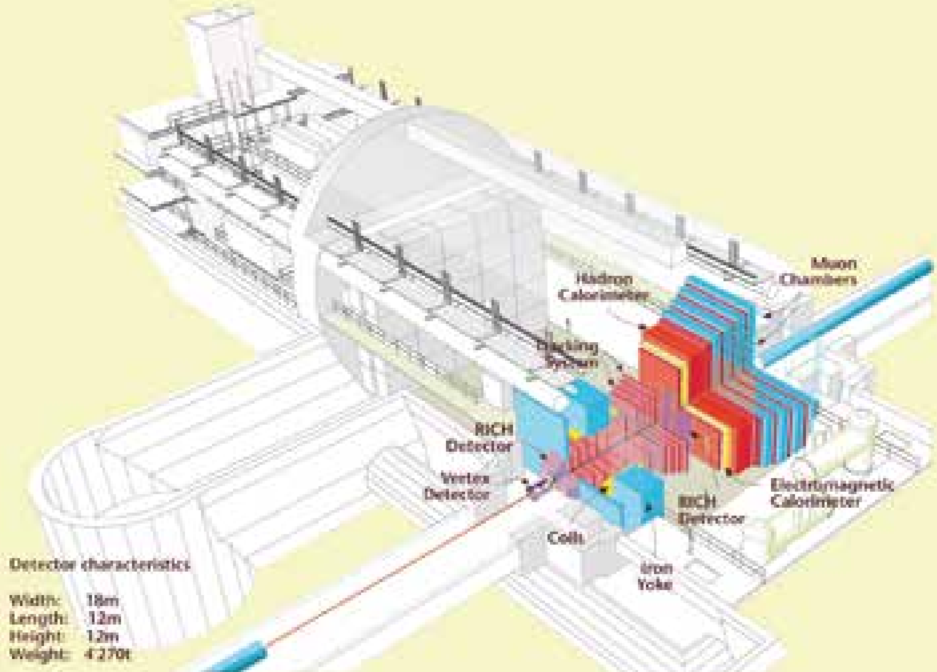
- Precision spectroscopy, direct measurement of the cosmic acceleration
- Light element abundances (Li and Be): primordial nucleosynthesis, galactic enrichment, stellar mixing
- Globular clusters: light elements anti-correlations
- Exo-planets, planets around evolved stars

DR. SOFIA RANDICH

INAF-Osservatorio Astrofisico
di Arcetri, ITALY

- Formation of stars and clusters
- Light element abundances as tracers of internal processes in stars and stellar ages
- Formation and evolution of the Milky Way.





The widely different strengths of transitions between the different quark flavours up, charm, top and down, strange, bottom are illustrated by the size of entries in the matrix on the left. While the strengths remain unexplained, the flavour-changing transitions are investigated by theorists and in experiments such as LHCb (right) to discover small deviations from the expectations that might be caused by "New Physics". *Credit: Left image: MIAPP; right image: LHCb © 1998-2016 CERN*

1st - 24th June 2015

Indirect Searches for New Physics in the LHC and Flavour Precision Era

The Standard Model of elementary particles is an incredibly successful theory of the microscopic laws of Nature, but it lacks a satisfactory explanation for its own structure and a candidate for dark matter and dark energy, prompting particle physicists to search for "New Physics". In this MIAPP programme, they took a close look at the quantum nature of the microscopic processes. By studying the tiny quantum fluctuations with high precision, the existence of a new particle might be revealed indirectly.

COORDINATORS: GERHARD BUCHALLA, GINO ISIDORI, ULRICH NIERSTE, JURE ZUPAN

The Standard Model of particle physics describes how the basic building blocks of matter interact and which forces are involved. The fundamental particles can be classified into force carriers such as photons and matter particles, the quarks and leptons. A curious, unexplained fact is that the matter particles come in three incarnations, called "flavours", which apart from their mass have very similar properties. The Standard Model of particle physics has been completed with the discovery of the Higgs boson in 2012. Nevertheless, particle physicists universally believe that it cannot be the final theory of Nature, since it leaves open fundamental issues related to the Universe at large (the existence of dark matter and dark energy, the origin of the matter over antimatter excess) and to its own structure, notably the origin of flavour, the unification of forces, and the stability of the electroweak scale. The search for the more fundamental theory is colloquially termed the search for "New Physics". This can be done directly, by annihilating particles at very high energies to produce new particles (see the following MIAPP programme), or by exploiting the subtle quantum nature of the theory. This allows new particles to appear "virtually" in small quantum fluctuations, even if not enough energy is available to produce them directly.

The third 2015 MIAPP programme was devoted to these indirect searches for New Physics with a focus on processes that change flavour, which are particularly suited to the purpose. These indirect

Participants of the “Flavour 2015: New Physics at High Energy and High Precision” topical workshop.
Photo: Haneburger/MIAPP

searches are conducted at low-energy experiments based on high-statistics production of muons, kaons, tau leptons, and charm- and B-mesons containing heavy quarks. In view of the current status after the first LHC results, with the discovery of a Higgs-like boson, but no other new particles, the importance of indirect tests is reinforced. In the history of physics this type of approach, i.e. precision measurements and observations of tiny deviations from expectations repeatedly led to breakthroughs and new discoveries. For instance in astronomy, Newton’s laws were known when scientists started to observe planets and planetary orbits with increasing precision. Anomalies in the motion of Uranus have led to the prediction, and subsequent discovery, of the new planet Neptune, invisible to the naked eye. Hence, the existence of Neptune had been anticipated from precision studies before it has actually been seen. In particle physics, the observation of the violation of matter-antimatter symmetry in a very rare decay mode of the longer-lived kaon particle led to the prediction of three generations of matter. The oscillation of a B-meson into its antiparticle pointed to the large mass of the top quark, long before it was observed directly at Fermilab in 1995. In short, there is ample motivation to look for precision observables and for anomalies in rare processes in order to identify new phenomena that so far might not have been seen (directly). Currently, important progress is made in experiments on different fronts, such as the LHC programme, in particular LHCb, which goes to high-statistics production of bottom quarks, as will the future Belle II experiment at KEK in Japan, and a plethora of dedicated experiments on rare kaon decays, lepton flavour violation and electric dipole moments. The MIAPP programme brought together an impressive number of theoretical physicists (and a few experimentalists as well) to sharpen their precision calculations of rare processes and devise optimal observables.

“Since experts in our field attended this workshop, discussions after talks and during the day were very useful and motivating. I really would like to attend more workshops of this type.”
(Prof. Svjetlana Fajfer, Jožef Stefan Institute, Ljubljana, Slovenia)

Artist’s rendering of a so-called rare B-meson “penguin” decay showing the quark-level process. Penguin decays and other rare decays provide powerful indirect probes of New Physics. As contributions from the Standard Model are relatively small in rare decay modes, chances are high that contributions from new virtual heavy particles may be significant and observable as deviations from SM predictions.
Credit: Daping Du, Syracuse University and Maren Hachmann.

As a kick-off to the programme the three-day workshop "Flavour 2015: New Physics at High Energy and High Precision" provided an up-to-date review of the field and attracted many additional participants. Leading scientists from the major experiments were invited to present the current status of their searches. This served as a basis for subsequent discussions during the following weeks of the main programme. Here the emphasis was put on current highlights, open problems and new opportunities. For example, with the Higgs particle now well-established, the question arises,

"I had hoped to make more advance with my own calculations, but the number of relevant discussions was very large, and I did not want to postpone them because having them was the purpose of the workshop. Several interesting projects are in the air, so the programme could not have been better."

(Prof. Mikolaj Misiak, Institute of Theoretical Physics, University of Warsaw, Poland)

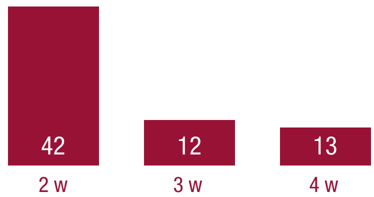
THE INDIRECT SEARCHES FOR NEW PHYSICS IN THE LHC AND FLAVOUR PRECISION ERA

104 registrations

67 participants
from 46 institutions
in 17 different countries

academic seniority:
40 faculty/staff
23 postdocs
4 PhDs

duration of stay:



What was the main focus and essence of this programme?, MIAPP Programme Manager Ina Haneburger wants to know. An interview with the programme coordinators, Gerhard Buchalla, Jure Zupan and Ulrich Nierste.

Gerhard Buchalla: *The main focus of this programme was a theoretical one on flavour and New Physics. However, we tried to make sure that from the major experiments we had leading scientists attending, who were presenting talks and were updating us on the status of the measurements from their experiments.*

Jure Zupan: *These experimentalists are well known scientists who can really drive the direction of research. If we can convince them that there is a chance of a discovery, they might follow our (theorists') advice and vice versa. It's really about finding out what's going on and what's feasible. In many respects, a theory input is needed or useful in order to understand what a measurement means. Regarding what happened between our proposal and the actual workshop: There are always measurements which are either difficult to interpret or may actually have a potentially big impact, but are not yet at the level of significance to say there has been a true discovery. Several such instances happened over the last year or so between the submission of the programme proposal and now. A substantial part of the discussions at the programme was how these results could be understood or resolved. So, discussions involved a short-term understanding of what's going on and also the long-term vision of where precision physics can be.*

Gerhard Buchalla: *To mention one particular example of a new direction, traditional observables are mostly rare processes of B-mesons or kaons. But now, since the recent discovery of the Higgs boson, the scientific community is thinking of flavour properties of the Higgs, i.e. how does the Higgs particle couple to different types of quarks and leptons. There has been even a totally unexpected experimental hint, which would be extremely exiting/surprising if it turns out to be true, but is not yet confirmed. According to these data the Higgs particle decayed to tau and mu, different flavours of leptons at the same time, which should not occur in the Standard Model...*

Ina Haneburger: *Where was this detected?*

Gerhard Buchalla: *At the LHC, at the CMS experiment…*

Jure Zupan: *… one of the two large general purpose experiments at CERN. The other still has to confirm this measurement...*

Gerhard Buchalla: *… but this is really a very speculative result ...*

Jure Zupan: *It's speculative but it's not completely crazy theoretically, which means it's interesting!*

Ulrich Nierste: *Another thing which we were discussing here, were some decays where the b-quark goes to strange-quark and a pair of muons. There are several measurements pointing into the direction of New Physics but each measurement by itself is not significant enough, and that's where theory is needed. So if you do a combined analysis of these measurements you can analyse it first within the Standard Model and then in a well-defined scenario of New Physics and compare whether it can describe the data. A priori, it could happen that no New Physics model would give a better description but that was not the case. In this situation when we combined everything we got get a very tantalizing hint of New Physics. And that was something we discussed a lot at this programme. This is one example of a hot topic which arises because there is so much experimental activity which stimulates our theory work.*

whether it changes the flavour of matter. While the Standard Model says it does not, this occurs naturally in many theories of "New Physics". Shortly before the programme, the CMS experiment released a vague but tantalizing hint that the Higgs particle decays into a tau lepton and muon simultaneously, which triggered much theoretical speculation. The new opportunities for the field provided by the Higgs particle and the suspected dark matter particle was reflected in many presentations revolving around "Higgs and Flavour", "Flavour at high and low pT" and "Light/Exotic New Physics, Dark Matter and Flavour" from various perspectives. The rare B-meson decay $B \to K^{(*)}\ell\ell$ provides a unique probe of electroweak flavour-changing quantum effects and has been a highlight of flavour physics thanks to the more and more precise measurements from the LHCb experiment. Several theoretical groups pursue the interpretation of the data, sometimes disagreeing on the details of their analysis and in particular the estimate of their uncertainties. All groups were represented at the MIAPP programme, leading to intense discussions. The theoretical interpretation of precision measurements involving the strongly interacting quarks is often complicated. A combination of analytic computations and numerical simulations of quantum chromodynamics ("lattice QCD") is required, but often the present technological limits do not permit to complete the task. Theorists present at the programme published what might be the first significant lattice QCD computation of direct CP symmetry violation in kaon decay, prompting immediate further work at the programme.

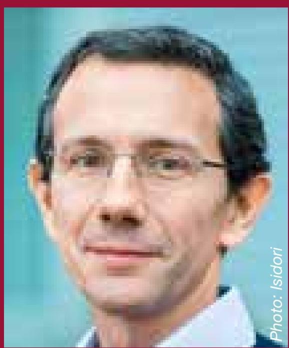
The coordinators declared themselves very satisfied with the outcome of the programme, noting that it "has already started to produce new results." Quite a few participants also stayed on for the subsequent programme, emphasizing the interdisciplinary nature of the search for New Physics.

COORDINATORS OF THE PROGRAMME "THE INDIRECT SEARCHES FOR NEW PHYSICS IN THE LHC AND FLAVOUR PRECISION ERA"

PROF. GERHARD BUCHALLA

LMU Munich, GERMANY

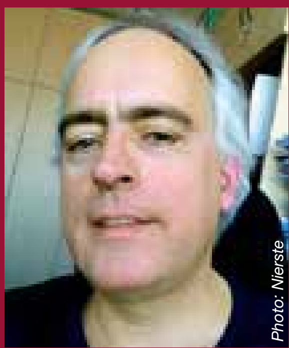
- Theoretical high energy physics
- Physics of flavour, rare processes and CP violation
- Electroweak symmetry breaking and Higgs physics
- Effective field theories



PROF. GINO ISIDORI

University of Zurich, SWITZERLAND

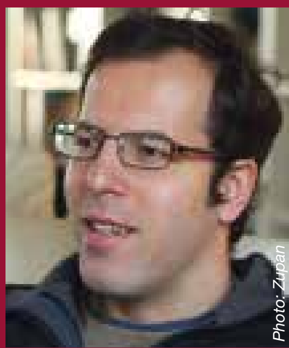
- Origin of quark and lepton masses
- Electroweak physics
- Hierarchy problem
- Effective field theories (EFT)



PROF. ULRICH NIERSTE

Karlsruhe Institute of Technology, GERMANY

- Beauty and charm physics
- CP violation
- Physics beyond the Standard Model
- Radiative corrections



PROF. JURE ZUPAN

University of Cincinnati, USA

- Theoretical high energy physics with particular interest in
- Dark matter
- Rare processes
- New Physics searches at the LHC

The Standard Model provides a good description of the subatomic world. Nevertheless several questions remain unanswered. At collider experiments and especially at the Large Hadron Collider, shown here, physicists work on identifying physics beyond the Standard Model. *© 2015-2016 CERN; OPEN-PHO-ACCEL-2015-001; LHC season 2: 3D dipole integration showing several parts with an interconnection open*

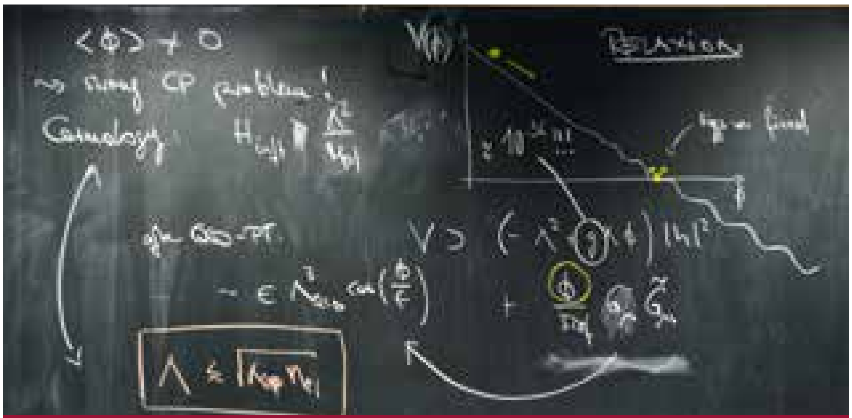
29th June - 24th July 2015

Anticipating 14 TeV: Insights into Matter from the LHC and Beyond

Although the Standard Model of elementary particles serves well to describe the known subatomic world and predicted the Higgs boson, it is unlikely to be the final theory of Nature. Smaller constituents of matter and new forces have traditionally been found by smashing particles together with ever higher energy. Just months after the Large Hadron Collider at CERN was turned on with an unprecedented energy of 13 TeV, experts in the fields of physics beyond the Standard Model, LHC physics, and dark matter met at MIAPP to discuss expectations, possibilities and challenges provided by particle collisions at the highest energies.

COORDINATORS: CSABA CSAKI, LISA RANDALL, MICHAEL RATZ, ANDREAS WEILER

One of the top priorities of particle physicists today is the search for “New Physics”, the physics beyond the Standard Model (SM), which would finally explain why the Higgs boson is so light, why there are three generations of matter particles, explain the imbalance between matter and antimatter, the nature of dark matter and why neutrinos are almost massless. The answer to these questions is most likely to be found by investigating the laws of Nature at smaller and smaller distances. One way to probe smaller distances is to use more powerful accelerators, in which two particles collide into each other at really high energies. In this sense, the Large Hadron Collider (LHC) with its 27 km circumference is the most powerful microscope in the world, which can resolve structures many thousand times smaller than the diameter of a hydrogen nucleus. After a nearly two-year shut-down, the LHC began to operate at 13 TeV in April 2015, shortly before the start of this MIAPP programme. (The anticipated 14 TeV energy will be reached in the next upgrade.) This is almost twice the previous collision energy and around 14,000 times the energy that is needed to make a proton. Experimenters can now investigate the particles’ internal structure with improved resolution or create new particles, which leave their traces in the debris of the collision. Hopes are therefore running high to find “New Physics.” At this timely moment, nearly 80 physicists, half of them from the American continent, met at MIAPP to take stock of their theories and to develop new ideas.



The recently proposed relaxion mechanism became the focus of many discussions. *Photo: MIAPP*

After the observation of the Higgs particle by the ATLAS and CMS experiments, the exploration of the Higgs particle properties has just begun to develop. This topic therefore formed a logical emphasis of the programme. The high-energy run of the LHC provides physicists with a historical chance to discover new particles relevant for the quantum stabilization of the Higgs potential and to elucidate the mechanism of electroweak symmetry breaking. Theoretically appealing explanations of these issues require extensions of the SM. Several sessions at the programme were devoted to this field of research. A long series of presentations focused on composite Higgs models and discussions of the phenomenology of possible exotic Higgs physics. In composite Higgs models, so far speculative, the Higgs boson is a bound state formed by a new strong interaction just as the proton and neutron were found to be bound states of quarks in quantum chromodynamics. A composite Higgs would lead to deviations in the measurements of the Higgs couplings from the SM expectation suppressed by the scale of compositeness, as well as to the existence of light top quark partners and heavier composite states. The energy upgrade of the LHC increases the sensitivity to the heavier partner masses and hence requires new search strategies involving jet substructure techniques. Of crucial importance in discriminating between a weakly and a strongly coupled stabilization mechanism of the Higgs is the $W_L W_L \to W_L W_L$ amplitude. The upgraded LHC starts to be sensitive to its behaviour and therefore simple effective models for the upcoming searches are needed. Other interesting possibilities include exotic decays of the Higgs boson, and alternative proposals on the nature of the scalar resonance, such as a hypothetical Higgs-like dilaton particle. In addition to that, twin Higgs models and neutral naturalness in general were greatly discussed throughout the programme. An unexpected topic that has become the focus of many discussions was the recently proposed relaxion mechanism. According to this mechanism the existence of a light Higgs boson and low electroweak symmetry breaking scale is connected to the cosmic evolution. The model promotes the squared Higgs mass parameter to a dynamical variable that evolves during inflation and finally stabilises at a small negative value.

Next to the Higgs particle properties and models, the possible signals of a dark matter particle, if produced in a particle collision at LHC, were another hotly discussed topic at the programme. Contrary to the Higgs boson, no evidence of a dark matter particle has yet been seen. As this particle must be stable, electrically neutral and very weakly interacting, dark matter is invisible at the LHC and can only be determined indirectly. Theories abound. While most researchers

“The people that were brought to the workshop were of the highest caliber, and the perfect mix of junior vs senior physicists.”
(Prof. Jay Hubisz, Syracuse University, USA)

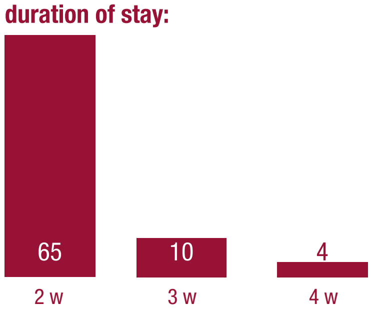
ANTICIPATING 14 TEV: INSIGHTS INTO MATTER FROM THE LHC AND BEYOND

138 registrations

79 participants
from 42 institutions
in 12 different countries

academic seniority:
45 faculty/staff
30 postdocs
4 PhDs

duration of stay:



Impressions from the “Anticipating Discoveries: LHC14 and beyond” topical workshop held at the Institute for Advanced Studies. This three-day conference was embedded into the four-week programme and featured physics beyond the Standard Model with focus on LHC physics and dark matter. The broader scope stimulated discussions during and in the aftermath of the workshop. *Photos: Schürmann*

"Fantastic scientific discussions. During just two weeks, we have a promising direction for a new project between postdocs in four different institutions spanning three time zones and two continents."
(Dr. Philip Tanedo, UC Irvine, USA)

believe that dark matter is composed of one type of particle, it might as well be several. According to a new hypothesis forwarded by one of the programme participants, these new dark matter particles would consist of heavy "dark protons" and light "dark electrons" and would open a new world of dark matter physics allowing a variety of interactions between dark photons and dark electrons mediated by dark forces. While the programme naturally focused on collider-physics aspects of dark matter, it also featured presentations on the complementary astroparticle-physics search strategies, covering, among others, the interaction of dark matter, the determination of correct abundances from relative red shifting and a possible dark matter evidence from an excess of radiation from the galactic centre.

Supersymmetric extensions of the SM are still considered among the leading contenders for New Physics at the LHC. In supersymmetric theories a partner is predicted for each particle in the SM. If the theory is correct, these particles would explain the mass of the Higgs boson and hence fix one of the major problems of the SM. These particles should eventually be seen in collisions at the LHC. The important topic of flavour physics of extensions of the SM was also considered in the context of constructing satisfactory theories beyond the SM. An intriguing general possibility is that the stabilization of the Higgs sector is connected to the generation of the SM flavour structure. Therefore, it is important to consider direct and indirect constraints of flavoured models in conjunction, since flavour can affect the sensitivity of particle searches at LHC dramatically.

While the search for New Physics has remained inconclusive up to now, and the multitude of theoretical ideas appears as confusing as impressive in times, the interest in uncovering the fundamental laws of Nature is overwhelming, making this the most oversubscribed MIAPP programme in the period of the present report.

COORDINATORS OF THE PROGRAMME "ANTICIPATING 14 TEV: INSIGHTS INTO MATTER FROM THE LHC AND BEYOND"

PROF. CSABA CSAKI
Cornell University, Ithaca, USA

- Physics beyond the Standard Model and the TeV scale
- Physics at the LHC
- Non-conventional super-symmetric models and their signals
- Composite Higgs models
- Models of neutral naturalness, their LHC signals and their flavour structure

PROF. LISA RANDALL
Harvard University, Cambridge, USA

- Theoretical particle physics and cosmology
- Large Hadron Collider and dark matter searches and models.

PROF. MICHAEL RATZ
Technical University of Munich, GERMANY

- Unified theories in four and more dimensions
- Advanced topics in quantum field theory (anomalies, super-symmetry etc.) dark matter
- Origin of neutrino masses (seesaw and alternatives)
- Explanation of dark matter/ baryogenesis

PROF. ANDREAS WEILER
CERN, Geneva, SWITZERLAND

- Theoretical high energy physics
- Beyond the Standard Model
- Collider physics

Determination of the star formation history of the Universe is fundamental to understand how galaxies form and evolve over cosmic time. Infrared image of the star formation region Monoceros R2, located some 2,700 light-years away. *Photo: ESO/J. Emerson/VISTA (Cambridge Astronomical Survey Unit).*

27th July - 21st August 2015

Star Formation History of the Universe

A fundamental goal of modern cosmology is to understand the formation and evolution of the populations of galaxies in the Universe. There has been spectacular progress over the last 15 years, especially with the surveys of the very distant Universe and the discovery of new populations of galaxies and supermassive black holes. The investigation of star formation history, the rates at which massive stars are born in galaxies, is the primary tool of astronomers to study how galaxies form and evolve over cosmic time.

COORDINATORS: AMY BARGER, ANDREAS BURKERT, RICHARD DAVIES, GUINEVERE KAUFFMANN

Understanding the origin and evolution of galaxies is fundamental to unravel the formation of cosmic structures, and to understand the events that took place after the formation of the first stars. Since the end of the cosmic dark ages and the reionization of the Universe by the first generation of stars an enormous diversity of building blocks of galaxies with different metallicity, colours, forms, sizes, masses, etc. developed, resulting in the galaxy diversity astronomers can observe today. Approximately 3.5 Gyr after the Big Bang the star formation rate peaked and later dropped exponentially. With a peak rate of nearly nine times the star formation rate of today the Universe was much more active in the past. For most galaxies formed since the peak, a tight correlation between star formation rate and galaxy mass can be observed. This dominating population of "main-sequence galaxies" suggests a strong interdependence of gas accretion processes and other processes related to the galaxy mass. Only a small fraction originated from so-called starburst regions with elevated star formation rate.

Modern astronomy uses telescopes on the ground and in space which cover the full range of the electromagnetic spectrum from the extremely short wavelengths of gamma-rays to the very large radio wavelengths. This is especially important for the study of galaxies through cosmic time, as due to the expansion of the Universe, ultraviolet light created by young stars in the star formation process is stretched for the very distant objects to infrared light (the so-called redshift z). Moreover, much of the UV and visible light emitted by stars in galaxies is reradiated by dust into the far-IR (30 – 300 μm) or submm (300 – 1000 μm) wavelength range, depending on the redshift of the galaxy. Thus, without additional observations at these wavelengths, it is very difficult to determine accurately the rate at which stars form, making the total amount of star formation in the Universe at any given time quite uncertain. In particular, many of the largest star-forming galaxies may be missed if a purely optical selection is applied. Revolutionary facilities like the Herschel Space Telescope, the Sub-millimeter Array, SCUBA-2 on the JCMT, and the Atacama Large Millimeter/sub-millimeter Array now allow the screening at these longer wavelengths and started the era of far-IR/sub-mm astronomy. Very important to consider is cosmic dust, as it is abundant throughout the Universe, and hence, influences all astronomical observations. Therefore, cosmic dust and its features have been prominently discussed in the course of the programme. Exciting discoveries of very high-redshift dusty galaxies ($z > 4$), and detailed analyses of the properties of dusty galaxies at all redshifts become possible with the techniques available today. With these observations at hand one can examine how the dusty population relates to UV/optical samples and follow their evolution into galaxies seen at redshift $z \leq 2$, where the star formation occurs in large part. Hence, following the evolution of galaxies to the present day is a challenging prospect due to different wavelength observations and different selection criteria.

In the relaxed environment at MIAPP, observers and theorists had the opportunity to reconcile their apparently very diverse ideas. For example, theorists pointed

STAR FORMATION HISTORY OF THE UNIVERSE

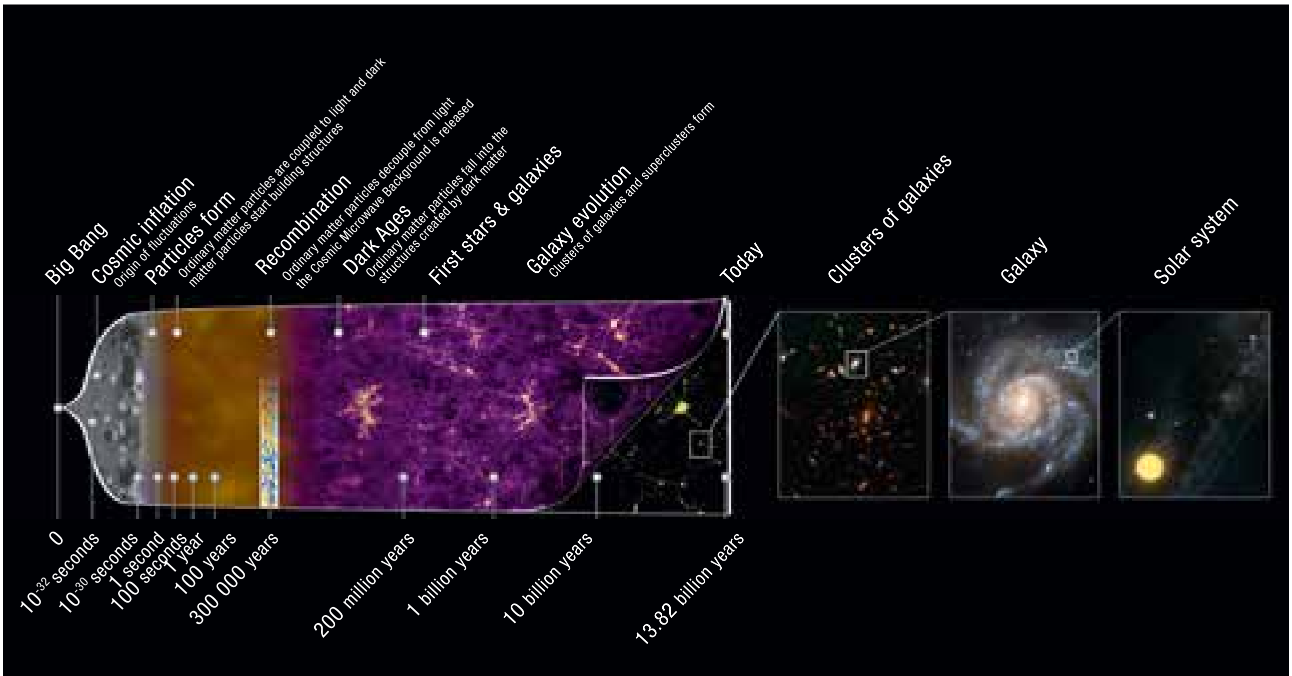
77 registrations

49 participants
from 31 institutions in
13 different countries

academic seniority:
26 faculty/staff
16 postdocs
7 PhDs

duration of stay:

"I am extremely pleased with my overall experience. Time spent at the workshop was very productive and enriching. I plan to attend another workshop in Apr 2016 and am considering organizing a new workshop myself. This is an extremely useful avenue and format, please continue this programme."
(Prof. Nick Gnedin, Fermilab, USA)



Understanding the events and the prerequisites for star formation helps to unravel the diversity of galaxies astronomers can observe today. © *ESA – Christophe Carreau* out that for constraining the theoretical models observers should make a better effort to include systematic errors as well as statistical errors in their plots. Thus, theorists get a better sense of the significance of their claims, especially when they deal with variations in the observational results obtained from different surveys, which are often not consistent within the quoted error bars. The theorists also suggested that observed quantities be plotted rather than derived quantities, as the latter require a lot of assumptions that the theorists would prefer to make themselves as part of their simulations. They would then be able to compare their theoretical predictions with a range of observational studies more straightforwardly.

Star formation participants at the observatory on Mount Wendelstein, close to Munich. *Photo: Barger*

Another prominent theme at the programme was the importance of the growth of the central bulges for understanding galaxy evolution. The bulge of a galaxy is the tightly packed group of stars at the centre of a (spiral) galaxy. Currently there is a severe controversy within the community about the concept of classical versus pseudo bulges. At MIAPP the researchers did not come to a consensus about whether a bulge is a photometric or mass concentration, nor about whether it must be spheroidal or can be disky. It became clear that there is a severe mismatch between low and high redshifts: at low redshifts, it is known that many galaxies have central concentrations (pseudo bulges) that are not spheroidal, while the data at high redshifts are not good enough to constrain the physical nature of bulges at all. The Milky Way remains a problem. Its bulge has characteristics of both classical (old stars) and pseudo (dynamically it resembles a bar buckling) bulges. Despite observations of hundreds of galaxies at z = 1 - 3, none has been identified as a possible progenitor of a galaxy like the Milky Way with its bulge. Simulations also typically have difficulties producing Milky Way-like galaxies. The properties of bulges and pseudo-bulges may hold the key to understanding galaxy growth and formation, but tracing that process back via local galaxy observations is very complex, because their structures are a relic of the combined events in the galaxy's evolution over time. At the programme the role of bulges in the decrease of the cosmic star formation rate from z = 2 to z = 0 has been

"Thanks for letting me be involved. I really enjoyed the experience. As a fairly junior postdoc new to the field, it was a great opportunity for me to meet the experts and spend a decent amount of time with them to discuss my research and get suggestions. I learned a lot very rapidly. The staff and facilities were excellent and the whole trip was pleasant and enjoyable."

(Dr. Jacinta Delhaize, University of Zagreb, Croatia)

discussed heavily together with many other important topics related to the star formation history of the Universe. Observers and theorists debated details of the physics of the star formation process, i.e. the transformation of gas into stars, the production of heavy elements, the reionization of the Universe and how this can be assessed by a range of complementary techniques and theoretical tools. Very promising new concepts were presented and further developed which have great potential to lead to a better understanding of the star formation history of the Universe.

The Atacama Large Millimeter/sub-millimeter Array (ALMA) on the Chajnantor Plateau, at an altitude of 5,000 m, and other powerful facilities allow observations of the Universe at longer wavelength providing new insights in the star formation history. *Credit: ESO*

COORDINATORS OF THE PROGRAMME "STAR FORMATION HISTORY OF THE UNIVERSE"

PROF. AMY BARGER

University of Wisconsin-Madison, USA

- Observational cosmology
- Distant galaxies and supermassive black holes
- Observations at multiple wavelengths
- Star formation and accretion histories of the Universe

PROF. ANDREAS BURKERT

Ludwig-Maximilians-University, Munich, GERMANY

- Structure and formation of dark matter halos
- Formation and evolution of galaxies
- Structure of the multi-phase, turbulent interstellar medium
- Formation of stars and stellar clusters.

DR. RICHARD DAVIES

Senior Scientist, MPI for Extraterrestrial Physics, Garching, GERMANY

- Formation and evolution of galaxies
- Active galactic nuclei
- Adaptive optics observations

PROF. GUINEVERE KAUFFMANN

MPI for Astrophysics, Garching, GERMANY

- Modelling the formation and evolution of galaxies
- Observed properties of galaxies and their supermassive black holes
- Wide-field galaxy surveys

Neutron stars are very rapidly rotating compact massive stellar objects consisting of densely packed neutrons and have an extremely strong magnetic field. They are the remnants of supernova explosions at the final stages of the life of massive stars. Neutron stars are cosmic lighthouses emitting signals of radiation with periods as short as a thousandth of a second. *Photo: ESO/L.Calçada. Artist's impression of a magnetar, i.e. a neutron star with an extremely potent magnetic field.*

24th August - 19th September 2015

The Many Faces of Neutron Stars

Neutron stars are among the most exciting objects in the Universe. They are born after the supernova core collapse of a massive star when the remaining mass (more than two solar masses) is densely compressed into an object with a small radius (~10 km). They rotate rapidly with periods between a second and a millisecond and exhibit magnetic fields and gravitational fields of enormous strengths. Although there has been a dramatic increase in knowledge on neutron stars, based on observations and theoretical models, there is still a lot to explore. In the course of the sixth 2015 MIAPP programme observational and theoretical astrophysicists as well as nuclear physicists met to develop an improved understanding of neutron star physics.

COORDINATORS: WERNER BECKER, DAVID BLASCHKE, ED VAN DEN HEUVEL, PHILIPP PODSIADLOWSKI, MICHAEL KRAMER, NICK KYLAFIS, JOACHIM TRÜMPER

Neutron stars – signals from extraterrestrials. Neutron stars form during a supernova explosion in the final phases of the life of a massive star. During the explosion the stellar core collapses and forms a neutron star, while all other remnants are carried away. As neutron stars maintain most of the angular momentum of their parental star, yet are much smaller, they revolve extremely fast. The interaction of particles with the strong magnetic field produces detectable periodic radio signals, where the period is determined by the stellar rotation. As these signals are regularly repeating themselves, neutron stars are also called "pulsars". These signals were first discovered by Jocelyn Bell (Burnett) when she observed radio signals with a rather simple antenna and detected a faint but regular signal. Soon, researchers realised that this signature was not the effort of some extraterrestrials to contact earthlings but rather originated from a very small (about 10 km in radius) but very heavy (about two times the weight of the sun) star. Besides their heaviness and strong magnetic field neutron stars show a remarkable observational diversity with respect to the type and timing of their signal. Neutron stars can be distinguished according to their pulsing signal into radio pulsars, millisecond pulsars, rotating radio transients (RRATs), X-ray sources in high- and low-mass binary systems, isolated neutron stars showing quasi-thermal X-ray emission (XDINs) and soft gamma-ray repeaters, which exhibit occasionally huge outbursts in soft gamma-rays that may outshine all other cosmic soft gamma-ray sources combined. Neutron stars with the strongest magnetic fields are called magnetars. The unique and diverse traits of neutron stars allow many branches of physics to use them for either fundamental research or to apply known physics to exotic astronomical phenomena.

Many of the different faces of neutron stars have been discussed during the four-week programme, starting with talks focusing on the formation of neutron stars in the first week. Albeit a dramatic progress in recent years many questions concerning the formation of neutron stars remain unsolved. It became clear that the favoured postulated explosion mechanism, delayed neutrino heating, basically works but needs further investigation. Improved model simulations are needed to quantitatively assess a number of important questions. These questions include the formation and evolution of magnetic fields of neutron stars and the emission mechanism leading to the observed periodic radiation pulses. Interestingly, two completely different pictures have been proposed with respect to the emission mechanism of magnetars.

Neutron stars are not only equipped with a strong magnetic field but are also very dense objects with enormous gravitational fields. Consequently, their physical understanding requires the application of nearly all fundamental forces and hence in turn they can be used to test theoretical predictions. Therefore, the participants took a closer look at these applications, ranging from the equation of state of super-dense matter to theories of gravity. While some very precise mass measurements for neutron stars exist, radius measurements are still rather uncertain and controversially discussed between different groups of observers. One dilemma is that radius determinations rely on the extraction of radius estimates from observations that cannot directly be verified. Also, knowledge of the atmospheric composition of the neutron star is crucial as the determined radii vary depending on the

"I have met many new people working on different "faces" of neutron stars than I (radio pulsar emission), such as equation of state, tests of general relativity, magnetic fields of neutron stars, pulsar magnetosphere models. We had many interesting discussions, and I learned a lot, and hope other people also learned from me about studies of radio pulsars, especially millisecond pulsars, we are doing with the LOFAR telescope."
(Dr. Vladislav Kondratiev, ASTRON, Netherlands Institute for Radio Astronomy, Dwingeloo, the Netherlands)

Extraordinary sounds at MIAPP. Meetings at MIAPP inspire the participants to collaborate in manifold ways. *Photo: Haneburger/MIAPP*

Light echoes from Circinus X-1 allowed to precisely determine its distance to Earth. The rings recorded by NASA's X-ray observatory Chandra arise from bursts of X-rays. The X-rays originate from the neutron star and are ricocheted of clouds of dust between Circinus X-1 and the observatory. *Credit: X-ray: NASA/CXC/Univ. of Wisconsin-Madison/S. Heinz et al; Optical: DSS*

"Such a long-term conference provides our community with a good chance to discuss the current situation of our field, and stimulates us to make a consensus of our field."
(Prof. Teruaki Enoto, Department of Astronomy, Kyoto University, Japan).

dominating atom. All in all the programme was considered to have been really successful. It brought together leaders of the field which belong to different communities and were able to interact and discuss their different point of views, especially on controversial issues like the radius measurements and the equation-of-state theory. Thus, it contributed to a better mutual understanding which will help to define the directions of future research and collaborations and hence also facilitated the scientific discourse. The mixture of participants with different backgrounds allowed very broad and comprehensive discussions, leading to new ways of looking at old problems.

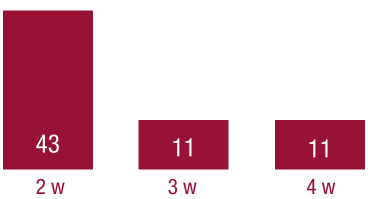
THE MANY FACES OF NEUTRON STARS

99 registrations

65 participants
from 46 institutions
in 17 different countries

academic seniority:
50 faculty/staff
10 postdocs
5 PhDs

duration of stay:



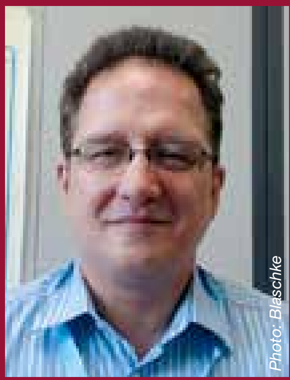
Philipp Podsiadlowski, Joachim Trümper and Thomas Tauris discussing neutron stars at a happy hour event. *Photo: Haneburger/MIAPP*

COORDINATORS OF THE PROGRAMME "MANY FACES OF NEUTRON STARS"

PROF. WERNER BECKER

MPI for Extraterrestrial Physics, Garching, GERMANY

- Neutron stars
- X-, Gamma-ray, optical and radio astronomy
- General relativity and cosmology
- Gravitational waves and their detection
- Spacecraft navigation by pulsar signals and their flavour structure



PROF. DAVID BLASCHKE

University of Wroclaw, POLAND

- The physics of neutron stars
- Quantum field theory
- Matter at extreme conditions
- Astrophysics

PROF. ED VAN DEN HEUVEL

Anton Pannekoek Institute for Astronomy, Amsterdam, NETHERLANDS

- Stellar and binary evolution
- Physics and formation of X-ray binaries
- Formation of binary pulsars
- Gamma-ray bursts

PROF. PHILIPP PODSIADLOWSKI

University of Oxford, UK

- Theoretical astrophysics
- Stellar evolution theory with applications to binary stellar evolution, supernovae, gamma-ray bursts, galaxy evolution, planet formation
- Stellar hydrodynamics

PROF. MICHAEL KRAMER

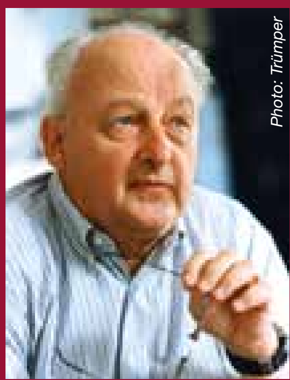
MPI for Radio Astronomy, Bonn, GERMANY

- Gravitational physics & cosmology
- Pulsar & neutron star properties
- Binary & stellar evolution

PROF. NICK KYLAFIS

University of Crete, GREECE

- Theoretical astrophysics
- Production and transfer of radiation
- Compact X-ray sources
- Spiral galaxies



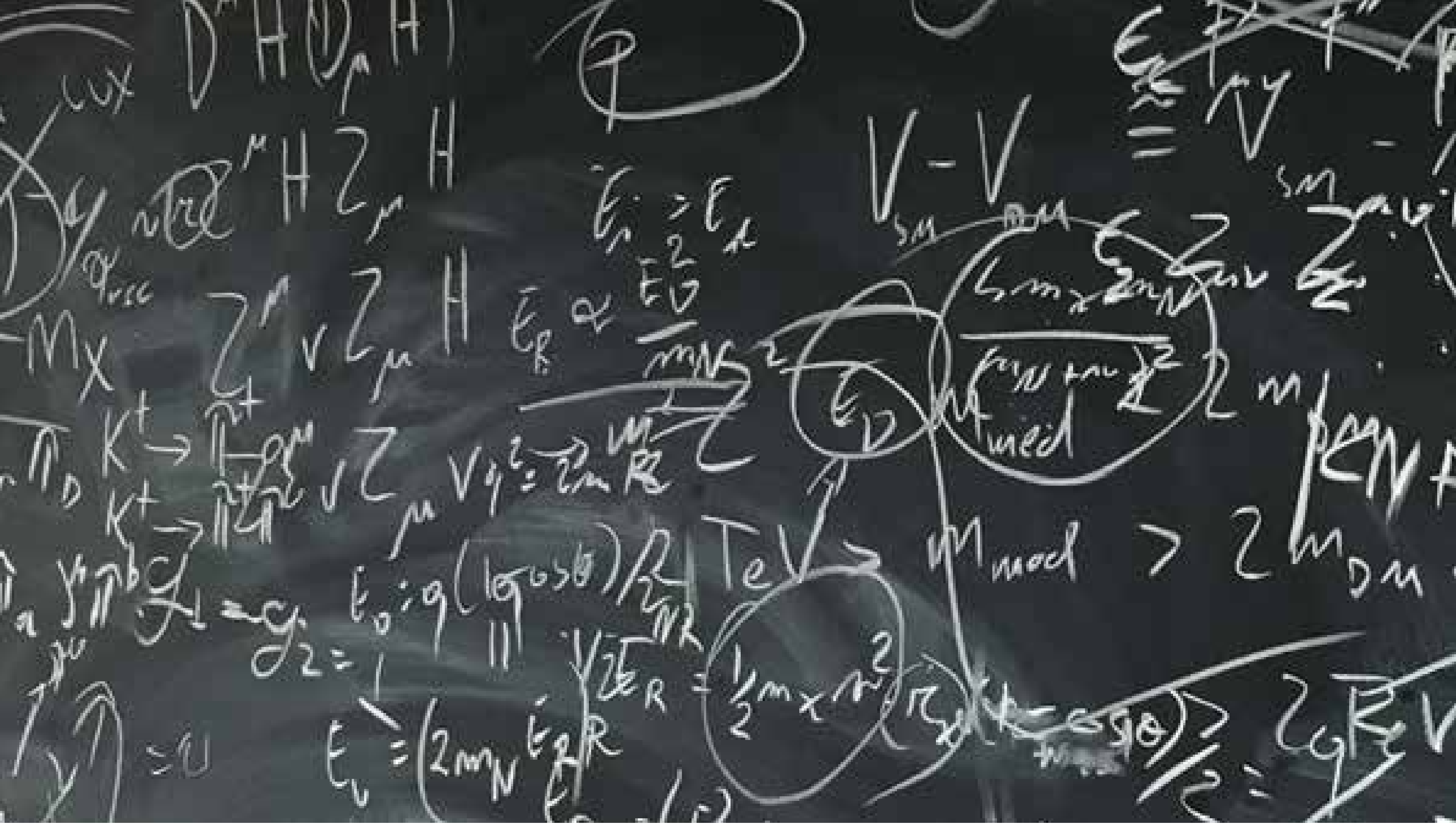
PROF. JOACHIM TRÜMPER

MPI for Extraterrestrial Physics, Garching, GERMANY

- The physics of neutron stars
- Cosmological evolution of active galaxies

"I think it was 100% great. Good balance between scheduled activities and free time, good number and choice of participants, adequate length of presentations, extremely friendly and helpful staff, and adequate infrastructure."

(Prof. Andreas Reisenegger, Pontificia Universidad Católica de Chile, Santiago, Chile)



FACTS & FIGURES

The MIAPP building at the Forschungszentrum Garching. *Photo: MIAPP*

What is MIAPP?

The Munich Institute for Astro- and Particle Physics (MIAPP) is part of the Excellence Cluster Universe and was founded in 2012 to foster and strengthen the scientific exchange and international discourse among physicists. It is financed through the Excellence Initiative of the German Science Foundation (Deutsche Forschungsgemeinschaft).

MIAPP hosts six four-week programmes and several shorter workshops every year. Scientists from all over the world can submit proposals covering recent and exciting topics from astrophysics, cosmology, particle and nuclear physics. An international committee decides on the programme schedule to ensure an appealing and high-quality programme.

In order to set MIAPP apart from an ordinary conference venue and to allow every participant to benefit

MIAPP seminar room. *Photo: Haneburger/MIAPP* from the MIAPP programme in the best possible way, a minimum stay of two weeks is required. To ensure informal interaction, attendance is limited to 45 participants at any time. Office space for individual work is available for every participant and most of the offices are in the MIAPP building, facilitating scientific interchange. The MIAPP building is located on the campus of the Max Planck Institute for Plasma Physics (IPP) in Garching. It is situated in the immediate vicinity of the physics department of the Technical University of Munich, the Max Planck institutes in Garching and the European Southern Observatory (ESO) and therefore is the ideal place for scientific collaboration with local colleagues to thrive.

MIAPP lounge area. *Photo: Haneburger/MIAPP*

Within its four-week programmes MIAPP hosts around 400 scientists per year. Approximately one third of them is from a local partner organisation. External participants are financially supported in order to assist their extended stays.

To ensure lively discussions and fruitful interactions the coordinators are recommended to invite a well-balanced mixture of experts, established scientists and young researchers. The participation of excellent PhD students is supported by up to five MIAPP student fellowships with an additional financial contribution to their travel costs.

The scientific coordinators of each programme, all experts in the field of the programme focus, organise the schedule during their programme according to their own preferences. As MIAPP programmes should be distinct from regular conferences, only one to two scientific presentations or discussion sessions, often less, are scheduled every day, in order to leave enough time for individual work and collaboration.

A typical MIAPP desk. Office sizes range from single offices to larger offices with up to four desks. Every desk is equipped with a telephone, desk lamp, LAN cable, base cabinet and office supplies. *Photo: Haneburger/MIAPP*

The spectrum of scientific sessions covers plenary talks, discussion sessions, mini-workshops as well as chalk and talk sessions held in the MIAPP lounge area. Every room is equipped with either a white or a black board. Thus, ideas and thoughts can directly be noted down and be shared with other MIAPP attendees. The common areas serve as interaction platforms and meeting points for planned and spontaneous chats. To recharge the batteries during the day a fully equipped kitchen is at the participants' disposal. In-between talks the MIAPP staff prepares coffee breaks for the participants. At get-togethers organised by the MIAPP staff, new ideas can be discussed in a more relaxed atmosphere and new collaborations and networks can be started in MIAPP's stimulating environment.

The MIAPP team: Theresa Kämper (assistant), Prof. Martin Beneke (director), Tina Jacobs (assistant), Prof. Rolf Kudritzki (director), Ina Haneburger (programme manager) and Mario Neßler (system administrator).
Photo: Eckert & Haneburger

The MIAPP Team

The organisation of the MIAPP programmes is in the hands of a small team, directed by Prof. Dr. Martin Beneke, particle physicist at Technical University of Munich and Prof. Dr. Rolf Kudritzki, astrophysicist at Ludwig-Maximilians-University Munich and University of Hawaii. The directors coordinate the operation of MIAPP and ensure the high scientific level of the programmes. Programme manager Dr. Ina Haneburger leads the administrative staff and supports the coordinators in the scientific preparation of the programme and their follow-up assessment, reporting and documentation. The MIAPP assistants arrange for a smooth transition from the selection of a programme towards its implementation. They communicate with the scientific coordinators on the process of participant selection, with the attendees during the preparation of the programme (housing, visa, etc.) and are in charge of the programme's website. Shortly before the start of a programme the MIAPP team prepares the venue to welcome the new guests. As every participant gets a designated desk, offices need to be assigned and prepared for them. Upon arrival every attendee is welcomed with a personalised folder containing the most important information about MIAPP. During the programme the MIAPP team takes care of coffee breaks and organises informal get-togethers. In order to ensure a fast processing of the financial support the MIAPP team assists with and handles the paperwork. With enthusiasm and dedication the MIAPP team helps in every circumstance. In the MIAPP office, Tina Jacobs and Theresa Kämper are on-site during the day and ready to assist. System administrator Mario Nessler lends a helping hand in all IT issues. The MIAPP team is backed by the administrative team of the Excellence Cluster. Cluster accountants Gabriele Hartmann and Thomas Würstl, in particular, take care of the financial processes. Team assistant Sonja Lutz stands in whenever additional hands are needed.

Committees

SCIENTIFIC ADVISORY BOARD:

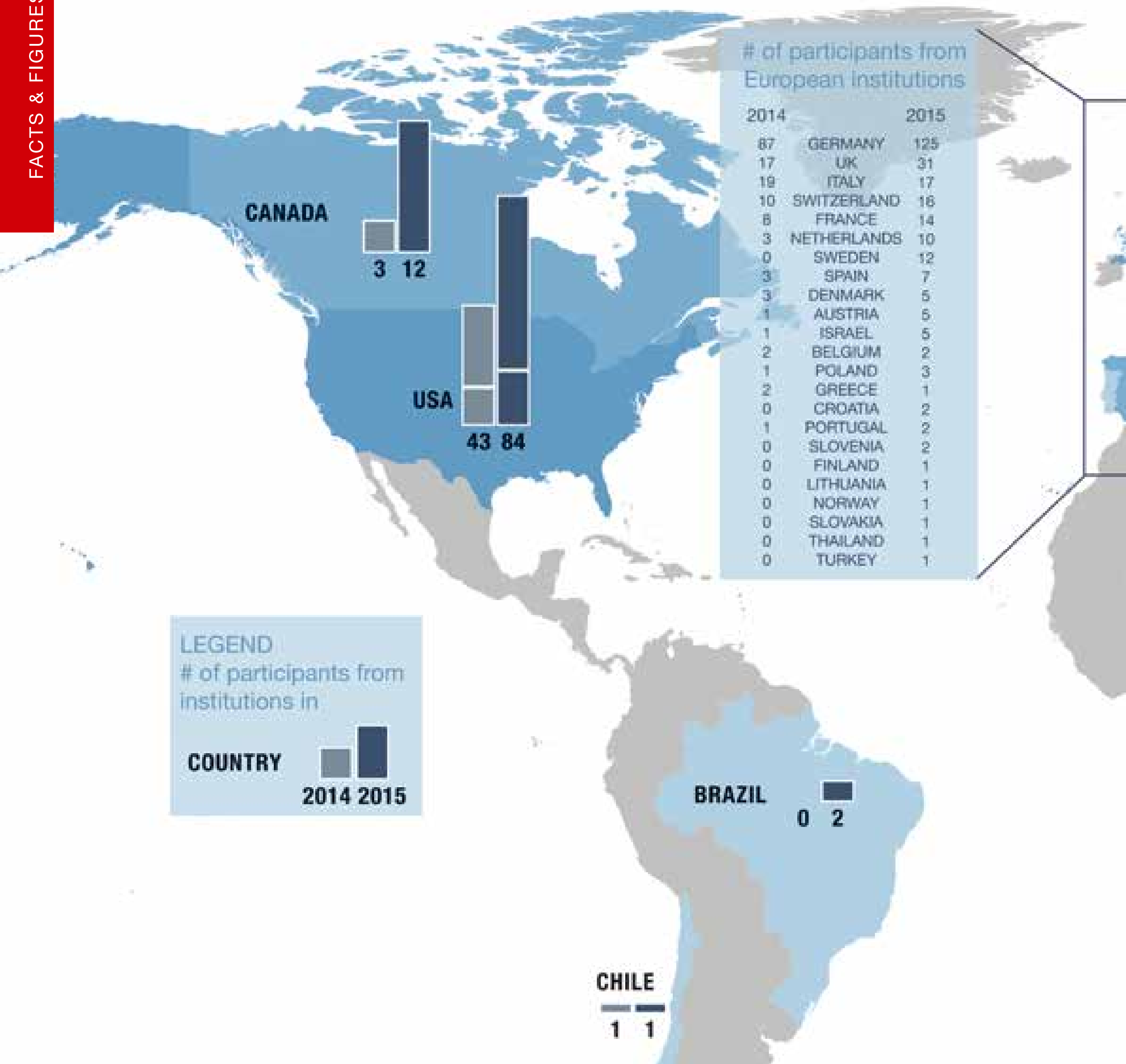
- Prof. Riccardo Barbieri, Scuola Normale Superiore Pisa (until 2015)
- Prof. Lance Dixon, Stanford University (Chair)
- Prof. Richard Ellis, California Institute of Technology (Chair until 2015)
- Prof. Francis Halzen, University of Wisconsin-Madison
- Prof. Jeremy Mould, Swinburne University of Technology (from 2016)
- Prof. Yosef Nir, Weizmann Institute of Science (from 2016)
- Prof. Scott Tremaine, Institute for Advanced Study Princeton (until 2015)

PROGRAMME COMMITTEE:

- Prof. Sigfried Bethke, Max-Planck-Institut für Physik, München (until 2014)
- Prof. Gerhard Buchalla, Ludwig-Maximilians-Universität München (from 2015)
- Prof. Andrzej Buras, Technische Universität München (until 2014)
- Prof. Helene Courtois, IPNL, University Lyon (from 2015)
- Prof. Laura Covi, Georg-August-Universität Göttingen (Chair until 2014)
- Prof. Barbara Ercolano, Ludwig-Maximilians-Universität München (until 2014)
- Dr. Laura Greggio, INAF-Astronomical Observatory of Padua (Chair)
- Prof. Günther Hasinger, University of Hawaii (until 2014)
- Prof. Robert Kennicutt, University of Cambridge (until 2014)
- Prof. Reiner Krücken, TRIUMF, Vancouver
- Prof. Johann Kühn, Karlsruher Institut für Technologie (KIT)
- Dr. Bruno Leibundgut, ESO Garching (from 2015)
- Prof. Dieter Lüst, Ludwig-Maximilians-Universität München (from 2015)
- Dr. Georg Raffelt, Max-Planck-Institut für Physik, München (until 2014)
- Prof. Michael Ramsey-Musolf, University of Massachusetts Amherst
- Prof. Hans-Walter Rix, Max-Planck-Institut für Astronomie, Heidelberg
- Prof. Stefan Schönert, Technische Universität München (from 2015)
- Dr. Stella Seitz, Ludwig-Maximilians-Universität München (from 2015)
- Dr. Geraldine Servant, DESY, Hamburg
- Prof. Simon White, Max-Planck-Institut für Astrophysik, München (until 2014)

The Scientific Advisory Board and Programme Committee meet every year in late November or early December to select the MIAPP programmes for the year after next.

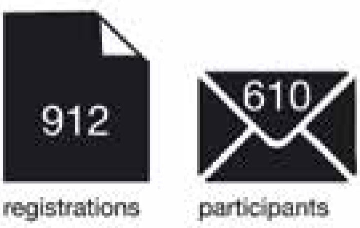
Statistics 2014 & 2015



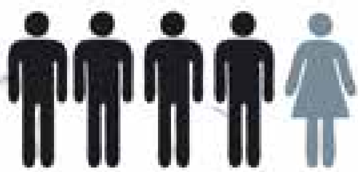
# of participants from European institutions

2014		2015
87	GERMANY	125
17	UK	31
19	ITALY	17
10	SWITZERLAND	16
8	FRANCE	14
3	NETHERLANDS	10
0	SWEDEN	12
3	SPAIN	7
3	DENMARK	5
1	AUSTRIA	5
1	ISRAEL	5
2	BELGIUM	2
1	POLAND	3
2	GREECE	1
0	CROATIA	2
1	PORTUGAL	2
0	SLOVENIA	2
0	FINLAND	1
0	LITHUANIA	1
0	NORWAY	1
0	SLOVAKIA	1
0	THAILAND	1
0	TURKEY	1

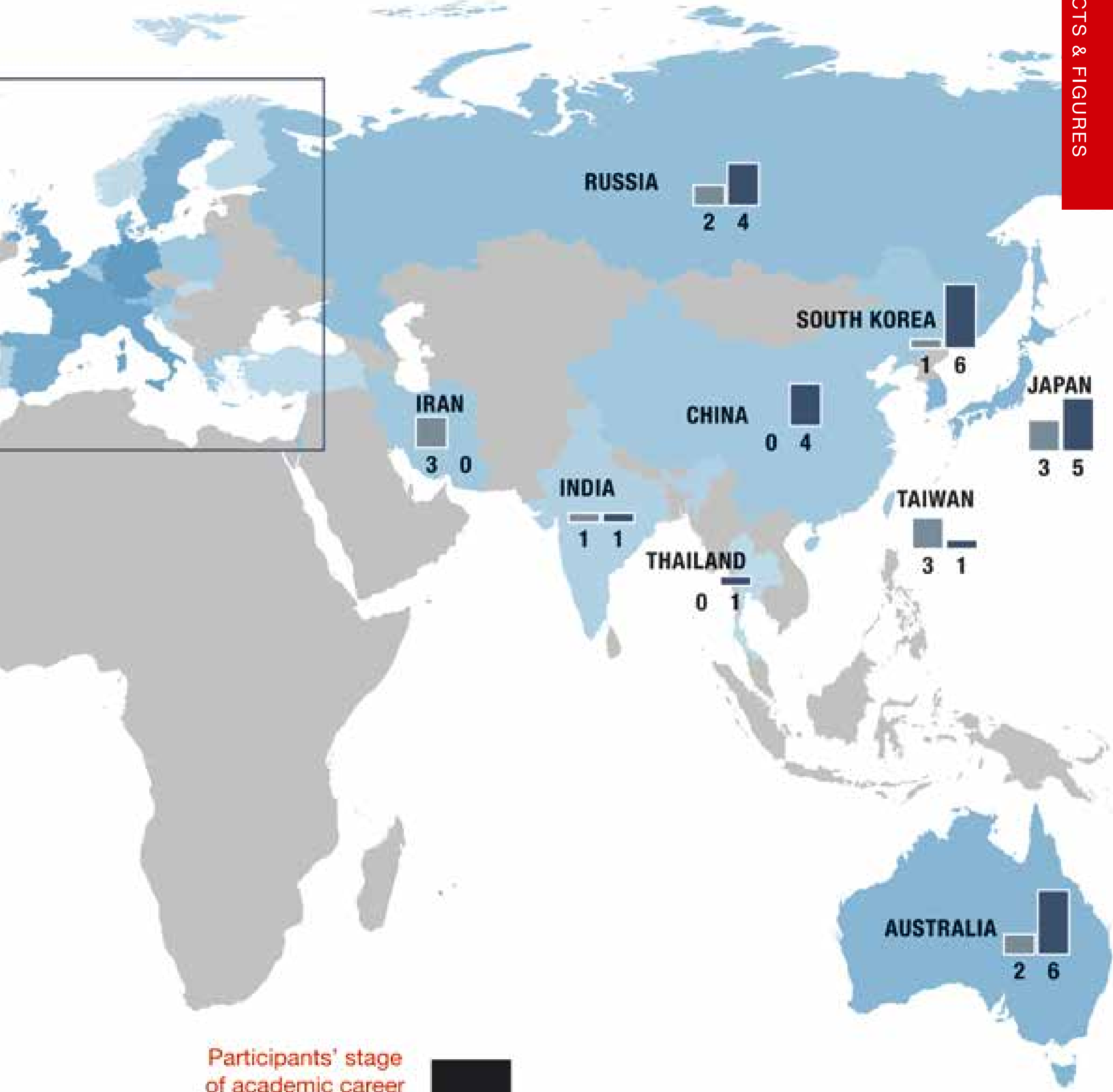
Number of registrations and participants



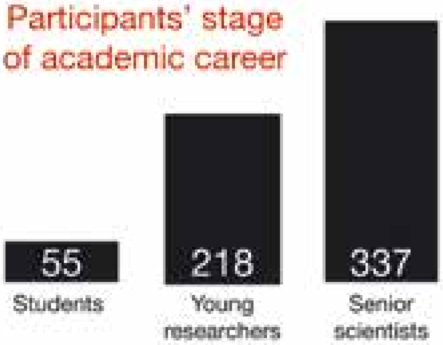
Participants' gender



80 % male, 20 % female



Participants' stage of academic career



Average duration of participation
2.6 weeks

MIAPP Posters 2014 - 2015

Images on this page: Munich (istock); Galaxy (© Giovanni Benintende); Collision (© CERN); spices (Wikimedia Commons, ©Ppsw Wiberg Gewürze 2); Anticipating Discoveries (map: Library of Congress, Geography and Map Division, detector: Cern/CMS photo by Michael.Hoch@cern.ch)

Activities in 2014

MIAPP programmes:

- **The Extragalactic Distance Scale** — 26 May – 20 June 2014
  L. Macri, W. Gieren, W. Hillebrandt, R. Kudritzki
- **Neutrinos in Astro- and Particle Physics** — 30 June – 25 July 2014
  S. Schönert, G. Raffelt, A. Smirnov, T. Lasserre
- **Challenges, Innovations and Developments in Precision Calculations for the LHC** — 28 July – 22 August 2014
  M. Krämer, S. Dittmaier, N. Glover, G. Heinrich
- **Cosmology after Planck** — 25 August – 19 September 2014
  N. Aghanim, E. Komatsu, B. Wandelt, J. Weller

MIAPP topical workshops:

- **NIAPP Topical Workshop** — 10 – 12 July 2014
  S. Schönert, G. Raffelt, A. Smirnov, T. Lasserre
- **Top Quark Physics Day** — 11 August 2014
  M. Krämer, S. Dittmaier, N. Glover, G. Heinrich

Activities in 2015

MIAPP programmes:

- **Dark Matter: Astrophysical Probes, Laboratory Tests, and Theory Aspects** — 2 – 27 February 2015
  A. Ibarra, J.-C. Lanfranchi, J. Pradler, C. Rott, J. Schieck
- **The New Milky Way: Impact of Large Spectroscopic Surveys on our Understanding of the Milky Way in the Gaia Era** — 4 – 29 May 2015
  A. Burkert, S. Feltzing, G. Gilmore, L. Pasquini, S. Randich, A. Weiss
- **Indirect Searches for New Physics in the LHC and Flavour Precision Era** — 1 – 26 June 2015
  G. Buchalla, G. Isidori, U. Nierste, J. Zupan
- **Anticipating 14 TeV: Insights into Matter from the LHC and Beyond** — 29 June – 24 July 2015
  C. Csaki, L. Randall, M. Ratz, A. Weiler
- **Star Formation History of the Universe** — 27 July – 21 August 2015
  A. Barger, A. Burkert, R. Davies, G. Kauffmann
- **The Many Faces of Neutron Stars 24** — August – 18 September 2015
  W. Becker, D. Blaschke, E. v.d. Heuvel, M. Kramer, N. Kylafis, P. Podsiadlowski, J. Trümper

MIAPP topical workshops:

- **Flavour 2015: New Physics at High Energy and High Precision** — 1 – 3 June 2015
  G. Buchalla, G. Isidori, U. Nierste, J. Zupan
- **Anticipating Discoveries: LHC14 and Beyond** — 13 – 15 July 2015
  C. Csaki, L. Randall, M. Ratz, A. Weiler

External workshops:

- **Neutrinos from GUTs down to low energies** — 25 – 27 November 2015
  C. Hagedorn, D. Meloni, E. Molinaro, T. Ohlsson, M. A. Schmidt
- **Theory of Gas Phase Scattering and Reactivity for Astrophysics** — 25 November – 10 December 2015
  P. Caselli, F. Gatti, E. Herbst, T. Komatsuzaki, A. v. d. Avoird,
  L. Wiesenfel External workshops:

Activities in 2016

MIAPP programmes:

- **Cosmic Reionization** — 24 – 29 April 2016
  B. Ciardi, M. Haehnelt, D. Stark, S. Zaroubi
- **Higher-Spin Theory and Duality** — 2 – 27 May 2016
  J. Erdmenger, S. Giombi, I. Klebanov, I. Sachs, M. Vasiliev
- **Why is there more Matter than Antimatter in the Universe?** — 30 May – 24 June 2016
  M.J. Ramsey-Musolf, B. Garbrecht, S. Huber, J. Shu
- **The Chemical Evolution of Galaxies** — 25 July – 19 August 2016
  B. Davies, M. Bergemann, F. Bresolin, A. Font, R.-P. Kudritzki
- **The Physics of Supernovae** — 22 August – 16 September 2016
  C. Fransson, S. Jha, K. Maguire, S. Woosley
- **Flavour Physics with High-Luminosity Experiments** — 24 October – 18 November 2016
  S. Paul, M. Ciuchini, B. Golob, P. Krizan, T. Mannel

MIAPP topical workshops

- **Aspects of Higher Spin Theory** — 23 – 25 May 2016
  J. Erdmenger, S. Giombi, I. Klebanov, I. Sachs, M. Vasiliev
- **Bayogenesis – Status of Experiment and Theory** — 6 – 8 June 2016
  M.J. Ramsey-Musolf, B. Garbrecht, S. Huber, J. Shu
- **Supernovae: The Outliers** — 12 – 16 September 2016
  K. Maguire, C. Fransson, S. Jha, M. Modjaz, S. Woosley
- **MIAPP - B2TiP Workshop** — 15 – 17 November 2016
  C. Bobeth, T. Kuhr

External workshops:

1st Atmospheric Neutrino Workshop (ANW'16)

7 – 9 February 2016

S. Böser, T. Gaisser, T. Kajita, T. Katori, E. Lisi, E. Resconi

Prof. Stefan Schönert (TUM) and Prof. Elisa Resconi (TUM), discussing with Nobel Laureate Prof. Takaaki Kajita (University of Tokyo) and MIAPP director Prof. Martin Beneke (TUM) (from left). *Photo: Riedel*

In early 2016, Prof. Elisa Resconi (TUM), member of the Excellence Cluster Universe, and her colleagues organised a follow-up workshop of the second MIAPP programme 2014. The workshop, focusing on how to solve the problem of neutrino mass hierarchy with the help of atmospheric neutrinos, attracted researchers from the leading experiments of neutrino searches. Among them Nobel Laureate Prof. Takaaki Kajita, professor at the University of Tokyo and director of the Japanese Institute for Cosmic Ray Research. In 2015, he was awarded the Nobel Prize in Physics for the discovery of neutrino oscillations with the Super-Kamiokande detector. At the workshop Prof. Takaaki Kajita introduced the prospects of the future detector Hyper-Kamiokande that is supposed to be about 20 times larger than its predecessor. Within the three-day workshop the participants discussed the physical issues and challenges related to the analysis of atmospheric neutrinos and the respective experiments. "The very pleasant and relaxed atmosphere at our international visiting research centre MIAPP has ensured that everybody felt comfortable and immediately got into discussion." commented Elisa Resconi on the success of the workshop.

Towards the Construction of the Fundamental Theory of Flavour

8 – 11 March 2016

G. Buchalla A. Buras, A. Ibarra, G. Isidori, M. Ratz

In March 2016, TUM Emeritus of Excellence, Prof. Andrzej Buras, organised a workshop on the theory of flavour physics. Andrzej Buras has been a member of the Excellence Cluster Universe in the first funding period as well as a member of the MIAPP Programme Committee.

Participants of the 1st Atmospheric Neutrino Workshop 2016. *Photo: Riedel*

Activities in 2017

MIAPP programmes:

- **Astro-, Particle and Nuclear Physics of Dark Matter Direct Detection** — 6 – 31 March 2017
  R. Catena, J. Conrad, C. Forssén, A. Ibarra, F. Petricca
- **Superluminous Supernovae in the Next Decade** — 2 – 26 May 2017
  J. Mould, F. Patat, J. Cooke, L. Wang, A. Heger
- **Protoplanetary Disks and Planet Formation and Evolution** — 29 May – 23 June 2017
  W. Kley, B. Ercolano, L. Testi, C. Mordasini
- **In & Out. What rules the Galaxy Baryon Cycle?** — 26 June – 21 July 2017
  P. Popesso, G. De Lucia, C. Peroux, M. Brusa, A. Saintonge
- **Automated, Resummed and Effective: Precision Computations for the LHC and Beyond** — 24 July – 18 August 2017
  T. Becher, M. Beneke, R. Frederix, K. Melnikov, M. D. Schwartz
- **Mathematics and Physics of Scattering Amplitudes** — 21 August – 15 September 2017
  S. Stieberger, L. Dixon, C. Duhr, L. Ferro

MIAPP topical workshops

- **Direct Dark Matter Detection: Experiment meets Theory** — March 2017
  R. Catena, J. Conrad, C. Forssén, A. Ibarra, F. Petricca
- **The formation and evolution of planets** — May/June 2017
  W. Kley, B. Ercolano, L. Testi, C. Mordasini

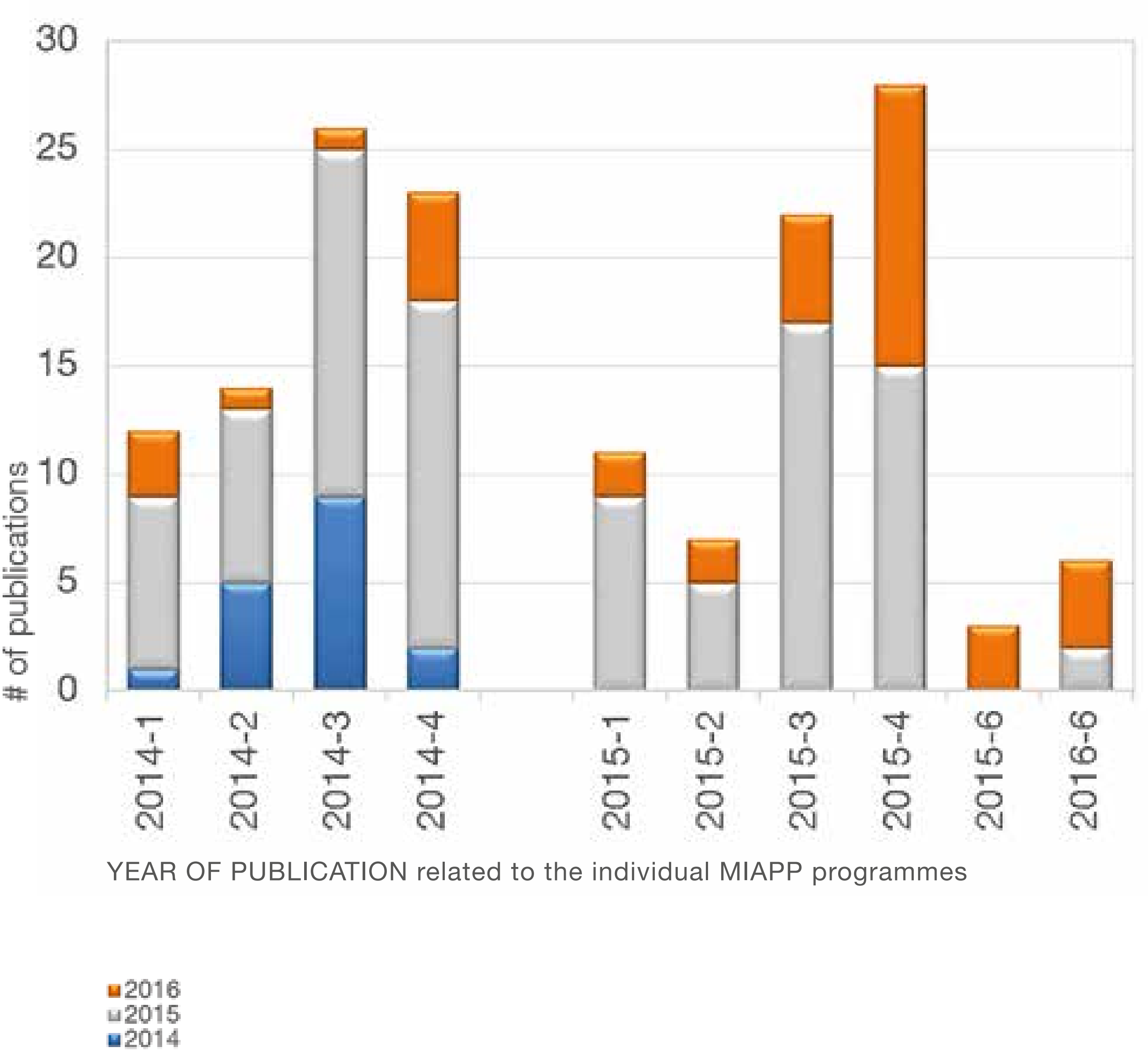
MIAPP Posters 2016 - 2017

Images on this page: Munich Skyline + Matterhorn (collage: MIAPP, Matterhorn viewed from the Gornergratbahn, Riffelberg / Zermatt, Switzerland by Andrew Bossi, Wikimedia Commons collection, Munich: istock); Supernovae (NASA, ESA. Before and after Hubble Space Telescope images of the outlier "Type Iax" supernova 2012 in NGC 1309 [McCully et al. 2014, Nature, 512, 54]); Detector (©Belle II Collaboration); Higher Spin (collage: MIAPP; Chess board by Petras Gagilas from Erith, Kent, UK; Flickr; Spinning tops made by David Earle)

Publications

Papers explicitly acknowledging MIAPP: 152
(reference date: 21 July 2016)

- in refereed journals: 122
- non-refereed: 30
- 2014-related: 75
- 2015-related: 77



Publications related to 2014 programmes

2014-1: The Extragalactic Distance Scale

- Bhardwaj A., S.M. Kanbur, et al., 2016. Large Magellanic Cloud Near-Infrared Synoptic Survey – III. A statistical study of non-linearity in the Leavitt Laws. Monthly Notices of the Royal Astronomical Society 457, 2, 1644-1665.
- Bhardwaj A., S.M. Kanbur, et al., 2015. On the variation of Fourier parameters for Galactic and LMC Cepheids at optical, near-infrared and mid-infrared wavelengths. Monthly Notices of the Royal Astronomical Society 447, 4, 3342-3360.
- Braga V., M. Dall'Ora, et al., 2015. On the Distance of the Globular Cluster M4 (NGC 6121) Using RR Lyrae Stars. I. Optical and Near-infrared Period- Luminosity and Period-Wesenheit Relations. The Astrophysical Journal 799, 2, 165.
- Casertano S., A.G. Riess, et al., 2016. Parallax of Galactic Cepheids from Spatially Scanning the Wide Field Camera 3 on the Hubble Space Telescope: The Case of SS Canis Majoris. The Astrophysical Journal 825, 1, 11.
- Kodric M., A. Riffeser, et al., 2015. The M31 Near-infrared Period-Luminosity Relation and its Non-linearity for δ Cep Variables with $0.5 \leq \log(P) \leq 1.7$. The Astrophysical Journal 799, 2, 144.
- Kudritzki R., M. Urbaneja, et al., 2016. A spectroscopic study of blue supergiant stars in the Sculptor galaxy NGC 55: chemical evolution and distance. arXiv preprint arXiv:1607.04325.
- Kudritzki R.-P., I.-T. Ho, et al., 2015. The chemical evolution of local star-forming galaxies: radial profiles of ISM metallicity, gas mass, and stellar mass and constraints on galactic accretion and winds. Monthly Notices of the Royal Astronomical Society 450, 1, 342-359.
- Lee C.-H., J. Koppenhoefer, et al., 2014. Properties of M31. V. 298 Eclipsing Binaries from PAndromeda. The Astrophysical Journal 797, 1, 22.
- Macri L.M., C.-C. Ngeow, et al., 2015. Large Magellanic Cloud Near-Infrared Synoptic Survey. I. Cepheid variables and the calibration of the Leavitt Law. The Astronomical Journal 149, 4, 117.
- Mould J., M. Colless, et al., 2015. Modified gravity and large scale flows. Astrophysics and Space Science 357, 2, 1-5.
- Ngeow C.-C., C.-H. Lee, et al., 2015. VI-Band Follow-Up Observations of Ultra-Long-Period Cepheid Candidates in M31. The Astronomical Journal 149, 2, 66.
- Suchomska K., D. Graczyk, et al., 2015. The Araucaria Project: accurate stellar parameters and distance to evolved eclipsing binary ASAS J180057-2333.8 in Sagittarius Arm. Monthly Notices of the Royal Astronomical Society 451, 651-659.

2014-2: Neutrinos in Astro- and Particle Physics

- Abelof G. and A. Gehrmann-De Ridder, 2014. Light fermionic NNLO QCD corrections to top-antitop production in the quark-antiquark channel. Journal of High Energy Physics 2014, 12, 1-42.
- Adhikari R., M. Agostini, et al., 2016. A White Paper on keV Sterile Neutrino Dark Matter. arXiv preprint arXiv:1602.04816.
- Agostini M., M. Allardt, et al., 2014. Production, characterization and operation of ^{76}Ge enriched BEGe detectors in GERDA. The European Physical Journal C 75, 2, 1-22.
- Agostini M., M. Allardt, et al., 2015. Improvement of the energy resolution via an optimized digital signal processing in GERDA Phase I. The European Physical Journal C 75, 6, 1-11.
- Agostini M., M. Allardt, et al., 2015. Results on $\beta\beta$ decay with emission of two neutrinos or Majorons in ^{76}Ge from GERDA Phase I. The European Physical Journal C 75, 9, 1-12.
- Chen M.-C., M. Ratz, et al., 2015. R parity violation from discrete R symmetries. Nuclear Physics B 891, 322-345.
- Cherry J.F., A. Friedland, et al., 2014. Neutrino Portal Dark Matter: From Dwarf Galaxies to IceCube. arXiv preprint arXiv:1411.1071.

- Denton P.B. and T.J. Weiler, 2015. The Fortuitous Latitude of the Pierre Auger Observatory and Telescope Array for Reconstructing the Quadrupole Moment. The Astrophysical Journal 802, 1, 25.
- Esmaili A., S.K. Kang, et al., 2014. IceCube events and decaying dark matter: hints and constraints. Journal of Cosmology and Astroparticle Physics 2014, 12, 054.
- Esmaili A., O. Peres, et al., 2014. Probing large extra dimensions with IceCube. Journal of Cosmology and Astroparticle Physics 2014, 12, 002.
- Esmaili A. and P.D. Serpico, 2015. Gamma-ray bounds from EAS detectors and heavy decaying dark matter constraints. Journal of Cosmology and Astroparticle Physics 2015, 10, 014.
- Fu L., C.M. Ho, et al., 2015. Aspects of the flavor triangle for cosmic neutrino propagation. Physical Review D 91, 5, 053001.
- Gaisser T.K. and S.R. Klein, 2015. A new contribution to the conventional atmospheric neutrino flux. Astroparticle Physics 64, 13-17.
- Vissani F., 2015. Comparative analysis of SN1987A antineutrino fluence. Journal of Physics G: Nuclear and Particle Physics 42, 1, 013001.

2014-3: Challenges, Innovations and Developments in Precision Calculations for the LHC

- Banfi A., H. McAslan, et al., 2014. A general method for the resummation of event-shape distributions in e^+e^- annihilation. Journal of High Energy Physics 2015, 5, 1-47.
- Becher T., A. Broggio, et al., 2015. Introduction to Soft-Collinear Effective Theory, Springer.
- Becher T., R. Frederix, et al., 2015. Automated NNLL+ NLO resummation for jet-veto cross sections. The European Physical Journal C 75, 4, 1-16.
- Beneke M., A. Maier, et al., 2015. The bottom- quark mass from non-relativistic sum rules at NNNLO. Nuclear Physics B 891, 42-72.
- Beneke M., A. Maier, et al., 2016. NNNLO determination of the bottom-quark mass from non-relativistic sum rules. arXiv preprint arXiv:1601.02949.
- Bonocore D., E. Laenen, et al., 2015. A factorization approach to next-to-leading-power threshold logarithms. Journal of High Energy Physics 06.
- Bonocore D., E. Laenen, et al., 2015. The method of regions and next-to-soft corrections in Drell–Yan production. Physics Letters B 742, 375-382.
- Campbell J.M., R.K. Ellis, et al., 2015. Top-pair production and decay at NLO matched with parton showers. Journal of High Energy Physics 2015, 4, 1-33.
- Crivellin A. and U. Haisch, 2014. Dark matter direct detection constraints from gauge bosons loops. Physical Review D 90, 11, 115011.
- Crivellin A., U. Haisch, et al., 2015. LHC constraints on gauge boson couplings to dark matter. Physical Review D 91, 7, 074028.
- Dixon L.J., M. von Hippel, et al., 2015. The four-loop six-gluon NMHV ratio function. arXiv preprint arXiv:1509.08127.
- Forte S., A. Nisati, et al., 2015. The Standard Model from LHC to future colliders. The European Physical Journal C 75, 11, 1-49.
- Gao J. and H.X. Zhu, 2014. Electroweak production of top-quark pairs in e^+e^- annihilation at NNLO in QCD: The vector current contributions. Physical Review D 90.
- Gao J. and H.X. Zhu, 2014. Top Quark Forward-Backward Asymmetry in e^+e^- Annihilation at Next-to-Next-to-Leading Order in QCD. Physical Review Letters 113.
- Gehrmann T., M. Grazzini, et al., 2014. $W^+ W^-$ Production at Hadron Colliders in Next to Next to Leading Order QCD. Physical Review Letters 113.
- Grozin A., J.M. Henn, et al., 2015. Three Loop Cusp Anomalous Dimension in QCD. Physical Review Letters 114.
- Hahn T., 2015. Concurrent Cuba. Journal of Physics Conference Series 608.
- Harlander R.V., A. Kulesza, et al., 2014. Soft gluon resummation for gluon-induced Higgs Strahlung. Journal of High Energy Physics 2014, 11, 1-20.
- Harlander R.V., H. Mantler, et al., 2014. Transverse momentum resummation for Higgs production via

gluon fusion in the MSSM. Journal of High Energy Physics 2014, 11, 1-31.
- Henn J.M., 2015. Lectures on differential equations for Feynman integrals. Journal of Physics A: Mathematical and Theoretical 48, 15, 153001.
- Hollik W., J.M. Lindert, et al., 2015. Electroweak corrections to squark-antisquark production at the LHC. arXiv preprint arXiv:1506.01052.
- Kallweit S., J.M. Lindert, et al., 2014. NLO electroweak automation and precise predictions for W^+ multijet production at the LHC. Journal of High Energy Physics 2015, 4, 1-51.
- Monni P.F. and G. Zanderighi, 2014. On the excess in the inclusive $W^+ W^- \rightarrow l^+ + l^- \nu\bar{\nu}$ cross section. Journal of High Energy Physics 2015, 5, 1-13.
- Pires J., 2015. Precise QCD predictions for jet production at the LHC, EPJ Web of Conferences, EDP Sciences.
- Pittau R., 2015. Integration-by-parts identities in FDR. Fortschritte der Physik 63, 601-608.
- von Manteuffel A., R.M. Schabinger, et al., 2015. The two-loop soft function for heavy quark pair production at future linear colliders. Physical Review D 92.

2014-4: Cosmology after Planck

- Abolhasani A.A., M. Akhshik, et al., 2016. Primordial statistical anisotropies: the effective field theory approach. Journal of Cosmology and Astroparticle Physics 2016, 03, 020.
- Bartelmann M., 2015. Trajectories of point particles in cosmology and the Zel'dovich approximation. Physical Review D 91, 8, 083524.
- Bartelmann M., F. Fabis, et al., 2014. Non-equilibrium statistical field theory for classical particles: Initially correlated canonical ensembles. arXiv preprint arXiv:1411.0806.
- Bartelmann M., F. Fabis, et al., 2014. Non-equilibrium statistical field theory for classical particles: Linear and mildly non-linear evolution of cosmological density power spectra. arXiv preprint arXiv:1411.1153.
- Cannone D., J.-O. Gong, et al., 2015. Breaking discrete symmetries in the effective field theory of inflation. Journal of Cosmology and Astro-Particle Physics 08.
- Chon G., H. Böhringer, et al., 2015. On the definition of superclusters. Astronomy & Astrophysics 575, L14.
- Erfani E., 2016. Primordial black holes formation from particle production during inflation. Journal of Cosmology and Astroparticle Physics 2016, 04, 020.
- Feix M., A. Nusser, et al., 2015. Growth Rate of Cosmological Perturbations at z~0.1 from a New Observational Test. Physical Review Letters 115.
- Fergusson J., H. Gruetjen, et al., 2015. Combining power spectrum and bispectrum measurements to detect oscillatory features. Physical Review D 91, 2, 023502.
- Ferreira R.Z. and J. Ganc, 2015. Inflationary dynamics of kinetically-coupled gauge fields. Journal of Cosmology and Astroparticle Physics 2015, 04, 029.
- Foreman S. and L. Senatore, 2016. The EFT of large scale structures at all redshifts: analytical predictions for lensing. Journal of Cosmology and Astroparticle Physics 2016, 04, 033.
- Gong J.-O., 2015. Running of scalar spectral index in multi-field inflation. Journal of Cosmology and Astroparticle Physics 2015, 05, 041.
- Iqbal A., S. Majumdar, et al., 2016. Little evidence for non-gravitational energy feedback beyond r_{500} - An end to ICM preheating? arXiv preprint arXiv:1606.00014.
- Kadota K., J.-O. Gong, et al., 2015. CMB probes on the correlated axion isocurvature perturbation. Journal of Cosmology and Astroparticle Physics 2015, 03, 026.
- Kobayashi T., Y. Watanabe, et al., 2015. Breaking of Vainshtein screening in scalar-tensor theories beyond Horndeski. Physical Review D 91, 6, 064013.
- Kunimitsu T., T. Suyama, et al., 2015. Large tensor mode, field range bound and consistency in generalized G-inflation. Journal of Cosmology and Astro-Particle Physics 08.
- Lewandowski M., A. Perko, et al., 2015. Analytic prediction of baryonic effects from the EFT of large scale structures. Journal of Cosmology and Astroparticle Physics 2015, 05, 019.

- Martins C., 2015. Fundamental cosmology in the E-ELT era: the status and future role of tests of fundamental coupling stability. General Relativity and Gravitation 47, 1, 1-19.
- Nusser A. and P. Tiwari, 2015. The Clustering of Radio Galaxies: Biasing and Evolution versus Stellar Mass. The Astrophysical Journal 812.
- Tasinato G., 2015. A scenario for inflationary magnetogenesis without strong coupling problem. Journal of Cosmology and Astroparticle Physics 2015, 03, 040.
- Terada T., Y. Watanabe, et al., 2015. Reheating processes after Starobinsky inflation in old-minimal supergravity. Journal of High Energy Physics 2015, 2, 1-26.
- Tiwari P. and A. Nusser, 2016. Revisiting the NVSS number count dipole. Journal of Cosmology and Astroparticle Physics 2016, 03, 062.
- Watanabe Y. and J. White, 2015. Multi-field formulation of gravitational particle production after inflation. Physical Review D 92.

Publications related to **2015** programmes

2015-1: Dark Matter: Astrophysical Probes, Laboratory tests, and Theory Aspects

- Aoki M., T. Toma, et al., 2015. Non-thermal production of minimal dark matter via right-handed neutrino decay. Journal of Cosmology and Astroparticle Physics 2015, 09, 063.
- Cabrera-Catalan M.E., S.i. Ando, et al., 2015. Indirect and direct detection prospect for TeV dark matter in the nine parameter MSSM. Physical Review D 92, 3, 035018.
- Chala M., F. Kahlhoefer, et al., 2015. Constraining Dark Sectors with Monojets and Dijets. arXiv preprint arXiv:1503.05916.
- Chowdhury D. and O. Eberhardt, 2015. Global fits of the two-loop renormalized Two-Higgs-Doublet model with soft Z_2 breaking. Journal of High Energy Physics 2015, 11, 1-36.
- Chowdhury D., A.M. Iyer, et al., 2016. Constraints on dark matter annihilation to fermions and a photon. arXiv preprint arXiv:1601.06140.
- Guo F.-K., P. Ruiz-Femenía, et al., 2015. One loop renormalization of the electroweak chiral Lagrangian with a light Higgs boson. Physical Review D 92, 7, 074005.
- Hamaguchi K. and K. Ishikawa, 2016. Prospects for Higgs-and Z-resonant neutralino dark matter. Physical Review D 93, 5, 055009.
- Kouvaris C. and N.G. Nielsen, 2015. Daily modulation and gravitational focusing in direct dark matter search experiments. Physical Review D 92, 7, 075016.
- Lacroix T., C. Böhm, et al., 2015. Ruling out thermal dark matter with a black hole induced spiky profile in the M87 galaxy. Physical Review D 92.
- Laha R., 2015. Directional detection of dark matter in universal bound states. Physical Review D 92, 8, 083509.
- Murase K., R. Laha, et al., 2015. Testing the dark matter scenario for PeV neutrinos observed in IceCube. Physical review letters 115, 7, 071301.

2015-2: The New Milky Way: Impact of Large Spectroscopic Surveys on our Understanding of the Milky Way in the Gaia-era

- Altmannshofer W., S. Gori, et al., 2016. Uncovering mass generation through Higgs flavor violation. Physical Review D 93, 3, 031301.
- Bertolami M.M., M. Viallet, et al., 2016. On the relevance of bubbles and potential flows for stellar convection. Monthly Notices of the Royal Astronomical Society 457, 4, 4441-4453.
- Fernández-Trincado J., A. Robin, et al., 2015. Mapping the inner stellar halo of the Milky Way from 2MASS and SDSS-III/APOGEE survey. arXiv preprint arXiv:1510.01255.
- Fernández-Trincado J., A. Robin, et al., 2015. RAVE stars tidally stripped or ejected from the ω Centauri globular cluster. Astronomy & Astrophysics 583, A76.

- □ Fernandez-Trincado J.G., T. Verdugo, et al., 2015. Mapping optically variable quasars towards the Galactic plane, in F. Martins (Ed), SF2A-2015: Proceedings of the Annual meeting of the French Society of Astronomy and Astrophysics.
- □ Kordopatis G., R. Wyse, et al., 2015. The Gaia-ESO Survey: characterisation of the [α/Fe] sequences in the Milky Way discs. Astronomy & Astrophysics 582, A122.
- □ Lucatello S., A. Sollima, et al., 2015. The incidence of binaries in globular cluster stellar populations. Astronomy and Astrophysics 584.

2015-3: Indirect Searches for New Physics in the LHC and Flavour Precision Era

- □ Allanach B., B. Gripaios, et al., 2015. Anatomy of the ATLAS diboson anomaly. Physical Review D 92, 5, 055003.
- □ Altmannshofer W., S. Gori, et al., 2016. Uncovering mass generation through Higgs flavor violation. Physical Review D 93, 3, 031301.
- □ Bell G., M. Beneke, et al., 2015. Two-loop current–current operator contribution to the non-leptonic QCD penguin amplitude. Physics Letters B 750, 348-355.
- □ Beneke M., P. Moch, et al., 2016. Lepton flavour violation in RS models with a brane- or nearly brane-localized Higgs. Nuclear Physics B 906, 561-614.
- □ Blanke M., A.J. Buras, et al., 2016. Quark flavour observables in the Littlest Higgs model with T-parity after LHC Run 1. The European Physical Journal C 76, 4, 1-20.
- □ Buchalla G., O. Cata, et al., 2016. Fitting Higgs data with nonlinear effective theory. The European Physical Journal C 76, 5, 1-13.
- □ Buras A.J., M. Gorbahn, et al., 2015. Improved anatomy of ε'/ε in the Standard Model. Journal of High Energy Physics 2015, 11, 1-32.
- □ Calibbi L., A. Crivellin, et al., 2015. Effective Field Theory Approach $b \to sll^{(\prime)}$, $B \to K^{(*)} \nu\bar{\nu}$ and $B \to D^{(*)} \tau\nu$ with Third Generation Couplings. Physical Review Letters 115, 18, 181801.
- □ Cata O., 2015. Chiral methods at the electroweak scale. arXiv preprint arXiv:1512.07140.
- □ Dermisek R., E. Lunghi, et al., 2015. Two Higgs doublet model with vectorlike leptons and contributions to $pp \to WW$ and $H \to WW$. arXiv preprint arXiv:1509.04292
- □ Dror J.A., M. Farina, et al., 2015. Strong tW Scattering at the LHC. arXiv preprint arXiv:1511.03674.
- □ Duplančić G. and B. Melić, 2015. Form factors of $B, B_S \to \eta^{(\prime)}$ *and* $D, D_S \to \eta^{(\prime)}$ transitions from QCD light-cone sum rules. Journal of High Energy Physics 2015, 11, 1-38.
- □ Fajfer S. and N. Kosnik, 2015. Prospects of discovering new physics in rare charm decays. European Physical Journal C 75.
- □ Gershon T., J. Libby, et al., 2015. Contributions to the width difference in the neutral D system from hadronic decays. Physics Letters B 750, 338-343.
- □ Ghosh D., P. Paradisi, et al., 2015. CP Violation Tests of Alignment Models at LHCII. arXiv preprint arXiv:1512.03962.
- □ Grinstein B., C.W. Murphy, et al., 2015. One-Loop Corrections to the Perturbative Unitarity Bounds in the CP-Conserving Two-Higgs Doublet Model with a Softly Broken Z_2 Symmetry. arXiv preprint arXiv:1512.04567.
- □ Gronau M. and J.L. Rosner, 2011. Triple-product asymmetries in $K, D_S,$ *and* B_S decays. Physical Review D 84, 9, 096013.
- □ Khodjamirian A., T. Mannel, et al., 2015. Direct probes of flavor-changing neutral currents in $e^+ e^-$-collisions. Journal of High Energy Physics 11.
- □ Lee G. and C.E. Wagner, 2015. Higgs bosons in heavy supersymmetry with an intermediate m_A. Physical Review D 92, 7, 075032.
- □ Moch P. and J. Rohrwild, 2016. $\bar{B} \to X_S \gamma$ with a warped bulk Higgs. Nuclear Physics B 902, 142-161.
- □ Müller S., U. Nierste, et al., 2015. Sum Rules of Charm C P Asymmetries beyond the $SU(3)_F$ Limit. Physical review letters 115, 25, 251802.
- □ Nierste U. and S. Schacht, 2015. CP Violation in $D^0 \to K_S K_S$. arXiv preprint arXiv:1508.00074.

2015-4: Anticipating 14 TeV: Insights into Matter from the LHC and Beyond

- □ Abercrombie D., N. Akchurin, et al., 2015. Dark matter benchmark models for early LHC run-2 searches: report of the ATLAS/CMS dark matter forum. arXiv preprint arXiv:1507.00966.
- □ Bellazzini B., C. Cheung, et al., 2016. Quantum gravity constraints from unitarity and analyticity. Physical Review D 93, 6, 064076.
- □ Bellazzini B., C. Csáki, et al., 2015. The Quantum Critical Higgs. arXiv preprint arXiv:1511.08218.
- □ Boucenna S.M., A. Celis, et al., 2016. Non-abelian gauge extensions for B-decay anomalies. Physics Letters B 760, 214-219.
- □ Carena M., H.E. Haber, et al., 2016. On the Alignment limit of the NMSSM Higgs sector. Physical Review D 93, 3, 035013.
- □ Cata O., 2015. Chiral methods at the electroweak scale. arXiv preprint arXiv:1512.07140.
- □ Cheng H.-C., S. Jung, et al., 2016. Exotic quarks in Twin Higgs models. Journal of High Energy Physics 2016, 03, 074.
- □ Cohen T., M.J. Dolan, et al., 2016. Dissecting Jets and Missing Energy Searches Using n-body Extended Simplified Models. arXiv preprint arXiv:1605.01416.
- □ Csaki C., M. Geller, et al., 2015. The Flavor of the Composite Twin Higgs. arXiv preprint arxiv: 1512.03427.
- □ Curtin D. and P. Saraswat, 2016. Towards a no-lose theorem for naturalness. Physical Review D 93, 5, 055044.
- □ Dermíšek R., E. Lunghi, et al., 2016. Two Higgs doublet model with vectorlike leptons and contributions to $pp \to W W$ and $H \to W W$. Journal of High Energy Physics 2016, 2, 1-29.
- □ Dolan M.J., J. Hewett, et al., 2016. Simplified Models for Higgs Physics: Singlet Scalar and Vector-like Quark Phenomenology. arXiv preprint arXiv:1601.07208.
- □ Falkowski A., M. Nardecchia, et al., 2015. Lepton flavor non-universality in B-meson decays from a U(2) flavor model. Journal of High Energy Physics 2015, 11, 1-26.
- □ Feng J.L., J. Smolinsky, et al., 2016. Dark photons from the center of the Earth: Smoking-gun signals of dark matter. Physical Review D 93, 1, 015014.
- □ Feng J.L., J. Smolinsky, et al., 2016. Detecting dark matter through dark photons from the Sun: Charged particle signatures. Physical Review D 93, 11, 115036.
- □ Feruglio F., P. Paradisi, et al., 2015. Lepton flavour violation in composite Higgs models. European Physical Journal C 75.
- □ Ghosh D., P. Paradisi, et al., 2016. CP violation tests of alignment models at LHCII. Journal of High Energy Physics 2016, 2, 1-24.
- □ Giudice G.F., P. Paradisi, et al., 2015. Indirect determinations of the top quark mass. Journal of High Energy Physics 2015, 11, 1-30.
- □ Gonçalves D., F. Krauss, et al., 2015. Augmenting the diboson excess for the LHC Run II. Physical Review D 92.
- □ Gori S., J. Gu, et al., 2015. The $Zb\bar{b}$ Couplings at Future $e^+ e^-$ Colliders. arXiv preprint arXiv:1508.07010.
- □ Kappl R., 2015. SOLARPROP: Charge-sign Dependent Solar Modulation for Everyone. arXiv preprint arXiv:1511.07875.
- □ Katz A., M. Perelstein, et al., 2015. Stop-catalyzed baryogenesis beyond the MSSM. Physical Review D 92, 9, 095019.
- □ Katz A., M. Reece, et al., 2016. Continuum-mediated dark matter–baryon scattering. Physics of the Dark Universe 12, 24-36.
- □ Kim J.S., O. Lebedev, et al., 2015. Higgsophilic gauge bosons and monojets at the LHC. Journal of High Energy Physics 2015, 11, 1-17.
- □ Patil S.P. and P. Schwaller, 2015. Relaxing the Electroweak Scale: the Role of Broken dS Symmetry. arXiv preprint arXiv:1507.08649.
- □ Raby S., 2015. Long-Lived Gluinos and Stable Axinos. Physical review letters 115, 23, 231801.
- □ Randall L., J. Scholtz, et al., 2016. Flooded Dark Matter and S level rise. Journal of High Energy Physics 2016, 3, 1-26.

- Shi B. and S. Raby, 2015. Basis invariant description of chemical equilibrium with implications for a recent axionic leptogenesis model. Physical Review D 92, 8, 085008.

2015-5: Star Formation History of the Universe

- Casey C.M., 2016. The Ubiquity of Coeval Starbursts in Massive Galaxy Cluster Progenitors. The Astrophysical Journal 824, 1, 36.
- Cowie L., A. Barger, et al., 2016. Luminosity Dependence and Redshift Evolution of Strong Emission-Line Diagnostics in Star-Forming galaxies. The Astrophysical Journal 817, 1, 57.
- Mayer L., T. Peters, et al., 2016. Direct Detection of Precursors of Gas Giants Formed by Gravitational Instability with the Atacama Large Millimeter/submillimeter Array. The Astrophysical Journal Letters 823, 2, L36.

2015-6: The Many Faces of Neutron Stars

- Antoniadis J., T.M. Tauris, et al., 2016. The millisecond pulsar mass distribution: Evidence for bimodality and constraints on the maximum neutron star mass. arXiv preprint arXiv:1605.01665.
- Grigorian H., D. Voskresensky, et al., 2016. Influence of the stiffness of the equation of state and in-medium effects on the cooling of compact stars. The European Physical Journal A 52, 3, 1-19.
- Jia K. and X.-D. Li, 2015. Evolution of Transient Low-Mass X-ray Binaries to Redback Millisecond Pulsars. The Astrophysical Journal 814, 1, 74.
- Psaltis D., N. Wex, et al., 2016. A Quantitative Test of the No-hair Theorem with Sgr A* Using Stars, Pulsars, and the Event Horizon Telescope. The Astrophysical Journal 818, 2, 121.
- Rea N., M. Gullón, et al., 2015. Constraining the GRB-magnetar model by means of the Galactic pulsar population. The Astrophysical Journal 813, 2, 92.
- Rijken T.A. and H.-J. Schulze, 2016. Hyperon-hyperon interactions with the Nijmegen ESC08 model. The European Physical Journal A 52, 2, 1-10.

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