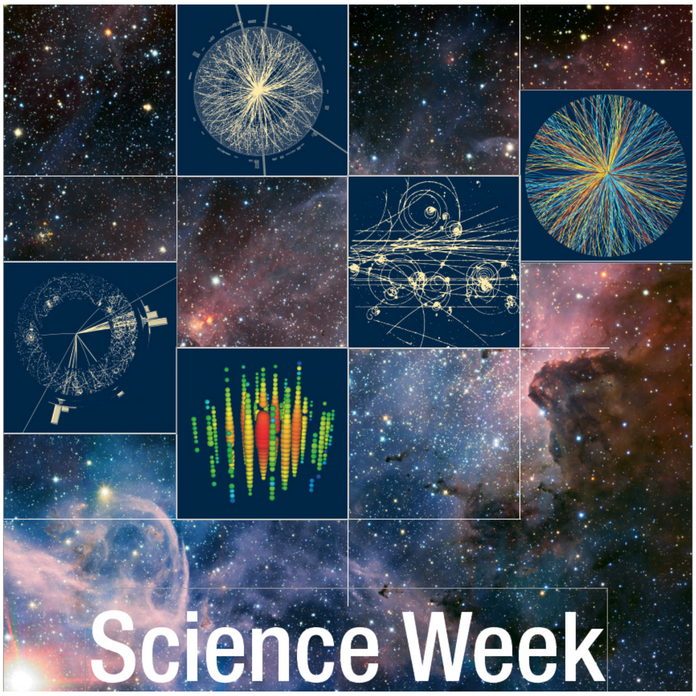


Astro-, Nuclear- & Particle Physics

**THE ANNUAL SCIENCE MEETING OF THE EXCELLENCE CLUSTER UNIVERSE and INTRODUCTION OF ORIGINS**
**3 - 6 December 2018**

# Talk Abstracts

orderered following the appearance in the program

Philipp Holliger

## The rise of information: systems chemistry of RNA oligomer pools

A critical event in the origin of life is thought to have been the emergence of function and ultimately self-replication from pools of random genetic oligomers generated by prebiotic chemistry. I'll be presenting recent work on the functional potential of pools of random sequence RNA oligomers as well as analogous pools derived from chemically related but distinct genetic polymers [1] as well as ongoing work on the non-canonical properties of a recently discovered ribozyme that polymerises RNA oligomers and the system-level properties of oligomer substrate pools, specifically RNA trinucleotides (triplets) [2].

[1] Mutschler H, Taylor AI, Porebski BT, Lightowlers A, Houlihan G, Abramov M, Herdewijn P & Holliger P (2018) Random-sequence genetic oligomer pools display an innate potential for ligation and recombination. eLife, in press

[2] Attwater J, Raguram A, Morgunov AS, Gianni E & Holliger P (2018) Ribozyme-catalysed RNA synthesis using triplet building blocks. eLife. 7: e35255. doi: 10.7554 / eLife.35255

Cornelia Meinert

## Photochemical synthesis, chirality and detection of the building blocks of life in (simulated) cometary matter

What is responsible for the emergence of life's homochiral biopolymers, DNA, RNA and proteins, where all the constituent monomers exhibit the same handedness?

Based on in-situ observations and laboratory studies, we propose that this handedness occurs when chiral biomolecules are synthesized asymmetrically through interaction with circularly polarized photons in interstellar space. My recent research has shown that the central chiral units of RNA and proteins form readily under simulated comet conditions and this has provided new insights into the accessibility of precursors of prebiotic material in interstellar environments. The significance of my research arises due to the current lack of experimental demonstration that amino acids and sugars can simultaneously and asymmetrically be synthesized by a universal physical selection process whether in space or on the Early Earth.

Kristian Le Vay

## Compartmentalized RNA catalysis in membrane-free coacervate protocells

Phase separation of mixtures of oppositely charged polymers provides a simple and direct route to compartmentalisation via complex coacervation, which may have been important for driving primitive reactions as part of the RNA world hypothesis. We demonstrate that simple RNA catalysis is viable within coacervate microdroplets, and further show that these membrane-free droplets can selectively retain longer length RNAs while permitting transfer of lower molecular weight oligonucleotides.

Thomas Litschel

## Genetic exchange between protocells

Early protocells are thought to have consisted of a self-replicating, RNA-based genetic system and a primitive metabolism enclosed within an amphiphilic membrane [1]. These protocells would have relied on simple self-organization processes presumably driven by environmental events. One such process, likely critical for early cellular evolution, is the exchange of content such as genetic material between individual protocells.
Using DNA-containing giant unilamellar vesicles (GUVs) as model systems, we investigated freeze-thaw cycles as an environmental driver for content exchange between vesicles [2]. We tested various freezing and thawing scenarios and, under certain conditions, found content mixing between vesicles to be very thorough with evidence thereof in all observed vesicles. Surprisingly, we found that content is transferred through diffusion across the membranes of tightly packed GUVs, and not through vesicle fusion and fission, as was observed in similar experiments [3].
In future experiments, we will incorporate RNA-based systems within GUVs to model the implications of reoccurring content exchange in such prebiotic systems. In particular, we aim to combine freeze-thaw driven ribozyme activity with content mixing to probe if both processes could have synergistically driven primitive forms of protocell proliferation.

[1] J. C. Blain and J. W. Szostak, Annu. Rev. Biochem. 83, 615–40 (2014)
[2] T. Litschel et al., New J. Phys. 20, 055008 (2018)
[3] G. Tsuji et al., Proc. Natl. Acad. Sci. 113, 590–5 (2016)

Martin J. Losekamm

## The ORIGINS Laboratory for Rapid Space Missions and Technology Development

Small satellites have become a versatile and widely used platform for scientific and commercial technology-demonstration missions. In such short-term missions, costs can be substantially reduced through the use of commercial-off-the-shelve components and ride-share launches. For the same reasons, development times are significantly shorter than for larger satellites. Despite strict limitations in size, mass, and available power, the CubeSat standard—the foundation of the most abundant class of small satellites—has enabled numerous scientists around the world to test or operate their instruments in space.
To make use of the opportunities small satellites offer to the scientific community, the ORIGINS Laboratory for Rapid Space Missions (LRSM) will develop a versatile CubeSat bus for missions in low Earth orbit. It shall primarily be used by ORIGINS scientists, but could also be shared with national and international partners. Instruments currently under development at TUM and MPE for the International Space Station and the SkyHopper satellite shall serve as trailblazers for future science missions. These could either be preparatory missions to demonstrate technologies for larger endeavors or be self-contained experiments in their own right.

In this talk, I will present the rationale for the LRSM and the technologies we intend to develop. I will also briefly introduce the two ‘trailblazer’ missions and outline ideas for future experiments that could use LRSM-developed technologies.

Bernhard Flierl

## Particle Tracking with Micro-Pattern Gaseous Detectors

GEM and micromegas detectors are Micro-Pattern Gaseous Detectors (MPGDs). They are intrinsically high-rate capable and show excellent spatial resolution due to small drift lengths and high read-out granularity. Large micromegas detectors will replace parts of the forward high-precision muon tracking system of the ATLAS detector, which will be able to cope with the increased background when the Large Hadron Collider will exceed its current luminosity of $2 \times 10^{34}$ $cm^{-2}$ $s^{-1}$ after 2020. The full tracking potential of these detectors cannot be reached by standard read-out and reconstruction techniques. Different novel approaches are discussed and introduced, which allow a distinct enhancement in position information. This is achieved by employing methods that take into account the full track information of a charged particle in the detector. In thin planar GEM and micromegas detectors particle tracking is performed by utilization of a time resolving read-out, which allows a Time-Projection-Chamber-like (TPC) track reconstruction for several applications. This is shown exemplarily for thermal neutrons, which are detected with high precision by reconstructing the tracks of ions emerging from a neutron capture process in a thin thin $^{10}B$ conversion layer. In a 2 μm conversion layer a spatial resolution of (100 ± 10) μm is achieved in a thermal neutron beam of 3.7 meV.
An alternative reconstruction method for tracking of minimal ionizing particles in multiple detector layers allows for a significantly enhanced position determination for small GEM-detectors. For muons of 10–150 GeV a spatial resolution below 150 μm is obtained independent of the track inclination. This method is also applied to micromegas detectors for the ATLAS muon spectro- meter upgrade, where a $2m^2$ prototype with four layers is tested in a 10–150GeV muon beam. Perpendicularly incident muons are reconstructed with a spatial resolution below 100μm and an efficiency above 95%. With a modified tracking technique and by application of a timing compensation a considerably improved spatial resolution of 200 μm is obtained for inclinations of 20 and 30 degrees with a high reconstruction efficiency of 97 %.

Rafael Delgado

## Hidden Graviton phenomenology in C2PAP

Massive gravitons appear naturally in theories with large extra dimensions and other modifications of gravity, like the Arkani-Hamed-Dimopoulos-Dvali (ADD), Randall-Sundrum (RS) and Bimetric gravity models. In this work, we use a testing project at C2PAP and a local departmental cluster for studying the collider phenomenology of a hidden graviton (massive spin-2 particle + Einstein-Hilbert GR), described at the lowest order by a Fierz-Pauli Lagrangian.

Eran Palti

## Cosmological aspects of the String Theory Swampland

I will introduce the idea of the String Theory Swampland. This is a programme aimed at determining what types of low-energy effective theories are consistent with string theory, or more generally quantum gravity. I will then focus on cosmological aspects of this programme, in particular regarding primordial gravitational waves, the nature of dark energy and the mass of the graviton.

Patrick Rieck

## Searches for Dark Matter at LHC and their relation to direct and indirect searches

The majority of the matter content of the universe is known to be transparent. Therefore astrophysical experiments could only reveal this dark matter by means of its gravitational interactions so far. Different strategies are pursued in order to discover the particle nature of dark matter. Assuming particle masses up to the TeV scale and sufficiently strong interactions with proton constituents, such dark matter particles could be produced at the LHC. In this talk, the dark matter search programme at the LHC and its relation to other experimental approaches to the search for dark matter are discussed. The LHC dark matter searches cover a large set of final states, leading to various constraints on dark matter production. By means of simplified models of the interactions between dark matter particles and quarks, the constraints resulting from the LHC searches are compared with results from direct detection experiments which probe elastic scattering between dark matter and nucleons. In case of significant rates of dark matter annihilation or decay in space, also astrophysical experiments can probe the particle nature of dark matter. Corresponding results also influence dark matter searches at the LHC.

Martin Vollmann

## Improved theoretical predictions for indirect (wino) dark matter detection with next-generation gamma-ray telescopes

In the light of construction of the Cherenkov Telescope Array (CTA), the study of indirect detection avenues for heavy weakly interacting massive particle (WIMP) dark matter is imperative. Indeed, negative results in the search for 1-100GeV dark-matter (DM) mass scale wimps by current experiments calls for theoretical developments in the phenomenology of heavy DM. Indirect detection efforts with ground-based gamma-ray telescopes are especially interesting in this endeavour. A particularly promising prediction of several wimp DM models is the quasi-monochromatic emission of gamma rays due to their pair-annihilation in e.g. the innermost part of the Milky Way.
High energy gamma-ray fluxes due to DM annihilation are naively suppressed by the inverse-squared dependence on the heavy DM mass and by the fact that the cross section is loop-suppressed. However, non-perturbative effects (Sommerfeld) can play the opposite role of enhancing the signal by several orders of magnitude depending on the DM mass making the signal observable after a few hours of observation time. Relatedly, the mass/energy-scale hierarchy present in the problem of predicting heavy DM annihilation signal strengths, poses an additional technical difficulty. Namely, the radiative corrections of the relevant cross sections are hampered by the appearance of large (Sudakov) logarithms that break the validity of the perturbative expansion. In order to resum these, we (Prof. Beneke's group from Universe RA-E) employ soft-collinear effective-field-theory (SCET) methods. By means of process-specific factorization theorems, we are able to make very precise (Next-to-Leading Log prime) predictions for the relevant annihilation cross sections.
Focusing, for concreteness, on the pure-wino model I will give in this talk a short overview of these methods and their application to indirect DM detection with gamma-ray telescopes. Then, I will discuss our results and link them with experimental sensitivities and energy resolutions of existing (HESS) and next-generation (CTA) atmospheric Cherenkov telescopes.

Raimund Strauss

## Exploring coherent neutrino-nucleus scattering with NU-CLEUS

The detection of coherent-neutrino nucleus scattering opens up new opportunities to probe physics beyond the Standard Model such as the search for a neutrino magnetic moment, sterile neutrinos or non-standard neutrino interactions. I present a novel cryogenic neutrino experiment at a nuclear power reactor which allows for precision measurements with a miniaturized detector size. With a recent demonstrator we have achieved ultra-low energy thresholds of 20eV, one order of magnitude lower than previous devices. We have initiated the NU-CLEUS experiment which aims to operate at close distance to a power reactor. A promising site about 80m away from the twin reactor cores of the CHOOZ power plant in France has been identified and is currently being characterized by on-site background measurements. In this talk I will report on the cryogenic detector, the experimental strategy and the potential of NU-CLEUS for new physics.

Torsten Dahms

## Recent results on low-mass dielectron production in pp and Pb--Pb collisions with ALICE

Low-mass $e^+e^-$ pairs are a particularly useful probe to study the hot and dense medium created in ultra-relativistic heavy-ion collisions. Such pairs are produced during all stages of the collision and carry information about the whole space-time evolution of the system, unperturbed by strong final-state interactions.
The invariant-mass continuum of dielectrons is extremely rich in physics sources: on top of Dalitz and resonance decays of pseudoscalar and vector mesons, heavy-flavour hadron decays and thermal radiation from the medium contribute to the dielectron continuum. In particular the production of thermal radiation and the possible modification of the spectral function of the short-lived rho meson, decaying into dielectrons, are of great interest. The latter is an especially well suited probe of chiral symmetry restoration, which is predicted to be restored at the high temperatures reached in ultra-relativistic heavy-ion collisions. In the intermediate-mass region, the early temperature of the system can be extracted from the mass spectrum of its thermal black-body radiation. However, it is first necessary to understand the very large background of correlated dielectron pairs from semi-leptonic charm and beauty hadron decays.
The measurement of dielectron production in inelastic proton--proton collisions serves as crucial vacuum reference needed for the heavy-ion studies. In particular, the intermediate-mass region provides insight into heavy-flavour production complementary to single heavy-flavour hadron measurements. Recently, proton--proton collisions with high charged particle multiplicities have been found to exhibit phenomena similar to those attributed to the quark--gluon plasma formation in heavy-ion collisions. Dielectron measurements may contribute to a better understanding of the underlying physics processes in such collisions.
We present the latest results on low-mass dielectron production from the ALICE Collaboration in pp collisions at √s = 7 TeV and 13 TeV and in central Pb--Pb collisions at √s_NN = 2.76 TeV and 5 TeV. The implications for heavy-flavour and (thermal) direct photon production will be discussed. Furthermore, the results in pp collisions at √s = 13 TeV will be shown as a function of the charged-particle event multiplicity. Finally, perspectives for the LHC Run-3 will be shortly mentioned.

Robert Szafron

## All-order resummations in QCD at next-to-leading power

Perturbative expansion of cross-sections breaks down in certain kinematic regions of the phase space where logarithm of a large ratio of scales, log(R), can overcome suppression of higher orders due to the smallness of coupling constant. This means that large logarithms of R have to be resummed to all orders in perturbation theory in order to get meaningful theoretical predictions. This resummation is typically possible if one neglects power corrections, i.e. terms suppressed by R. In my talk, I will report on recent progress in resummation techniques that allows extending all-order resummation beyond leading power. I will show how the effective field theory approach allows for the systematic inclusion of power corrections and extension of factorization theorems beyond leading power. Using the example of the Drell-Yan threshold production, I will present the differences between next-to-leading power resummation and the established leading power case.

Stella Seitz

## Measuring the mass distributions in the Universe with the Dark Energy Survey: our progress report

In 2017/18 the Dark Energy Survey (DES) Team has published the so far most precise weak lensing analyses of mass distributions in the Universe, and cosmological constraints based on these. I will highlight results for which Munich DES members have played a strong or leading role -- thanks to the financial support of the Universe-Cluster allowing several groups to join DES. For the next ~3 years, Dark Energy Survey analyses will continue to be cutting edge regarding these measurements of structure growth in the late Universe. Thereafter DES will soon be outperformed by the LSST survey, for which the science teams' survey tasks and roles are assigned already now. Origins science groups should be enabled to join this survey as soon as possible in order to stay at the forefront of observational cosmology and to further develop the incisive role of Munich.

Titouan Lazeyras

## Investigations into Dark Matter Halo Bias

The large-scale bias parameters of dark matter halos are essential to describe the statistics of halos and galaxies on large scales. After introducing the bias formalism, I will review the main results of my thesis on the subject. These include results for the local bias parameters bn using so-called separate universe simulations, the effect of primordial non-Gaussianity on halo bias, the phenomenon known as assembly bias, and the first measurement of the complete set of bias parameters up to third order from a near-optimal estimator for the Trispectrum.

Razmik Mirzoyan

## Gamma-Ray and Multi-Messenger Highlights with MAGIC at the Very High Energies

In this report we want to reflect on highlights from the MAGIC collaboration, who is operating twin 17m diameter imaging air Cherenkov telescopes on the Roque de los Muchachos observatory on the Canary island of La Palma. These include measuring gamma-ray pulsations from sources above the energy of 20-30 GeV, spectrum measurements of Crab Nebula at a very low threshold and at the highest energy end of the spectrum, about the diffuse emission from the direction of the galactic center and number of other interesting results. Also, we want to dwell on the recent multi-messenger observation of extremely high energy neutrino by IceCube and gamma-ray emissions from the direction of the Bl-Lac object TXS0506, offering a physical interpretation scenario and linking the measured emissions to the extremely high energy cosmic rays in the jets of AGN.

Leonardo Testi

## Observing the dawn of planetary systems with ALMA

Planetary systems form in protoplanetary disks, the leftovers of the star formation process. These disks contain the raw material (solids and volatiles) that will form planetary cores and atmospheres. The study of protoplanetary disks and their evolution is a stepping stone to understand planet formation, hence the diversity of initial conditions for planetary systems architectures and their chemical heritage. In this talk I will report on our efforts to observationally constrain solids and gas content in disks and their evolution during the planet formation process.

Reinhard Genzel

## Testing General Relativity with Infrared Interferometry in the Center of the Milky Way

The Center of our Galaxy is a unique laboratory for exploring the astrophysics around a massive black hole and testing General Relativity and other theoretical concepts in this extreme environment. I will discuss the results of a major campaign of observing the Galactic Center in 2017/2108 with three instruments at the European Southern Observatory's VLT, including the novel GRAVITY interferometric beam combiner of the 4 UTs. During this period the B-star S2 completed a peri-passage at ~1400 $R_S$, and permitted for the first time a test of the equivalence principle and the detection of the first post-Newtonian orbital elements in a classical 'clock experiment' around a massive black hole.

Annop Wongwatharanat

## Nucleosynthesis of the 44Ti Isotope

The nucleosynthesis yield of radioactive isotopes such as 44Ti and its distribution inside gaseous supernova remnants provide extremely valuable insights into the explosion condition at the final moment of massive stars in their lifetime. We discuss recent results obtained by performing a 3D neutrino-driven core-collapse supernova simulation using a parameterized neutrino source of a hydrogen-stripped massive star. Our results demonstrate striking similarity in the distribution of 44Ti isotope when compared with recent observations of the Cassiopeia A (Cas A) remnant. In addition, we show that the high 44Ti abundance in Cas A may be explained by the standard neutrino-driven explosion mechanism without the need for rapid rotation or a jet-driven explosion.

Moritz Pleintinger

## Nucleosynthesis Feedback of Massive Star Groups on the Surrounding ISM

The interstellar medium in our Galaxy is understood to be of complex morphology and highly dynamic, far from a simple state of pressure equilibrium. Commonly, 3D MHD simulations have been exploited to get basic insights into the complexities of the ISM. Here, high-resolution simulations can trace physical processes down to the scales of shocks from winds and explosions which inject turbulent energy into the ISM, while studies at the few-hundred to kpc scale adopt subgrid models for simulating the appearance of the Galaxy's ISM.
Observations of the ISM are difficult due to biases towards different phases of the ISM in each of the known gas tracers. Here we exploit diffuse gamma-ray line emission, which complements such observations by a tracer of fresh nucleosynthesis ejecta, which is independent from gas density and temperature.
The 1.8 MeV emission line from 26 Al decay is a key tracer of ongoing nucleosynthesis and chemical enrichment in our Galaxy. This gamma-ray emission is prominent in the direction of individual massive star groups and in the inner part of the Galactic plane.
26 Al nuclei are ejected in strong stellar winds (Wolf-Rayet phase) and supernova explosions. Because their half-life of ~0.7 Myr is comparable to the crossing time of massive star ejecta inside superbubbles, the emission is closely connected to the dynamical properties of massive star groups and their surroundings. Investigating these circumstances provides a unique nexus between stellar physics and galactic evolution.
An overview of recent 26 Al observations performed with INTEGRAL/SPI and the current understanding of feedback processes of massive OB associations on the superbubble scale will be given. This includes the description of recent chemodynamical simulations and our galactic population synthesis calculations as well as how we can compare simulations with measurements. This opens the possibility to validate 3D spatial distributions of the lage-scale
26 Al emission and to test the underlying assumptions of stellar nucleosynthesis and feedback.

Mathias Garny

## Dark matter and dark radiation

In this talk we explore consequences of the assumption that dark matter is only very weakly coupled to the Standard Model of particle physics. If dark matter belongs to a dark sector comprising interactions within itself, the dynamics of the dark sector can lead to differences compared to the cold dark matter paradigm, and affect cosmic structure formation on a range of length scales. We review various setups of this type, discuss the evolution in the early universe, and possible observables.

Tim-Eric Rathjen

## The strong impact of cosmic rays on the structure of the ISM and outflows

Cosmic rays are a fundamental constituent of the interstellar medium (ISM). However, the impact of this relativistic component is neglected in most numerical ISM studies. We present results from the - worldwide - first three-dimensional magneto-hydrodynamic simulations of a multi-phase ISM accurate modeling of all major ‘feedback’ sources from massive stars: stellar winds, radiation, supernovae and cosmic ray injection and diffusion. We demonstrate how cosmic rays help accelerating warm gas resulting in a smoother and colder outflow structure, in much better agreement with many observations. The results indicate a paradigm shit in our understanding of galactic outflows. This project is co-funded by the excellence cluster “UNIVERSE”.

Klaus Dolag

## The challenge for Cosmological Simulations

The set of Magneticum Simulations still contains the largest, cosmological, hydrodynamical simulation to date and follows the formation of cosmological structures in so far unaccomplished detail. These simulations taking into account all important physical processes to allow a self consistent comparison of galaxies, super massive black holes and galaxy clusters to observations at multiple wavelength and throughout the entire epoch of structure formation (Magneticum, www.magneticum.org). They allow to study the interplay between the baryonic component and dark mater in galaxies and galaxy clusters and give unique insights into our understanding how the visible structures in the universe form and evolve across cosmic time.

Ortwin Gerhard

## The Milky Way's Dark Matter and Stellar Mass Distribution in the Era of Gaia

Earlier this year Gaia data release DR2 published accurate positions, parallaxes, and proper motions for 1.3 billion sources. For stars with well-determined distances, these proper motions lead to exquisite transverse velocities even beyond 10 kpc scales where typical Gaia parallaxes are no longer accurate. Using RR Lyrae stars we have measured the force field in the inner Galaxy between 5-20 kpc from the Galactic centre, and removing the contribution from the baryonic matter, obtained measurements for the flattening of the dark matter halo in this radial range, the dark matter density near the Sun, and the local circular velocity. Combining Gaia, VVV, and results from spectroscopic surveys now offers the exciting possibility to accurately measure the mass distribution in the inner 5 kpc (the bulge and bar region), and to characterize the (chemo)dynamics of Galactic stellar populations in the combined gravitational potential.

Rolf Kudritzki

## The Brightest Stars in the Universe as Extragalactic Probes of Cosmic Abundances and Distances

The determination of chemical composition and distance is crucial for investigating the formation and evolution of star forming galaxies. Stellar absorption line studies based on quantitative spectroscopy provide an attractive alternative to the standard techniques using the strong emission lines of HII regions for chemical composition or stellar photometric methods for distances. I will introduce a number of newly developed methods

- multi-object spectroscopy of individual blue and red supergiant stars, the brightest stars in the universe at visual and NIR wavelengths,
- NIR spectroscopy of super star clusters,
- optical spectroscopy of the integrated light of stellar populations in the disks of star forming galaxies,
- the flux-weighted gravity luminosity relationship for distance determinations

and present results accumulated in the last two years. I will then discuss the far reaching scientific perspectives and the potential of these methods for the use of future Extremely Large Telescopes (ELTs).

Peter Fierlinger

### Electric Dipole Moment searches

Since several decades people search for the electric dipole moments (EDMs) of fundamental particles, an unambiguous manifestation of parity (P) and time reversal symmetry (T) violation. Assuming the conservation of CPT, T violation in a fundamental system also means CP violation. This has only been observed in very few systems in the Standard Model of particle physics (SM) as a tiny effect. However, it would be needed in much larger quantities to help explain the matter-antimatter asymmetry in the Universe. With a long history of innovation and persistence, the neutron EDM dn is now limited to below 3·10−26 e·cm, an extraordinarily small number, corresponding to an energy resolution of 10-22 eV. As a complementary system among a variety of possible options to search for EDMs, the neutron is still a very promising candidate due to its comparably simple composition. I will discuss experimental efforts and challenges to develop a next generation of neutron EDM searches, with one focus on the PanEDM experiment starting to take data at ILL Grenoble in the first reactor cycle in 2019. I will also show technological advances in ultra-low magnetic fields with broader impact including probing ultra-light particle searches and a new concept to reach 10-29 ecm sensitivity with existing technology.

## Seed Money Posters

in alphabetical order (last name)

K. Bernert, C. Roick, H. Saul, S. Schönert, B. Märkisch

### Prototype detector system for precision beta spectroscopy to determine the electron anti-neutrino spectrum in the decay of 144Pr for a sterile neutrino search in CeSOX

The objective of the CeSOX experiment was to discover or to refute 4th sterile neutrinos in the relevant mass range to explain observed anomalies in oscillation experiments. An antineutrino source made of 144Ce / 144Pr would have been located below the Borexino detector. The search for sterile neutrinos using the CeSOX experiment requires excellent knowledge of the expected anti-neutrino spectrum, including the shape factor for the dominant first forbidden non-unique decay of Pr-144 to Nd-144.
To measure the shape factor we designed and built a dedicated plastic scintillator detector with improved light yield, uniformity, and stability to be used with the spectrometer Perkeo III. In the meantime, the CeSOX project is no longer pursued. The improvements in detector performance enable the search for a hypothetical Fierz interference term in the electron spectrum of neutron beta decay in an upcoming measurement campaign at the ILL, Grenoble, with unprecedented accuracy.

Natalia Borodatchenkova, Christian Alig

### An exploratory virtual and augmented reality lab for UNIVERSE and ORIGINS

Our goal was to build an exploratory virtual (VR) and augmented (AR) reality lab to be used by Cluster scientists for the upcoming ORIGINS Cluster. We concentrated on astrophysical simulations as our first application and aspired to create a prototype VR Visualisation Tool, that in the future could be upgraded into a stand-alone program to be used by scientists on their computers or in a visualisation facility. Our first main goal was to build a user friendly VR environment in which the user can load their data, switch between data types, visualisation types and conveniently view their data without having to leave VR. Multiple data formats for different simulation codes were planned to be included. Additional features were planned on request by people testing the Software. The second main goal included multi user capability for the VR Visualisation Tool, such that people sitting at different institutes could connect and work together on simulation data from within VR. In addition to VR Visualisation another goal was to explore the possibilities of AR Visualisation. For the remaining time, if the two main goals could be reached, it was planned to also include support for animated simulations and to be able to control the animations from within VR. Development of the project went well and we reached our two main goals before the end of the funding period, thus we were able to include additional features that were not planned originally, like support for 360 degree movies and a basic demonstration of support for large scale simulations that do not fit into memory at once. In conclusion our prototype for working with astrophysical data in VR is ready and our next step is to upgrade it to a stand-alone program, expanding the features and eventually include support for data of other scientific disciplines within the Cluster. In addition to the scientific use our VR Lab can also be used for educational and outreach purposes, due to the immersive nature of VR Visualisation.

Xavier Defay, Federica Petricca, Karoline Schäffner

## MeV-scale dark matter search with cryogenic silicon detectors

Dark Matter (DM) in the MeV mass range is a theoretically well-motivated paradigm but rather unexplored experimentally. Such light particles are undetectable by conventional nuclear recoil direct detection experiments but could be detected through DM-electron scattering. Semiconductors are particularly suitable target materials because of their small band gap which allows for ionization signals induced by dark matter particles of a mass lower than 1 MeV.c-2. We present here a project to develop a dark matter detector made of silicon and featuring single charge sensitivity at cryogenic temperature, taking advantage of our experience with the Neganov-Trofimov-Luke effect.

Klaus Dolag, Axel Meyer, Christian Sicka, Cecilia Scorza, Stefan Waldenmaier, Nicolay Hammer

## The Universe seen from Munich

This project aims to produce a spectacular movie of the evolving universe, based on cosmological hydrodynamical simulations (Magneticum), zoomed simulation of galaxy formation (Dianoga) as well as a simplified galaxy merger simulation. Together with the team from the German Museum, we are therefore producing a new planetarium show. A combination of the ZEISS SKYMASTER ZKP 4 optomechanical projector and six ZEISS VELVET digital projectors will be used to project 4k images and movies onto the 15m dome. This show will explain how the Universe (and galaxies within) evolve and how scientists are using computer simulation to understand these processes. Thereby, we put special emphasis on the Munich area, using simulations carried out within the UNIVERSE cluster, highlighting the role of LRZ as local HPC center for performing such simulations as well as the relevant science landscape in the Munich area. All observational images are taken with instruments at the Wendelstein Observatory. The ca. 25 minutes long show will include an explanatory audio track. It is supposed to become part of the standard planetarium shows within the German Museum. Given the typical visitor numbers we expect that this show will be watched by ca. 70.000 visitors per year.

Florian Dufter, Laura Fabbietti

## A silicon vertex tracker for the investigation of the tetraneutron

The possible existence of a four-neutron system as well as its properties have been a long-lasting question in nuclear physics. An experiment using the SAMURAI spectrometer at the RIKEN Nishina facility (Japan) was performed to investigate the 4n system via a new method, i.e., the measurement of $^{8}$He(p; p$\alpha$)4n reaction at large momentum transfer. A secondary $^{8}$He beam at an energy of 156 AMeV was impinging on the liquid hydrogen target of 5 cm thickness from the MINOS system. For a high resolution invariant mass reconstruction a precise vertex reconstruction is one of the most important contributions. For this task we have developed a new multi-layer setup of highly segmented 100 $\mu$m thin silicon detectors. The detector concept, its implementation and results for the performance, resolution and efficiency in the experiment will be presented. This work is supported by the SFB1245 of TU Darmstadt (DFG) and the DFG Cluster of Excellence "Origin and Structure of the Universe”.

Peter Fierlinger, William Terrano

## An upgrade helium-xenon comagnetometer

The HeXe experiment is based on two isotopes, 129-Xe and 3-He, which are compared to extract the electric dipole moment of 129-Xe. The isotopes are hyper-ploarized and their spins precess freely in a constant 1 muT magnetic field within the same volume. The signal is detected with a SQUID. During the preparation runs in 2016 and data taking runs in 2017, a dominating systematic effect has been identified, which could not be satisfactory explained with existing literature. Within the seed-funding project end of 2017, we asked for improved equipment to investigate this effect in more detail. The effect is a frequency shift between the comagnetometer substances, which is not stable in time and thus artificially limits the free precession time of the EDM data taking. As a consequence, the sensitivity improvement with measurement time improves only with the squareroot in time instead of linearly. The enhanced data taking capabilities due to the seed funding project enabled a thorough investigation of the effect, tracing it back to residual longitudinal polarization from non-perfect spin flips and geometrical artefacts. While the results are analyzed (https://arxiv.org/pdf/1807.11119.pdf) and have recently been submitted for publication, the outcomes have influenced the EDM data taking run in 2018 with competitive sensitivity, which is to be unblinded soon. The findings also enable an order of magnitude improvement for most experiments in the field with only minor changes to experimental apparatus.

Jochen Greiner, Elisa Resconi

## A novel cryogenic 4-channel VIS/NIR beam splitter

Quick identification of high-redshift GRBs requires multi-channel imaging of the afterglow emission. Aimed to fly on a CubeSat, we have designed a novel beamsplitter which focuses 4 channels in the 0.8-1.7 micron range onto one detector. Seed money was granted to build a first demonstrator. The poster describes the challenges, and presents the status of the hardware development in collaboration with Fraunhofer IOF.

Erwin Gutsmiedl, Stephan Paul , Igor Konorov, Wolfgang Schott, Torsten Soldner

## First measurement of the free neutron beta decay hydrogen atoms at a high flux beam reactor throughgoing beam tube

The mono-energetic (T=326 eV) free neutron bound beta decay (BOB) H atoms (n->H +anueelectron), generated at the center of a throughgoing beam tube (PIK reactor, Gatchina), are transformed with high efficiency (>10%) into H-ions with an Ar cell. After extraction from the beam tube, measured by means of a pulsed electric deflector, the metastable H- are selected, using a Bradbury-Nielsen (BN) gate-chopper, and measured by means of an MCP detector. Although the bound beta decay branching ratio is small ($4\ 10^{-6}$), the experiment seams feasible (several counts/s).

Stefan Knirck

## Hunting Axion Dark Matter with MADMAX - first proof-of-principle booster setup

Axions and axion-like particles are excellent low-mass dark matter candidates. The MADMAX experiment is aimed to directly detect galactic axions with masses between $40\,\mu\mathrm{eV}$ and $400\,\mu\mathrm{eV}$ by using their conversion to photons at interfaces between materials of different dielectric constants under a strong magnetic field. Combining many such surfaces, this conversion can be significantly enhanced using constructive interference and resonances. We present a first proof-of-principle realization of such a booster system consisting of a copper mirror and up to 5 sapphire disks. The electromagnetic response of the system is investigated by reflectivity measurements.

The mechanical accuracy, calibration process of unwanted reflections and the repeatability of the results using basic optimization algorithms to place the disks are investigated. We find that for the presented cases the electromagnetic response predicted by previous theoretical calculations is sufficiently realized in our setup.

Martin J. Losekamm, Jan Friedrich, Stephan Paul, Sebastian Uhl, Thomas Pöschl, Igor Konorov

### Seed Money project Seed3 02-2018: A New Track Trigger for Proton Radius Measurements at CERN's Super Proton Synchrotron

Muon-proton elastic scattering at high energies is regarded as a unique experimental method to help address the proton radius puzzle. The tiny scattering angles, the negligible energy loss of the scattered muons, and the high beam intensities required for a precise measurement have so far presented adamant experimental challenges. Recent advances in detection technologies and in real-time data acquisition and triggering systems now enable new opportunities for such a measurement. We are part of a new collaboration that proposes to measure the proton radius with a high-energy muon beam at the M2 beam line of CERN's Super Proton Synchrotron starting in 2021. The experiment will use an upgraded version of the current COMPASS spectrometer.
One of the proposed experiment layouts foresees a track trigger used to select only those events with scattering angles large enough for a precise analysis. This trigger would comprise three scintillating-fiber tracking stations, each consisting of 800 200-μm fibers read out individually by dedicated silicon photomultipliers. In this contribution, we present preparatory development work and initial measurements we performed to demonstrate the feasibility of this concept.

Benjamin Moster, Thorsten Naab

### Galaxy Formation Modeling with tensor core accelerated Deep Neural Networks and Reinforcement Learning

In our seed money project, we developed a way of using deep neural networks (DNNs) and reinforcement learning together with stochastic optimization, a particle swarm optimization (PSO) algorithm, to populate haloes from dark matter-only simulations with galaxies across redshifts $z = 0$–$8$. For this we acquired a workstation with 2 NVIDIA Volta graphic cards with powerful tensor cores that allow for a significant speed up of the network training. Using existing predictions from the empirical model Emerge, we showed that it is possible to first train a DNN by using supervised learning, targets coming from Emerge, and later with reinforcement learning using a PSO algorithm that judges the results against available observational data. The final DNNs are able to give 10.9% better predictions than the model they were based on, measured using the well-motivated loss function used when performing reinforcement learning.

C. Roick, H. Saul, B. Märkisch

### Prototype high-voltage Proton-to-Electron converter for PERC

We present the prototype of an electrostatic proton accelerator to be employed as converter device for coincident proton and electron detection using coated ultra-thin carbon foils. The device is designed to be used within PERC, the next-generation instrument for studies of the neutron beta decay. PERC is currently under construction at the MLZ, Garching.
Improvements over former concepts are lower costs, a better conformity with high vacuum and high voltage requirements and reliable installation of the fragile foils. The setup is shortly to be tested for high voltage and vacuum performance.

Stefan Rummel, Thomas Kuhr, Frank Simon

### Development of a small form-factor power supply for calorimeter applications

Large, highly granular calorimeter systems based on Silicon Photomultipliers (SiPMs), which are being developed for applications in collider experiments and other high energy physics projects, require stable, low noise supply voltages for optimal performance. Due to the high numbers of channels in these detectors and the low power consumption of SiPMs, commercial power supply units do not satisfy the space constraints imposed by the application. Therefore the development of an application specific supply unit is necessary. In our seed project we investigate an alternative approach of using a harmonic power oscillator to generate isolated, low noise primary voltages which feed a linear regulator. This method avoids the use of a hard switched H-bridge which can be identified as main source of high frequent interference.

Frank Simon, Naomi van der Kolk, Bela Majorovits

## Exploratory Study of PEN as Scintillator Material

Polyethylene naphthalate (PEN) was shown to produce scintillation light when penetrated by ionizing radiation, with light yields similar to those observed in commonly used plastic scintillators. We are studying the suitability of this material for calorimetry and low background applications. First results on the properties of samples produced in collaboration with external institutes, and first steps in the development of calorimeter readout elements will be presented.

Raimund Strauss, M. Mancuso, E. Mondragon, Lothar Oberauer, Federica Petricca, J. Rothe, Stefan Schönert

## Exploring coherent neutrino nucleus scattering with NU-CLEUS

The detection of coherent-neutrino nucleus scattering opens up new opportunities to probe physics beyond the Standard Model such as the search for a neutrino magnetic moment or sterile neutrinos. We present a novel cryogenic neutrino experiment at a nuclear power reactor which allows for precision measurements with a miniaturized detector size. With a recent demonstrator we have achieved ultra-low thresholds of 20eV, one order of magnitude lower than previous devices, using a novel type of detector based on CRESST technology. We have initiated the NU-CLEUS experiment which aims to operate at close distance to a power reactor. A promising site about 80m away from the twin reactor cores of the CHOOZ power plant is currently being characterized by on-site background measurements with our French collaborators at CEA. This poster will report on the most recent results on the NU-CLEUS cryogenic detector, the ongoing background measurements at CHOOZ and the experimental strategy of NU-CLEUS.

Berkin Ulukutlu, Laura Fabbietti, Piotr Gasik, Andreas Mathis, Lukas Lautner

## Facing destructive GEM discharges with an sCMOS

The Gas Electron Multiplier (GEM) has become a commonly employed technology for modern high- rate particle and nuclear physics experiments. The key parameter for their long-term operation is stability against electrical discharges. In particular, the so-called secondary discharges, which occur between GEMs in a stack, are still not well-understood phenomena. Unlike ordinary (primary) sparks in GEM structures, already one violent event of this type may cause irreversible damage to the detector.

It has been shown that when operated with adequate gas mixtures, the scintillation light emitted during the development of electron avalanches in GEMs can be used for track imaging using high-resolution integrating devices, such as CMOS or. Of particular interest are mixtures emitting in the visible and near-infrared regions (from 400 nm to 1000 nm), which match the sensitivity region of the modern CMOS sensors.

In our Seed Money Project we have built an optically read-out GEM detector and employed optical techniques as a new way to investigate thoroughly the secondary discharge phenomena in GEM-based detectors. The goal is to understand the mechanism of creation of such particularly harmful discharges and to find a way to avoid the occurrence of such events. The new set-up employs a GEM detector in a gas tight vessel with Borofloat® glass window. A 5 MPix scientific CMOS camera (Andor Zyla 5.5) registers the scintillation light emitted during the amplification process in Ar-CF4 (80-20) gas mixture. We report on the commissioning of the set-up with alpha particles and first approach to register primary and secondary discharges.

# Contributed Posters

in alphabetical order (last name)

Alan Ianeselli

## DNA Denaturation Induced by Low Atmospheric Pressure in a Thermal Gradient

Atmospheric pressure could have fluctuated considerably over the geological time. Globally as a result of changes in the thickness and composition of the atmosphere, or locally due to altitude differences, geological evidence suggest that the atmospheric pressure could have reached values lower than half of modern levels during the Archean eon. By determining the phase space of water, atmospheric pressure could play an important role during the molecular and biological evolution.

Here, we use FRET to study the effects of low pressure (P ~0.2 bar) on the conformation of a 51bp dsDNA. We found that a low P environment in a thermal gradient was able to furnish the conditions to induce the separation of the two complementary DNA strands. Our results provide insights into a new mechanism of non-thermal DNA denaturation which can override the temperature limits of aqueous solutions in a low pressure Earth scenario.

Patrick Kudella

## Sequence selection of oligonucleotides under a ligation chain reaction

The replication of information on RNA or DNA is central for the emergence of life [1]. Previously, the replication of one sequence has often been in the focus, but we think it is essential to monitor the replication and selection dynamics of a broader pool of sequences and how it behaves under simple replication conditions.

We focus on the transition from template-free polymerization to templated ligation and consider the possibility, that the same chemistry for polymerization also triggered the first replication cycles by templated ligation. Once polymerization could create oligomers long enough to hybridize at a given temperature, we expect a nonlinear ligation dynamic to set in. We study whether sequences were selected at this onset of replication and if interesting non-linear and frequency-dependent behavior can be found [2]. For short strands, the ligation is dominated by the weak hybridization dynamics (ssDNA linked by Watson-Crick-base-pairing [3]). By using AT-only (A: adenine, T: thymine) 12mer random sequences as starting material, the sequence space for the first ligation stage that creates 24mer can still be completely sampled. We found elongation to 36mers, 48mers and longer and could obtain more than 12 million individual strands using Next Generation Sequencing (NGS), showing a significant selection of sequences undergoing this elongation dynamics. We analyze the sequences with self-written LabView code and show how spiking with defined sequences changes the sequence selection dynamics of the replicated sequence pool.

[1] J. Szostak et al., in The RNA World, 1697402, (1990)
[2] S. Toyabe, D. Braun, arXiv:1802.06544v2 [physics.bio-ph], (2018)
[3] F. Crick, Nature 227(5258), (1970)

Kilian Lieret

## Construction of Angular Observables Sensitive to New Physics in $B \longrightarrow D^*\tau\nu$ Decays and Measurements of Differential Cross Sections of $B \longrightarrow D^*\ell\nu$ Decays with Hadronic Tagging at Belle

Recent measurements of $B \longrightarrow D^{(*)} l\nu$ cross sections at Belle, BaBar, and LHCb challenge lepton universality and thus the Standard Model at a combined confidence level close to four standard deviations. New measurements of differential decay rates could contribute to the understanding of these anomalies.

The differential cross section of the decay $B \longrightarrow D^*(\to D\pi) l\nu$ is parametrized according to different dependencies on the three decay angles and the coupling constants of potential new

physics contributions. Observables using binned measurements of the differential cross section are characterized and explicitly constructed. Based on an estimate for the obtainable sensitivity, optimal binnings for such measurements are discussed. The discriminatory power of the thus constructed observables is discussed based on a basis of dimension six operators with renormalizable couplings contributing to $B \longrightarrow D_* \tau \nu$. Furthermore, continuing work on an analysis of the $B \longrightarrow D_*(\rightarrow D\pi)\ell\nu$ decay channel for ell=e, mu using data from the Belle detector at KEKB is presented.
The events are selected from 772 million $e+e- \rightarrow Y(4S) \rightarrow B\bar{B}$ events, where one B meson is fully reconstructed in hadronic modes. Unfolded differential decay rates in four kinematic variables are presented separately for $\ell=e, \ell=\mu$ and a combined fit, allowing for precise calculations of Vcb and $B \longrightarrow D_*$ form factors. The new lepton flavor specific results are also expected to impact the discussion about potential light lepton flavor universality violations prompted by measurements of $B \longrightarrow K(*) \ell\ell$ decays.

Thomas Litschel

## Genetic exchange between protocells

Early protocells are thought to have consisted of a self-replicating, RNA-based genetic system and a primitive metabolism enclosed within an amphiphilic membrane [1]. These protocells would have relied on simple self-organization processes presumably driven by environmental events. One such process, likely critical for early cellular evolution, is the exchange of content such as genetic material between individual protocells.
Using DNA-containing giant unilamellar vesicles (GUVs) as model systems, we investigated freeze-thaw cycles as an environmental driver for content exchange between vesicles [2]. We tested various freezing and thawing scenarios and, under certain conditions, found content mixing between vesicles to be very thorough with evidence thereof in all observed vesicles. Surprisingly, we found that content is transferred through diffusion across the membranes of tightly packed GUVs, and not through vesicle fusion and fission, as was observed in similar experiments [3].
In future experiments, we will incorporate RNA-based systems within GUVs to model the implications of reoccurring content exchange in such prebiotic systems. In particular, we aim to combine freeze-thaw driven ribozyme activity with content mixing to probe if both processes could have synergistically driven primitive forms of protocell proliferation.

[1] J. C. Blain and J. W. Szostak, Annu. Rev. Biochem. 83, 615–40 (2014)
[2] T. Litschel et al., New J. Phys. 20, 055008 (2018)
[3] G. Tsuji et al., Proc. Natl. Acad. Sci. 113, 590–5 (2016)

Thomas Matreux

## Microfluidic rock-like reactors to study the synthesis of the first nucleotides

Amongst the many open questions in the origin of life is the origin of the first biomolecules: from lipids to amino acids to nucleotides, life exhibits a wealth of complex molecules whose prebiotic synthetic pathways remain unclear. Whatever the answers, early biomolecules must have arisen under realistic geological boundary conditions. Recent chemical advances have shone light upon potential synthetic pathways for the production of nucleotides in the laboratory, starting from simple abiotic precursors [1]. However, and in spite of the latest progress [2], most experiments have been performed in bulk chemistry, and through independent and successive synthetic steps. Therefore, geological plausibility remains largely unexplored.
We have emulated the conditions of microfluidic flow in rock pores, to uninterruptedly drive, within one single system, the sequential reactions necessary to produce an activated nucleotide [1]. Using CAD software and finite-element-method simulations, we have designed microfluidic devices to run the nucleotide synthesis autonomously, and to recreate a scenario analogous to what could be found in porous rocks on early Earth. We produce the reactors assembled from a repertoire of modular building blocks using stereolithographic 3-D printers, allowing for many applications beyond our own. The flow can be driven by gravity, increasing the geological realism

of our system. Our methods also allow us to embed rock powders into the microfluidic system, enabling the testing of potential pre-enzymatic catalysts and further increasing geological plausibility. These results open the door to studies of any scenarios for the emergence of life, whereby chemistry is driven in a geologically realistic system to generate the earliest biologically relevant molecules.

[1] Powner, Gerland & Sutherland. Nature doi.org/10.1038/nature08013 (2009)
[2] Ritson et al. Nat. Comm. doi.org/10.1038/s41467-018-04147-2 (2018)

Matthias Morasch

## Heated microbubbles condense and encapsulate molecules for early evolution

Non-equilibrium mechanisms are crucial for the emergence of early life. They allow the fundamental continuous accumulation of prebiotic molecules into microcompartments. In addition, cyclic temperature changes, localized wet-dry cycles, crystallization, and encapsulation in lipids that undergo cell fission are considered crucial for the emergence of informational polymers. Here we show that all above mechanisms are triggered in less than 30 minutes at microbubbles in a heat flow. At the heated bubble, molecules accumulate by the continuous evaporation of water up to 1000-fold. The evaporating water recondenses at the cold side, implementing a heat pipe geometry that drives a continuous coffee-ring effect. The findings offer multiple reaction scenarios for the early chemistry of life. The setting is expected ubiquitously on early rocky planets where outgassing promotes gas bubbles, water is encapsulated in porous volcanic rock, and temperature gradients are provided from hydrothermal flows of steam or water.

Marc Schartmann

## The life cycle of starbursting circum-nuclear gas discs

High-resolution observations from the submm to the optical wavelength regime resolve the central few 100 pc region of nearby galaxies in great detail. Concentrating on the role circumnuclear discs play in the life cycles of galactic nuclei, we employ 3D adaptive mesh refinement hydrodynamical simulations with the RAMSES code to self-consistently trace the evolution from a quasi-stable gas disc, undergoing gravitational (Toomre) instability, the formation of clumps and stars and the disc’s subsequent, partial dispersal via stellar feedback. We find that observed nuclear starbursts in nearby galactic nuclei can be understood as the result of gravitational instabilities in dense circumnuclear discs. By comparing these simulations to available integral field unit observations of a sample of nearby galactic nuclei, we find consistent gas and stellar masses, kinematics, star formation and outflow properties. The knowledge of the resulting simulated density structure and kinematics on pc scale is vital for understanding inflow and feedback processes towards galactic scales.

Philipp Schwintek

## Monitoring the accumulation of molecules inside hydrothermal chambers via UV-Spectroscopy

The accumulation of molecules inside porous rock of hydrothermal vents is of great interest for origin of life research [1]. Of special relevance is the behavior of prebiotic molecules e.g. formamide (a potential precursor of nucleobases), single nucleobases themselves, and 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC - a catalyst for polymerization and ligation reaction of phosphorylated nucleotides) [2-6]. Due to their size, the in situ observation of such small molecules inside microfluidic compartments is difficult. Using real time and spatially resolved UV-spectroscopy the setup at hand allows for the quantification of molecules in aqueous solutions at micro- to millimolar concentrations. Preliminary results show the accumulation and hydrolysis dynamics of EDC and well as nucleobases inside mimicked hydrothermal pores. The setup opens new perspectives in quantifying and observing processes such as EDC polymerization reactions of single nucleotides. Moreover, we can monitor chemical conversions, thermophoresis, and non-equlibria of chemical gradients (e.g. concentrations, redox and pH gradients) directly or via gradient sensing molecular systems, going beyond the fluorescence-based methods used previously [7].

[1] M. Kreysing et al. Nature chemistry 7(3), 203(2015)
[2] D. Niether et al. PNAS, 113(16), 4272-4277(2016)
[3] R. Saladino et al. ChemBioChem 7(11), 1707-1714 (2006)
[4] A. Kaiser & C. Richert Journal of Organic Chemistry, 78(3) (2013)
[5] M. Kramer & C. Richert Chemistry & biodiversity, 14(9) (2017)
[6] M. Jauker et al. Angewandte Chemie International Edition, 54(48) (2015).
[7] L.Keil et al. Nature communications 8(1897), (2017)

Oliver Trapp

## Early Pathways to Life: Mechanisms to Molecular Evolution and Homochirality

Mechanisms leading to a molecular evolution and the formation of homochirality in nature are interconnected and a key to the underlying principles that led to the Origin of Life. In this presentation I will focus on mechanisms that lead to the formation of homochirality by creation of self-amplifying and auto-catalytic molecular networks. The most prominent example of an autocatalytic process that leads to high amplification of chirality is the Soai reaction, where aldehydes are transformed into the corresponding alcohols by addition of dialkylzinc reagents. Mechanistic investigations and a novel mechanism of the Soai reaction will be presented with a focus to transfer the knowledge to reactions that are relevant in the context of Origin of Life. In the second part I will present our latest results to create a catalytic system showing evolution on a molecular level under strictly prebiotic reaction conditions. This system could have potentially triggered the transition from dead matter to self-sustainable reaction networks. The third part is dedicated to a novel synthesis of desoxyribonucleosides that provides also interesting structures that can be considered as progenitors of our known DNA.

Christian Vogl

## A machine learning approach to measuring distances to type II supernovae based on NLTE spectral modeling

Type II supernovae provide an independent way to probe cosmology. Due to the comparatively simple physics of their hydrogen-rich envelopes distances to these objects can be inferred directly from first-principle radiative transfer modeling. As such, their use as distance indicators is based on well-understood physics and does not rely on calibration by a purely empirical correlation or a distance ladder.
Up to now, the high computational costs of radiative transfer calculations, as well as the need to fit the data through optimization by hand and eye, have prevented the wide-spread application to cosmology. To tackle this issue, we have used machine learning techniques to develop a spectral emulator to replace the simulator i.e. the radiative transfer code during the fit process at a fraction of the original computational cost. We demonstrate that the spectral emulator can learn to predict the output of our radiative transfer code, an extended version of the MC code TARDIS, based on a set of precomputed spectra to high accuracy. This allows us to efficiently explore the high-dimensional parameter space including, for example, metallicity, density profile or expansion velocity. In a next step, we combine our spectral emulator with a framework for Bayesian inference that explicitly accounts for the complicated covariance structure present in spectral residuals. Finally, we present preliminary results for modeling spectra of SN1999em and SN2005cs using the newly developed approach.