STRUCTURES | NEWS

STRUCTURES CLUSTER OF EXCELLENCE

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

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ERC Synergy Project: Dynamics and Control of Neural Stem Cells

February 2023

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April 24: Start of Academic Lunch Hour
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STRUCTURES Short News

NEW YRC SPOKESPERSONS

The Young Researchers Convent (YRC) has elected Ricardo Waibel and David Maibach as their new speakers in the General Assembly on January 19. They follow Elena Kozlikin and Christophe Pixius, whom we want to thank for their great commitment. We introduce the new speaker duo on p.3.

NEW STRUCTURES MEMBERS

We are happy to welcome Roland Herzog (Scientific Computing and Optimization, IWR) and Peter Smillie (Differential Geometry, MI) as new members of the STRUCTURES Cluster. The two were elected in last December's General Assembly. We wish them a good start and look forward to many joint projects.

SCIENTIFIC MACHINE LEARNING

The "Machine Learning Galore!" event held on 19. January launched a new initiative, *Scientific Machine Learning*, which aims to foster interaction within the local machine learning community. Its portal, http://mlai.uni-heidelberg.de summarises the many relevant events and news from across campus that would otherwise remain scattered across single institutes or fields. The initiative is a joint effort by the Interdisciplinary Center for Scientific Computing (IWR) and the STRUCTURES Cluster of Excellence.

The goals of this new platform align with STRUCTURES' objective of driving research into the fundamental understanding of current and future machine learning, and with IWR's aim to leverage machine learning to enable the solution of long-standing problems in the natural and life sciences, the engineering sciences, as well as the humanities.

SCIENCE OUTREACH: AKADEMISCHE MITTAGSPAUSE 2023

We are delighted to announce that this spring, STRUCTURES is going to host Heidelberg University's "Akademische Mittagspause" (academic lunch hour), a format of 15-minute public science talks aimed at a general audience, taking place at the University Church (Peterskirche) from April 24 to July 21 at 1:00 pm.

The focus of the talks will be structures in the world, explaining their formation, complexity and underlying unifying concepts and principles. The talks will be recorded and partially accompanied by musical performances.

RESEARCH SPOTLIGHT

ERC Synergy Project: Dynamics & Control of Neural Stem Cells

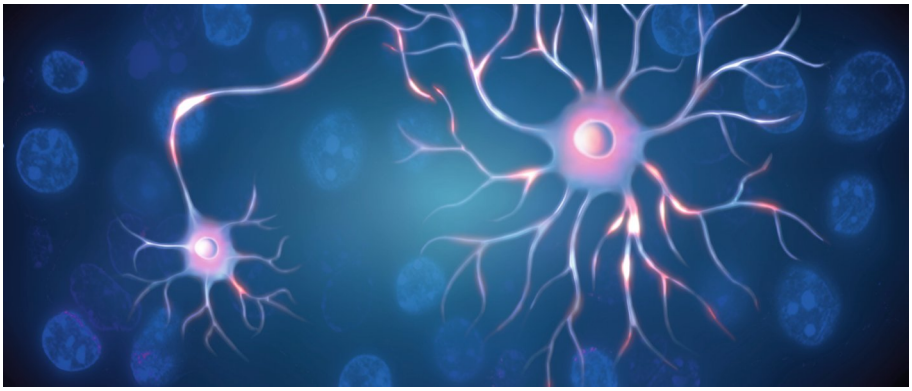
We are happy to announce the upcoming start of the PerPetuating Stemness (PEPS) project in summer. PEPS is an ERC funded multi-disciplinary collaborative research effort to understand how stem cells in the vertebrate brain maintain their ability to renew themselves and differentiate over the course of an individual's lifetime.

STRUCTURES members Anna Marciniak-Czochra and Simon Anders, leading the research groups "Applied Analysis and Modelling in Biosciences" and "Biostatistics for Omics Data" respectively, will contribute as PIs to this project, which is run in collaboration with Prof Ana Martin-Villalba from the German Cancer Research Centre (DKFZ) and biologist Dr Laure Bally-Cuif from Institut Pasteur in Paris. They will combine experimental methods with mathematical modelling to decipher the complex spatio-temporal interactions that regulate the balance between producing the required cells and maintaining the stem cell reservoir.

Why Explore Stem Cells?

Stem cells are cells with the ability to divide and differentiate into various other cell types, allowing the body to regenerate and repair damaged tissue. The brain has such stem cells too, but their ability to repair injuries is very limited in mammals, much more so than e.g. in fish. PEPS will compare the function of stem cells in zebrafish and mouse and will map out the mechanisms that regulate the number of brain stem cells and how they contribute to maintaining brain function over the lifespan, down to processes at the single cell level. How do interactions at the single-cell level lead to the emergence of properties at population level, such as the balance between producing the required cells and maintaining the stem cell reservoir?

Gaining insights into how the brain's ability to generate new functional neurons through stem cell differentiation is sustained over time and space is highly relevant for understanding how the potential or activity of stem cell niches can be increased to combat neurodegenerative disorders or, conversely, how stem cell-like activity can be suppressed to slow the progression of brain tumours.



Artistic visualisation of stem and nerve cells.

Methods

To bridge the gap between individual stem cell behaviour and systemic properties at the population level, the PEPS consortium will combine expertise from multiple disciplines. Within STRUCTURES, Prof Marciniak-Czochra and her team will use their expertise in applied analysis and modelling to study stem cell dynamics, while JProf Anders and his team will apply their skills in bioinformatics/statistics to the analysis of omics data.

ERC Funding

The project will receive 11 million euros in funding from the European Research Council (ERC) over a six-year period. The ERC Synergy Grants are designed to fund collaborative projects that require the combined expertise of several scientists and their groups in order to achieve breakthroughs that would not be possible in individual projects. In the case of PEPS, the four-PI consortium comprises experts in stem cell biology of mouse and fish, in bioinformatics, and in applied mathematics. The four PEPS PIs are among the only 105 researchers in Europe that receive this prestigious and highly selective grant in 2022.

Scientific PIs in STRUCTURES

Left: **Anna Marciniak-Czochra**, Professor of Applied Mathematics at IAM, IWR and BioQuant Centre, STRUCTURES PI and Cluster Spokesperson.
Right: **Simon Anders**, JProf Bioinformatics, BioQuant Centre, STRUCTURES Faculty Member.
Image credit: Tobias Schwerdt / Uni Heidelberg.

BIOPHYSICS IN STRUCTURES

The structural complexity of biological systems is unsurpassed by any other part of the physical world and resonates strongly with the primary research question of STRUCTURES: why is so much of nature structured rather than diffuse?
From the biological point of view, one might think that this question is answered by the principles of evolution. However, it is an open and important question which mathematical and physical principles nature uses to achieve this aim. Questions like these are at the heart of STRUCTURES' CP3.

STRUCTURES COMMUNITY

Young Researchers Convent (YRC): New Speakers and Upcoming Activities

The Young Researchers Convent (YRC) has elected Ricardo Waibel and David Maibach as their new speakers in its General Assembly on January 19. The two follow Elena Kozlikin and Christophe Pixius, whom we want to thank for their great commitment!

To introduce the new speaker duo, who both are PhD students at the Institute for Theoretical Physics (ITP), we interviewed them for this newsletter issue:

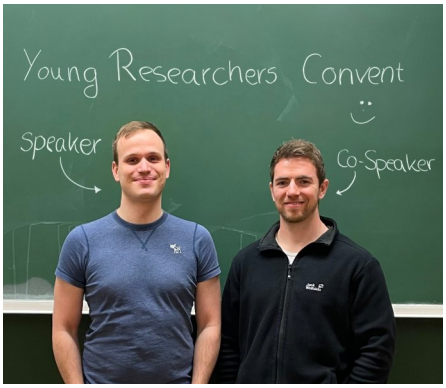
Interview with Ricardo Waibel:

What are you working on? As a PhD student I work in cosmology with a focus on different aspects. I look at the new gravitational wave observatory LISA and try to improve the prototype modelling. But I also work on more theoretical aspects such as gravitational wave propagation in alternative cosmologies and structure formation in the universe using kinetic field theory.

What are you an expert for? I would not use the term "expert", but I am quite good at coding, especially C++. I also enjoy working with asymptotic techniques, which I used in my MSc thesis to make analytical calculations possible in certain limits.

What is your connection to STRUCTURES? As a member of Prof. Heisenberg's group, I am also in STRUCTURES. I have participated in several cluster events and I am very glad it provides so many opportunities to look and connect outside your own research topic. As new YRC speaker, I am very happy about the upcoming work. The YRC offers a lot of opportunities for travelling and connecting with other researchers at a similar level and I am excited to be able to continue with the good work of the last speakers.

How does one recognise you? I am relatively tall, and I have been told that I am bad at whispering. So I guess if you see a tall person who you can also easily hear from the other side of the room, it is probably me.



Interview with David Maibach:

What are you working on? I am currently involved in multiple projects with the broad goal of constraining (quantum) gravity using gravitational waves. In particular, I am investigating how modifications of Einstein's theory of General Relativity result in detectable alterations of gravitational waveforms and what implications can be derived analytically from such models. Besides I am working on a book on advanced techniques in General Relativity together with collaborators in Heidelberg and at ETH Zurich.

What are you an expert for? As a PhD student it is a bit bold to claim expertise but I am well-versed in asymptotically flat spacetimes, their symmetries, structure and connection to memory effects and soft scattering theorems. There is a beautiful interplay between geometry and gravitational waves in asymptotic spacetimes that I am investigating. Besides that, I can tell you a hell lot about benchpress, squats and deadlifts.

What is your connection to STRUCTURES? I have been part of the YRC and STRUCTURES for one year through my group (Prof. Heisenberg). Newly arriving in Heidelberg for my PhD, I was surprised by what STRUCTURES has to offer to young researchers. As new co-speaker, I aim to broadcast this message to all passive and soon-to-be YRC members. Thus, if you (the reader) are curious about the YRC or have questions of any kind feel free to reach out to me, via email or in my office 213 in Phil. 12.

How does one recognise you? Multiple trademarks expose me. The most prominent one is probably the amount of food I consume during lunch. If you see a dude with a huge lunchbox in the common room at Phil. 12, that would be me. Also, I always run around with a cup of tea and if I am not at the institute I am probably in the gym.

ABOUT THE YRC:

The YRC is a subgroup of the STRUCTURES cluster that brings together and supports students (from BSc to PhD) and Postdocs – whether directly funded by STRUCTURES or working on related topics – in realising their own projects. Support ranges from travel funds and the organisation of seminars to the participation in the STEPS mentoring program that promotes exchange between scientists at different career levels.

Regular activities of the YRC include the Schöntal Workshop, special lectures (e.g. at the Physics Graduate Days) and seminars. This year, the YRC will also organise "STRUCTURES Day(s)", a format to foster interaction and exchange, inviting everyone in the cluster, including the PIs.

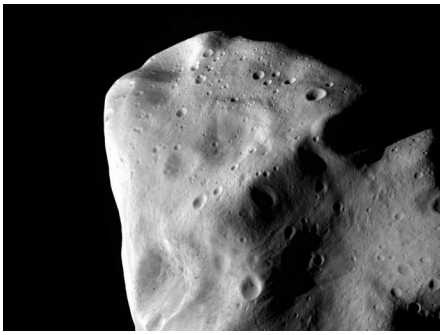
JOIN THE YRC:

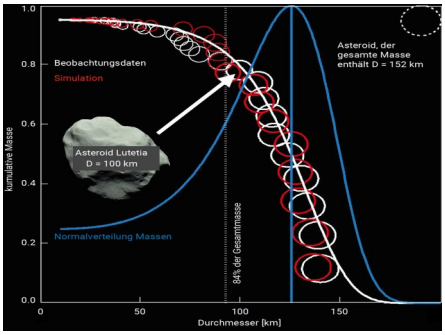
Interested in joining the YRC? Contact us at *structuresyrc(at)thphys.uni-heidelberg.de.* Any student or postdoc in the group of a STRUCTURES member or who works on closely related topics is welcome to apply for membership. If you are curious, feel free to stop by the YRC's regular table.

RESEARCH NEWS

Simulations of Planetesimal Formation Reproduce Key Properties of Asteroids, Comets

With simulations that resolve finer details than ever before, Brooke Polak and Hubert Klahr (MPIA/ZAH, STRUCTURES) have modelled a key phase in the formation of planets in our solar system: the growth of centimetre-size pebbles into planetesimals tens to hundreds kilometres in size.





Left: The main belt asteroid 21 Lutetia (© ESA 2010 MPS). Right: Comparison between the predictions by Polak and Klahr for the mass distribution of asteroids (reproduced from B. Polak and H. Klahr, 2023, © H. Klahr / MPIA).

From Dust To Planets

Planet formation proceeds in several stages. Initially, cosmic dust particles in the swirling protoplanetary disk clump together, bound by van der Waals forces, to form so-called pebbles a few centimetres in size. The pebbles then join together to form planetesimals: space rocks between tens and hundreds of kilometres in diameter. Finally, collisions among these planetesimals form even larger, gravitationally-bound, solid cosmic objects: planetary embryos, which can grow into planets. Simulating this progression from centimetre-size pebbles to planetesimals is challenging due to the enormous scale range involved.

Simulating a "Pebble Gas"

The simulations by Polak and Klahr follow an innovative approach by using a kinetic description in which small groups of pebbles in collapsing clouds are treated like a gas that undergoes certain phase transitions and is assigned a pressure. The simulation reproduces the initial size distribution of planetesimals as observed for present-day asteroids. It also yields unprecedented results about close binary planetesimals, which are predicted to form in great numbers early on. *Text from MPIA Press Release (shortened).*

RESEARCH NEWS

Annalisa Pillepich Receives ERC Consolidator Grant

Annalisa Pillepich

The European Research Council (ERC) has awarded Annalisa Pillepich, research group leader at MPIA and PI within STRUCTURES (CP 1), one of the prestigious ERC Consolidator Grants. In her project *COSMIC-KEY*, Pillepich and her colleagues will be developing the next generation of simulations of galaxies and of the universe as a whole – a key to understanding observational data that is set to become available over the next years.

The objective of *COSMIC-KEY* is to create the most realistic suites of simulations yet of galaxy formation and its consequences for cosmic evolution and cosmic structures. This includes, among many other physical phenomena, the influence of the central black holes not only on the rate of star formation in galaxies but, crucially, on the physical properties of the gas that surrounds galaxies and permeates dark-matter halos. The ultimate goal is to use such numerical and theoretical models to fit data of the X-ray and Sunyaev-Zel'dovich signatures of groups and clusters of galaxies and in turn to infer fundamental cosmological parameters that describe the functioning of the Universe.

The European Research Council (ERC) is the premier European funding organisation for excellent frontier research, and funds creative researchers of any nationality and age to run projects based across Europe.

With a total amount of 2 million euros, Annalisa Pillepich's consolidator grant will be used to fund four post-doctoral positions and two PhD students over the next five years.

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The production of this newsletter is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy EXC 2181/1 - 390900948 (the Heidelberg STRUCTURES Excellence Cluster).

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