STRUCTURES | NEWS

STRUCTURES CLUSTER OF EXCELLENCE

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

April 2026

Contents

Upcoming

- **"Machine Learning Galore!"** April 29. Register until April 22.
- **Workshop "Geometry Space Surrey"** June 8-10. Registration now open!
- **Workshop "Multiple Systems Across Scales"** – April 27, 28
- **Les Houches Summer School: "Quantum Theory On All Scales"** August 3-28

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RESEARCH

STRUCTURES Office Settles Into EINC Building

Following an interim phase at Mathematikon, STRUCTURES has relocated its Neuenheimer Feld offices to their designated location on the third floor of the "EINC" building INF 225a. Together with the theory centre *Collis Philosophicus* at Philosophenweg, EINC now serves as one of two locations where the cluster has an office presence; and as a hub for its community and activities.

The STRUCTURES Project Management Office plays a key role in supporting and coordinating these activities. It offers comprehensive services for all cluster members, from administrative support related to membership, travel funding, and the guest programme, to the coordination of internal and public events. The office also oversees equal-opportunity initiatives such as *STEPS*, the parent–child offices *"KIDS"* operated in collaboration with IsoQuant, and the cluster's outreach activities.

Directly adjacent to the new office rooms at EINC is *Oberstübchen* – the cluster's main scientific venue for seminars, workshops, and meetings. The Oberstübchen is part of *STRUCTURES College*, an academic unit dedicated to fostering international scientific exchange across disciplines and career stages. Activities of the College include the guest programme, the weekly *STRUCTURES Jour Fixe* as a central forum for exchange, and research-oriented teaching measures – one example being the regular meetings of *STRUCTURES' Crowds* on topics such as Mathematical Physics, Computational and Quantum Physics. The expression *Oberstübchen* is a German colloquial for brain, literally "upper room."

For practical information related to room bookings of the Oberstübchen, all STRUCTURES members are welcome to contact us at office@structures.uni-heidelberg.de.

As part of its broader role as a research facility, EINC is becoming a hub for STRUCTURES' experimental activities in the direction of physical computation – and home to the groups of various STRUCTURES members, including Markus Oberthaler, Wolfram Pernice, Johannes Schemmel and Julian Schmitt. Physical computation refers to approaches going beyond *von-Neumann* computing architectures, building on physical structures available in highly controllable physical systems based on electrons, photons and atoms.

RESEARCH

Emergent Order Before Equilibrium: Researchers Identify Anomalous Dynamical State in a Quantum Gas

Far from equilibrium, physical systems are notoriously difficult to predict. They often depend sensitively on microscopic details, resulting in complex, seemingly erratic behaviour. Nevertheless, it has been known that even far from equilibrium, some systems with strong collective dynamics are able to evolve into long-lived dynamical states governed by simple universal rules.

In a recent study, experimental and theoretical physicists from the groups of STRUCTURES members Lauriane Chomaz and Thomas Gasenzer demonstrated the emergence of such a state in a simulated thin ultracold gas of magnetic atoms.

In this quantum gas, which is in a so-called superfluid state, rotational motion is carried by what is known as *quantized vortices* – tiny whirls that, in the configuration studied, come in pairs of opposite circulation. Unlike in many earlier works, the atoms in the gas interact via *dipolar forces* – long-range direction-dependent interactions that were found to suppress vortex clustering.

Notably, despite this suppression, the characteristic temporal scaling of the dynamics – encoded in the so-called *scaling exponents* – is found to be the same as in non-dipolar superfluids. The system enters a long-lived regime of anomalously slow, or subdiffusive dynamics, signaling the dominance of collective many-vortex processes over pairwise interactions. The finding that this behaviour persists in the presence of dipolar interactions suggests that the slow dynamics are not tied to vortex clustering, as was observed in non-dipolar gases, but to more general collective constraints on vortex annihilation. This is characteristic of an *anomalous nonthermal fixed point*: a self-similar non-equilibrium state in which the dependence on microscopic details is lost as a result of the interactions between more than two vortices. At later times, the system is found to cross over to faster, diffusive behaviour, dominated by two-vortex interactions, associated with what is called a *Gaussian nonthermal fixed point*.

The study shows that universal principles may govern nonequilibrium evolution more broadly than expected, extending the range of predictable aspects of complex many-body dynamics and sharpening the focus on their defining properties.

Original Publication:

Niklas Rasch, Lauriane Chomaz, and Thomas Gasenzer. *Physical Review A*, vol. 112, no. 5, Art. no. 053310, APS, 2025. doi:10.1103/x2rj-ptgy.

AWARDS & HONOURS

STRUCTURES Postdoc Alicia Castro Receives Funding in the Olympia Morata Programme

We congratulate our member Alicia Castro on receiving funding through the *Olympia Morata Programme* of Heidelberg University, following a competitive selection process. Dr. Alicia Castro is a postdoctoral researcher at STRUCTURES and a member of the STRUCTURES *Young Researchers Convent (YRC)*. Her research at the Institute for Theoretical Physics explores the fundamental structure of spacetime at the smallest scales, where familiar notions such as distance, volume and dimension break down. Using methods from *random geometry*, her work examines how these classical properties emerge in the context of quantum gravity and how they fluctuate. In this approach, quantum spacetime is modelled as a collection of many possible geometries rather than a single fixed one. This makes it possible to capture microscopic fluctuations of spacetime expected in quantum gravity; and lays the foundation for more detailed studies of the microscopic structure of the universe. *"I aim to connect the mathematical ideas of random geometry with the physical behaviour of spacetime, offering a clearer picture of how the universe behaves under extreme conditions,"* Alicia Castro says. *"With the support of the Olympia Morata Programme, I will establish the foundations of an independent research agenda that positions me to apply for grants to start my own group,"* she adds.

The *Olympia Morata Programme* supports excellent postdoctoral researchers with outstanding qualification projects, as they work toward higher academic qualifications (*e.g.* habilitation or equivalent achievements). The programme targets female and gender-diverse researchers, aimed at supporting their academic career progression as part of Heidelberg University's commitment to promoting equitable opportunities in academic careers. As part of the programme, recipients are appointed to two-year fixed-term positions and benefit from additional training and career development opportunities. The programme is named after Olympia Fulvia Morata, a 16th-century humanist scholar who taught in Heidelberg.

Dr. Blanca Alicia Castro Bermudez, Institute for Theoretical Physics (ITP)

COMMUNITY

Young Researchers Convent Elects New Representatives

The STRUCTURES *Young Researchers Convent (YRC)* has elected David Maibach, Fabius Krämer, and Thalia Traianou as its new speakers for 2026 in its recent General Assembly. We warmly congratulate the new speaker team and wish them a successful start! The new speaker team succeeds the previous speaker trio, Ricardo Waibel, Freya Jensen, and Marvin Sipp, whom we warmly thank for their exceptional commitment and outstanding service.

In this newsletter, we introduce the new speakers through short interviews:

Interview with David Maibach:

David Maibach
Postdoc, EP "Modelling Superfluid Dark Matter Using Cold Atoms" (EP 57)

What are you working on?
My work relates to gravity and gravitational waves with interdisciplinary projects exploring gravitational effects in condensed matter systems. My main project involves an analogue description of dark matter in terms of a critical Bose-Einstein-Condensate.

What is your connection to STRUCTURES?
I am currently hired on an exploratory project involving people from Heidelberg and ETH Zurich. Already before my Postdoc, I have tried to get involved in STRUCTURES as actively as I can, for instance, as a YRC speaker.

What motivated you to run for YRC Speaker?
As aforementioned, I have already been a speaker during my PhD here in Heidelberg and thoroughly enjoyed the work that comes with this position. For me, there lies great potential in having an overarching organization for young scientists through which they can discuss, exchange, and actively contribute to the cluster's future.

How do people usually recognize you?
I am wearing a lot of surf merchandise and a leather backpack.

Interview with Fabius Krämer:

Fabius Krämer
PhD student at IMa, group of Tim Laux

What are you working on?
My main research interest lies in the application of geometric flows to data science. Geometric flows are partial differential equations that describe how geometric structures evolve over time. With my background in computer science and mathematics, I am broadly interested in topics that bridge these two fields.

What is your connection to STRUCTURES?
Although I am still relatively new to the university, I was immediately drawn to the cluster's interdisciplinary approach.

What motivated you to run for YRC Speaker?
I am committed to encouraging and enabling young researchers to broaden their knowledge beyond their primary research area. STRUCTURES provides an excellent environment for this, and I would be glad to actively support this mission.

How do people usually recognize you?
The best way to recognize me is by my good mood or by the fact that I'm playing Kicker on the rooftop of the Mathematikon.

Interview with Thalia Traianou:

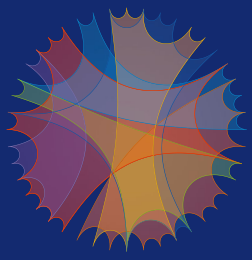
Thalia Traianou
Postdoc at IWR, Coordinator of AGN Group and Outreach at EHT.

What are you working on?
I study matter and magnetic fields in the vicinity of supermassive black holes, focusing on relativistic jets. My work combines ultra-high-resolution radio interferometry with multi-wavelength and multi-messenger observations to trace energy dissipation and causal links.

What is your connection to STRUCTURES?
What drew me to STRUCTURES is that it brings together scientists from such different disciplines that every coffee break, a mathematician, a neuroscientist, and an astrophysicist might end up at the same table, leading to a cross-disciplinary exchange that can foster the most innovative ideas.

What motivated you to run for YRC Speaker?
Honestly, because I have benefited enormously in my academic path from communities that made me feel visible and connected as an early-career researcher, and I want to help shape that for others.

How do people usually recognize you?
Probably by heading to dance tango after work, listening to good music, or engaging in philosophical discussions. If not that, by the camera I almost always carry, as photography is my favourite "human-scale" way of observing the beauty of the Universe!



The Young Researchers Convent (YRC) brings together BSc and MSc students, PhD candidates and postdoctoral researchers and supports them in realizing their own projects – from travel funding to the organization of seminars and talks. Any early-career researcher whose work fits within the concept of STRUCTURES can apply for YRC membership. Moreover, if you are in the group of a STRUCTURES member or funded by STRUCTURES, you are *directly eligible*. For more details, visit: *https://structures.uni-heidelberg.de/YRC.php.*

MEMBER INTERVIEWS

STRUCTURES Asks: Zahra Monfared

For this edition of STRUCTURES Asks, we interviewed Zahra Monfared, who joined STRUCTURES in 2020 and became a voting member in 2024. In her research group *Dynamical Systems and AI*, she bridges mathematical foundations and artificial intelligence (AI). Her research and academic service have been recognized with multiple honours, including a prestigious *BMBF* grant in 2024 and a *NeurIPS Outstanding Reviewer Award* in 2021.

Interview with Zahra Monfared:

What are you working on?

I work in two tightly connected directions: dynamical systems for AI and AI for dynamical systems. Concretely, I develop mathematical foundations for understanding machine learning models, and leverage dynamical systems (DS) theory and scientific computing to create efficient, explainable algorithms / architectures while also employing AI tools to tackle classical DS problems.

What fascinates you about your research?

What fascinates me most is that both fields ask essentially the same question from different angles: how complex behaviour emerges from simple rules. Bringing them together allows us not only to build more reliable learning systems, but also to gain new mathematical insight into complex dynamical phenomena.

Is there one insight you find most interesting in connecting dynamical systems theory to neural networks?

A key insight is that many neural network architectures — such as recurrent neural networks, residual networks, and neural ODE models — can be viewed as DS. This perspective allows us to apply classical concepts like stability, invariants, chaos, and bifurcations to understand their behaviour. It not only enhances our grasp of learning dynamics but also aids in designing more reliable and efficient architectures.

From your experience, what matters for good interdisciplinary research?

From my experience, good interdisciplinary research starts with patience and genuine curiosity about the other disciplines, and with the willingness to learn each other's language and question implicit assumptions, while also creating a real pathway from ideas into practice. Coming from a mainly mathematical background and working across AI, engineering, physics, and neuroscience, I have learned that adaptability and open-mindedness matter as much as technical skills, because real progress often comes from rethinking problems from new perspectives and building deeper connections.

What inspired you to become a scientist?

From childhood, I always wanted to be a scientist because I was very excited and curious about understanding the world. Later, I realized how much I love both abstract and applied mathematics, and by exploring many different fields such as AI (machine learning), engineering, physics, medicine, neuroscience, and even tourism, I discovered that the same mathematical ideas and structures can reveal universal principles behind very different real-world systems, which is what truly motivated me to follow this path.

Dr. Zahra Monfared, Interdisciplinary Centre for Scientific Computing (IWR)

Do you have any advice for aspiring students or early-career researchers?

Try to learn as much as you can and expose yourself to many different ideas, and always try to look at problems from several viewpoints. If something feels too difficult or even impossible, don't stop there — try other directions, take risks, don't be afraid of hard problems, look for collaborations that push you out of your comfort zone, and don't let setbacks or rejections make you lose motivation.

If you could meet a famous person in history over coffee, who would it be and what would you ask?

I would love to meet Maryam Mirzakhani, and I would ask her what advice she would give for building deep mathematical theory today, in a world dominated by data and computation – and what mindset helped her reach such an exceptional level in mathematics.

What can you never start a day at work without?

A short moment of stretching and meditation to clear my mind and get focused.

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