

Artistic illustration of an actin network growing from the surface of a bead in a biomimetic assay. (Based on Fig. 2 of Wössner et al. (2026), adapted by S. Stapelberg. CC-BY 4.0)

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Upcoming

- **STRUCTURES Jour Fixe**
 - Oct 16: Robert Jerrard (Toronto)
 - Joint event with ANGEL meeting, INF 205
 - Oct 23: Alexey Kazarnikov, Stefano Rinaldi
 - Oct 30: Discussion on AI in science
 - Nov. 06: Herbert Jaeger (U. Groningen)
- **Seminars and workshops:**
- **Oct. 16: 5th ANGEL Meeting**
- **Nov 04: CQD Colloquium**
by Leticia Tarruell (ICFO)

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A New Theory for the Coexistence and Selection of Cellular Structures

Biological cells are the smallest living units of an organism. To maintain their shape, divide, and move, they rely on the *cytoskeleton*, which is made from biopolymers like *actin*. Actin assembles into filaments and larger networks, which constantly undergo renewal, as monomers are added, removed, and re-used elsewhere. This dynamic behaviour allows the cell to rapidly adapt to changing environmental conditions. At the same time, this poses a problem: the different actin structures compete for a shared limited pool of free actin monomers. If one structure consumes more, less remains for the others, causing them to shrink, as they lose actin faster than they can replace it. Yet, one observes that multiple distinct structures can coexist at stable sizes. This raises the question of which mechanism prevents single structures from monopolizing the shared pool.

In a new study, STRUCTURES scientists Valentin Wössner, Falko Ziebert and Ulrich Schwarz have made substantial progress in solving this puzzle. They developed a theory for coexistence and selection of branched actin networks – going beyond earlier models that had focused mainly on single filaments and bundles. Using *ordinary differential equations (ODEs)* and *bifurcation ana-*

lysis, their framework shows how local depletion of actin can provide a natural self-regulating mechanism: as a dense network grows, it uses up the free actin at its leading edge, slowing its own further growth. When competition becomes too strong, coexistence gets replaced by selection. The new theory bridges so-called *limited pool models* and the growth physics of branched actin networks.

One strength of this study is the use of computational methods developed and shared in a strongly interdisciplinary research environment: the researchers compared their analytical model with detailed spatiotemporal simulations of actin dynamics using the numerical software framework *DUNE* – co-developed by STRUCTURES member Peter Bastian. The close agreement found between the two approaches supports the ODE model as an effective description of the dynamics.

This work is part of STRUCTURES' comprehensive project CP3 ("From Molecules to Cells and Tissue")

Original Publication:

Wössner, V., Ziebert, F., & Schwarz, U. S. (2026). Theory for Coexistence and Selection of Branched Actin Networks in a Shared and Finite Pool of Monomers. *PRX Life* 4, 033020. DOI: 10.1103/wmcg-9rq7.

COMMUNITY

STRUCTURES Office Welcomes Sara Konrad as New Managing Co-Director

We are pleased to announce that, as of first October, the management of STRUCTURES is shared by Christine Menn and Sara Konrad, who jointly lead the STRUCTURES Project Management Office.

The STRUCTURES Project Management Office supports the cluster's members in realizing their research projects and in their day-to-day work, coordinating finances, reporting, events and programmes as well as outreach. As managing directors, Christine Menn and Sara Konrad lead the office's team and work closely with the cluster's spokespersons and the steering committee. They are responsible for budget planning and personnel matters, and they steer the cluster's programmes, from the STRUCTURES College with its international guest and travel programmes to early-career support and measures for diversity and family-friendliness, such as the Parent-Child Offices. They coordinate the meetings of the cluster's bodies as well as the STRUCTURES Jour Fixe, and oversee reporting to the DFG and Heidelberg University. Together, they are the first point of contact for all members of STRUCTURES, including in confidential matters, and co-

ordinate the cluster's cooperation with its partner institutions and the university administration.

Dr Sara Konrad joins STRUCTURES from the Institute for Theoretical Physics (ITP) at Heidelberg University. During her PhD in cosmological structure formation, she participated in the planning phase of STRUCTURES and continued as a postdoctoral researcher and member of STRUCTURES' Young Researchers Convent (YRC). She already knows the office well: alongside her research, she previously worked as a Managing Scientist in the STRUCTURES office, taking care of the website development, supporting the YRC's networking, the mentoring and the STRUCTURES College programmes. She has also been a member of the STRUCTURES Outreach Committee since 2022. Having experienced the cluster from both sides, as a researcher and as a member of the administration, she brings a first-hand understanding of what scientists need to do their best work.

"My mission is to support all our members in doing excellent research by creating the conditions in which they can thrive, collaborate and pursue their ideas with enthusiasm."



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And I want them to know: I've got their backs," says Sara Konrad.

Christine Menn, Managing Director since the beginning of 2026, has been part of the Project Management Office since the start of the cluster. She has thus helped shape the office from its very beginnings and was closely involved in coordinating the STRUCTURES College's guest, travel and mentoring programmes, as well as its events, such as the Jour Fixe among others. Christine Menn has worked in research management for many years: before joining STRUCTURES, she was part of the management office of CellNetworks, a former Cluster of Excellence at Heidelberg University in the life sciences.

We warmly welcome Sara Konrad to the management team!

FAMILY SUPPORT

Four Years Parent-Child Offices "KIDS" by STRUCTURES and ISOQUANT

More than four years ago, the parent-child offices "KIDS" opened their doors. Jointly operated with IsoQuant, KIDS offers family-friendly workspaces at two locations in Heidelberg: at Mathematikon B (3rd floor) and at Albert-Überle-Straße 3-5 next to the Philosophenweg. The offices are open to all faculty members and campus neighbours.

When childcare falls through unexpectedly, parents can bring their children along and keep working in a family-friendly environment. The offices provide fully equipped workstations, a kitchen, a quiet room and plenty of play corners for the little ones. They

can be booked flexibly via our online calendar. KIDS aims to help make balancing family and career a natural part of everyday university life. *"My kids love the parent-child office, for them it is like a big playroom and they've been always keen on spending time there. I think it is a very valuable and useful asset of STRUCTURES,"* says Francesco Gozzini, postdoc at KIP. Christine Menn, also a regular user, agrees: *"When daycare is closed, I can simply go to the KIDS office, which keeps me more connected to my team than working remotely from home. And for the kids, it's a nice change to go there and try out the toys!"*



Register now – book when you need it!

ekb.thphys.uni-heidelberg.de

1. Scan the QR code to create your KIDS account.
2. Book your workspace via the online calendar.
3. For Mathematikon: contact us (> 1 day in advance) to get your key.



RESEARCH

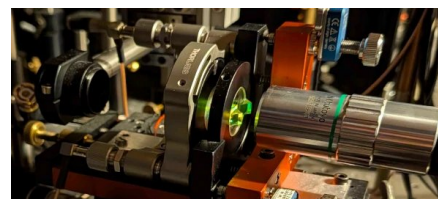
Quantum Gases of Light Exhibit Critical Scaling Behaviour

An international team of researchers from the University of Bonn, Heidelberg University and the National Autonomous University of Mexico has studied the critical behaviour of photons close to a phase transition, demonstrating the phenomenon of *critical scaling behaviour* in a quantum gas of photons. This behaviour, which sees thermodynamic quantities grow extremely large or diverge near phase transitions, had never before been seen in photon gases.

The researchers measured spatial correlations, *i.e.* how strongly the state of the light at different positions is related, in a nearly non-interacting 2D photon gas trapped in a mirror box just before the *Bose-Einstein condensation* phase transition. From this, they determined the *critical exponent*, which describes how sensitively the spatial extent of these correlations increases as the temperature changes near the phase transition.

They trapped the photons inside an optical microresonator (a microscopic cavity formed by two closely spaced mirrors) filled with a dye solution. Through processes of absorption and emission as the photons came into contact with the dye molecules, the photons effectively cooled down (*thermalized*) to a point where the quantum phase of condensation began. One of the resonator mirrors had been structured at the nanometre scale beforehand by means of laser writing to create a box-like potential, *i.e.* a trap for the photons. The angular distribution of the light emitted was then measured with a camera and analysed via *Fourier transform* to determine the spatial correlations.

This was the first-ever experiment that demonstrated that photon gases constitute a distinct, overarching *universality class* of physical systems in nature, meaning that they follow characteristic laws near a phase



Experimental optical setup consisting of a dye-filled optical microresonator. © Leon Kleebank / University of Bonn 2026.

transition. Much like water, which at the *critical point* suddenly turns cloudy due to *opalescence*, the photon gas in this case exhibits a rapidly increasing and diverging *correlation length* with a specific exponent.

The finding fills a key gap in the physics of phase transitions and may open up new avenues for research into systems well outside thermal equilibrium as well as for future applications in optics. The project was led by STRUCTURES Professor Julian Schmitt.

Original Publication:

Kleebank, L. et al., (2026) Observation of critical scaling in the Bose gas universality class. *Sci. Adv.* 12, eaee2942. DOI: 10.1126/sciadv.aee2942.

AWARDS & HONOURS

From Dissertation Award to ERC Advanced Grant: Honours for STRUCTURES members

Otto Haxel Dissertation Award for Klaus Paschek and Nikolas Liebster

Photo of the prize winners

From left to right: N. Liebster (Heidelberg), L. Reuter (Karlsruhe) and K. Paschek (Heidelberg). Image © KIT / Robert Fuge

We congratulate our YRC member Klaus Paschek and YRC alumnus Nikolas Liebster on receiving this year's *Otto Haxel* Award for Physics.

Dr Liebster received the award for his dissertation on *Pattern Formation and Super-solid Sound Modes in a Driven Superfluid*. Dr Paschek received the award for his dissertation *From Space to the Hadean Earth: Prebiotic Synthesis and the Origins of Life*. The annual prize honours the three best doctoral dissertations at KIT, Göttingen and Heidelberg University – the three institutions where nuclear physicist Otto Haxel (1909–1998) conducted his research.

2026 Astrophysical Software Award for Cornelis Dullemond

Prof. Dullemond

We congratulate our member Cornelis P. Dullemond (Centre for Astronomy Heidelberg, ZAH) on receiving the Astrophysical Software Award of the German Astronomical Society. The award recognizes his conception, development, and long-term stewardship of the radiative transfer software *RADMC-3D*.

ERC Advanced Grant for Fred Hamprecht

Prof. Hamprecht

We congratulate our member Fred Hamprecht, head of the Scientific AI lab at the Interdisciplinary Center for Scientific Computing (IWR), on securing one of the European Research Council's (ERC) prestigious ERC Advanced Grants.

The grant, endowed with € 2.5 million in funding over five years, will support his project *LearningOFDFT*, which aims to develop new methods for the precise and stable calculation of molecular energies based on electron densities, using what is called an orbital-free approach.

Originally started as an Exploratory Project of STRUCTURES, Fred Hamprecht and his collaborators, notably Roman Remme, pioneered a machine learning method to solve this long-standing problem by learning the mapping from electron density to molecular energy – using physics-inspired AI methods.

Interview with Prof. Hamprecht on page 4:

In this edition of the series "STRUCTURES Asks", where we regularly introduce principal investigators of STRUCTURES, we speak with Fred Hamprecht about his research, benefits and risks of AI, and life beyond the lab.

MEMBER INTERVIEWS

STRUCTURES Asks: Fred Hamprecht



Fred Hamprecht
Professor at IWR

In this edition of *STRUCTURES Asks*, we speak with Fred Hamprecht, a principal investigator of *STRUCTURES* and head of the Scientific AI lab at the Interdisciplinary Center for Scientific Computing (IWR). His group develops machine learning methods for problems in the natural sciences. Work on orbital-free density functional theory that began as a *STRUCTURES* Exploratory Project has grown into a new research line and recently earned Prof. Hamprecht a € 2.5 million ERC Advanced Grant.

Interview with Fred Hamprecht

Your lab develops principled AI methods to solve complex problems in the natural sciences. What strategy do you use to bring together fields that may seem very far from each other?

They are not far from each other. In previous years, when the lab worked on different problems from the life sciences, machine learning was the common denominator. Nowadays the applied maths that makes neural networks rotation-equivariant is the very same maths that was developed for quantum mechanics a century ago.

Your work on machine-learned orbital-free density functional theory began as a *STRUCTURES* Exploratory Project. What was your initial inspiration for this idea?

The central problem is to learn an accurate map from electron density to energy. Subtle changes of the density can result in drastic changes to energy, but ultimately, this is input data whose spatial structure matters,

just as in image processing. I first came across the problem of finding a universal density functional during my Master's thesis. It was beyond the grasp of the most gifted theoreticians. An analytical expression is what everybody really wants; but failing that, a learned functional is better than none (or one that describes the homogeneous electron gas only).

Your new ERC project targets larger systems and applications such as environmentally friendly materials. What is the key step towards making these applications realistic?

We need to correctly estimate energies for complex chemistry and materials including open shell systems, transition metals or those exhibiting large charge transfer. A large training corpus will be necessary, though likely not sufficient. We hope that enforcing physical properties such as scaling laws that are known to hold exactly will help improve generalization; but ultimately just how far we can generalize is unknown – it is research, after all.

Your group brings together physicists, mathematicians, computer scientists, engineers, and chemists, under the motto “Be nice and do great science”. What is the philosophy behind building such a varied team, and how do you create a shared language for ad-hoc collaboration? We need the skills that different people bring to the table; finding a common language is a major invest for everyone, but also a real necessity.

What advice would you give to early-career researchers who have new, unconventional ideas but do not yet know how to develop

them? Pursue them passionately, but also bail out eventually if you keep failing.

How do you view the risks associated with AI? Do you think popular fears are misconceptions of what AI really is?

There are risks on three levels: first, the rapid increase in capability that will squeeze out some professions, with the rapid roll-out leaving little time to adjust. Second, malicious actors using AI for nefarious goals. These two are definitely happening. The third risk is AI going rogue, in particular after becoming super-intelligent. While I share the concern, my more immediate fear is man-made disasters.

Are there any skills you believe AI cannot replace?

Too few, especially once the integration with robotics improves, which is only a question of time. But I think we owe it to ourselves, as individuals and as a species, to preserve intellectual agency and autonomy. That said, I absolutely love AI as a discussion partner, as a teacher, and as an enabling tool. For our work it is a blessing.

What do you enjoy doing outside research to recharge?

Work and family leave little time for anything else; but I do enjoy reading, notably old explorers' descriptions. They offer glimpses of the natural world and of societies before Europe steam-rolled the planet.

Do you have any habit or ritual that helps you begin the day?

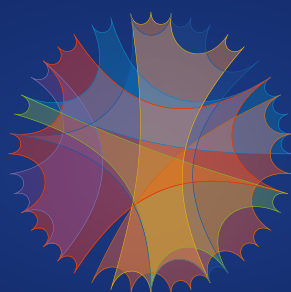
A habit I dislike: reading the news first thing after I wake up. A habit I enjoy: riding a 20k detour to work, out of cars' way.

STRUCTURES ON THE WEB

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