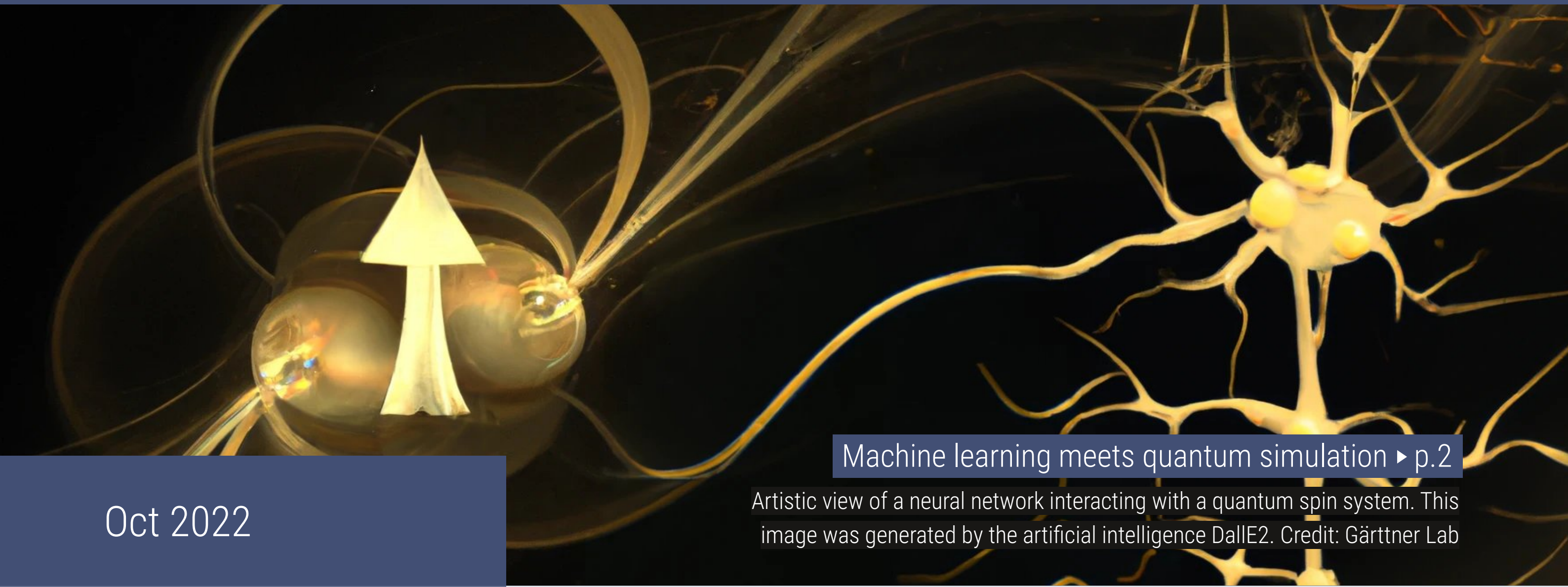
STRUCTURES | NEWS

STRUCTURES CLUSTER OF EXCELLENCE

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386



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Artistic view of a neural network interacting with a quantum spin system. This image was generated by the artificial intelligence DallE2. Credit: Gärttner Lab

Oct 2022

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More information can be found on the STRUCTURES website.

Web & Social Links

Discover the STRUCTURES BLOG and Social Media:

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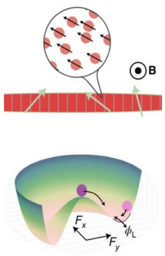
STRUCTURES Short News

DUAL SUPERFLUIDITY OBSERVED IN FERROMAGNETIC ULTRACOLD GAS

STRUCTURES scientists have experimentally demonstrated twofold superfluidity and dynamical thermalisation in an ultracold ferromagnetic spinor Bose gas of Rubidium atoms.



Bose-Einstein condensates form an ideal ground to explore dynamical phenomena emerging in the many-body limit. Due to their rich internal structure spinor condensates give rise to intricate symmetry breaking and superfluidity features. Superfluids can flow without dissipation and are an example of a macroscopic system dominated by quantum physics. The equilibrium state of the spin-1 gas at ultralow temperatures exhibits a dual condensate in the *easy-plane* ferromagnetic phase. This is a form of matter in which all atoms show phase coherence over the whole extent of the system in both density and spin. The direct observation of this dual state has previously been challenging. In a recent experiment carried out by the group of Markus Oberthaler (KIP) in collaboration with Daniel Spitz and Jürgen Berges (ITP) it has been prepared and thoroughly probed for the first time. The quantum gas could be stored long enough to observe the system's evolution towards equilibrium, and to demonstrate the emergence of long-range coherence and spin-superfluidity. The new methods and results are an important step towards understanding quantum many-body dynamics and thermalisation in large magnetic spin systems.

Associated Publication:
Prüfer, M., Spitz, D., Lannig, S. et al. Nat. Phys. (2022). https://doi.org/10.1038/s41567-022-01779-6.

STRUCTURES BLOG AND SOCIAL MEDIA

In August, STRUCTURES launched a science communication blog simultaneously with the start of its social media presence on Twitter and Instagram. In the STRUCTURES blog and on our social media channels, which are part of a broader outreach campaign, we present fascinating examples of structures related to the cluster's research through captivating pictures and short articles that provide further explanations. Our aim is to give a broad, interested audience an idea of what these structures are, how they come about, and why they fascinate us. Discover our blog and social media at https://structures.uni-heidelberg.de/blog, Twitter: @structures_hd, Instagram: @structures_heidelberg.

RESEARCH UPDATE

Machine learning meets quantum simulation

Authors: Tobias Schmale, Moritz Reh, Martin Gärttner

Fig. 1: Artistic view of a neural network interacting with a quantum spin system. This image was generated by the artificial intelligence DallE2. (Image credit: Gärttner Lab)

Quantum simulators solve quantum many-body problems that are hard to simulate on classical computers due to the exponential increase of computational cost with the number of simulated particles. This exponential hardness also hits when performing quantum tomography, which means fully characterising the prepared quantum states. Machine learning inspired variational approaches may overcome this challenge by restricting the manifold of trial states among which the experimentally prepared state is searched. The trick is to find structures inherent to the physical problem the simulator tries to solve, and to use them to create a compressed state representation, just like e.g. in image compression methods. In [1] we demonstrated that this method leads to a scalable tomography scheme using convolutional neural networks. We considered various experimentally relevant scenarios where we generated synthetic measurement data numerically. Working towards deploying this method on real experimental data, we recently applied it to an experiment creating entangled photon pairs [2]. A unique extension, possible thanks to collaborations within STRUCTURES, is the use of neuromorphic hardware. Optimising the parameters of an analogue neuromorphic chip we demonstrated the encoding of Bell states [3] and quantum ground states [4].

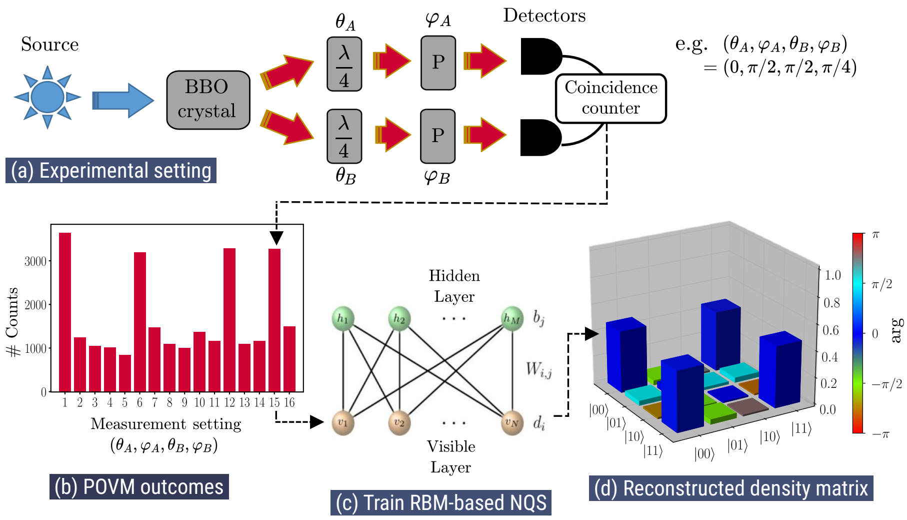


Fig. 2: Typical workflow of machine-learning assisted quantum state tomography. Adapted from Ref. [2].

Literature

[1] T. Schmale, M. Reh, M. Gärttner. Efficient quantum state tomography with convolutional neural networks. NPJ Quantum Information 8, 115 (2022).

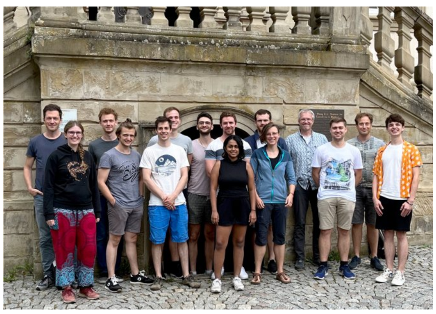
[2] M. Neugebauer, L. Fischer, A. Jäger, S. Czischek, S. Jochim, M. Weidemüller, M. Gärttner. Neural-network quantum state tomography in a two-qubit experiment. Phys. Rev. A 102, 042604 (2020).

[3] S. Czischek, A. Baumbach, S. Billaudelle, B. Cramer, L. Kades, J. M. Pawlowski, M. K. Oberthaler, J. Schemmel, M. A. Petrovici, T. Gasenzer, M. Gärttner. Spiking neuromorphic chip learns entangled quantum states. SciPost Phys. 12, 39 (2022).

[4] R. Klassert, A. Baumbach, M. A. Petrovici, M. Gärttner. Variational learning of quantum ground states on spiking neuromorphic hardware. iScience 25(8), 104707 (2022).

STRUCTURES ACTIVITIES

6th YRC Schöntal Workshop on “Renormalisation and Effective Theories”



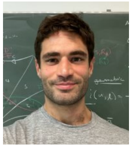
In this year's August, 13 YRC members from physics and mathematics participated in the 6th Schöntal Workshop on “Renormalisation and Effective Theories”. They were accompanied by Prof. Dr. Jan Pawlowski and Prof. Dr. Stefan Flörchinger who offered guidance and expertise throughout the sessions. The workshop consisted of discussion rounds of dedicated subtopics which were conducted by the participants. They served as foundation of exchange to further deepen the knowledge of the topic and integrate it in the bigger picture of physics and mathematics. We would like to thank everybody involved for the fruitful discussions, ideas and the great time.

STRUCTURES COMMUNITY

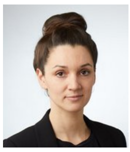
New Members and Fellows

The STRUCTURES cluster welcomes all new members elected by the general assembly in July, whose unique and complementary expertise will greatly strengthen the scientific portfolio of the cluster:

Simon Anders
Centre for Molecular Biology, Bioinformatics



James Farre
Mathematics Institute, Hyperbolic and Differential Geometry



Georgia Koppe
Central Institute of Mental Health, Computational Psychiatry

Agustin Moreno
Mathematical Institute, Symplectic Geometry

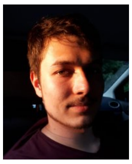
We wish all new members a good start and look forward to many new vibrant cooperations. We also congratulate our members Tilman Enss and Fred Hamprecht for being elected STRUCTURES fellows.

STRUCTURES COMMUNITY

We Are STRUCTURES

In each newsletter, we introduce three members of the Young Researchers Convent (YRC) to you. For this edition, we interviewed Kevin Paul Majowski (ITP), Johannes Reiter (PI) and Karen Wadenpfuhl (PI).

Interview with Kevin Paul Majowski:



Kevin Paul Majowski
PhD student, AG Salmhofer, ITP

What are you working on? I use the functional Renormalization Group to study how the Fermi surface of a two dimensional many-fermion system changes due to interaction effects in the presence of Van Hove singularities. Of particular interest is the possibility of a self-reinforcement of the singular behaviour.

What are you an expert for? While the word 'expert' seems a bit exaggerated, I am well-versed in the fields of condensed matter theory and the functional Renormalization Group.

What is your connection to STRUCTURES? My work is part of the Exploratory Project 4.5. 'Small-denominator problems and self-reinforcing singularities' led by Prof. Manfred Salmhofer.

What was your greatest scientific success up to now? Getting chosen to be interviewed for the STRUCTURES newsletter ;-).

Interview with Johannes Reiter:

Johannes Reiter
MSc student, AG Jochim, PI

What are you working on? Together with my team we are studying the emergence of collective quantum phenomena in few Fermion systems in an ultracold quantum gas experiment. The neutral atoms in our rotating traps resemble systems found in condensed matter and nuclear physics and thereby allow us to explore some of the most fundamental STRUCTURES of nature within the framework of quantum simulation.

What are you an expert for? The deterministic preparation of quantum states and precise control of individual atoms in optical potentials sets our experiment and my work apart from others.

What was your greatest scientific success up to now? Scientific advances and innovation are oftentimes induced by bringing together bright minds and providing the fertile ground for the exchange of their ideas. Hence, I would consider the initiation and organisation of the first European Spring School in Quantum Science and Technology to be my biggest contribution to the scientific community thus far.

How does one recognise you? I am the guy who occasionally runs out of the physics institute to come back in a fire engine.

Interview with Karen Wadenpfuhl:

Karen Wadenpfuhl
MSc student, AG Weidemüller, PI; QLM group, Durham

What are you working on? I am working on generating and studying an effective photon-photon interaction. Optical photons don't normally interact with one another beyond the quantum effects of bosons, but we can trick them into interacting by coupling the photons to matter in form of so-called polaritons.

What are you an expert for? Spotting imperially threaded screws at first glance. Seriously, they do real damage in a lab with mostly metric threadings. Otherwise, I have gathered some experience in maintaining an ultracold atom lab, diagnosing weird experimental problems and fixing issues we previously didn't even know we had.

What was your greatest scientific success up to now? Presenting my work at a spring school in Les Houches and discussing it with the other participants was really great, it gave me a lot of new ideas and perspectives. Experimentally, it was repairing the cavity lock for our coupling laser and then seeing an avoided crossing of energy levels.

How does one recognise you? I am equally happy to discuss physics as I am to join our research group's running team. Just ask if someone is up for both. If the answer is yes, then it's probably me.

MEMBER INTERVIEWS

STRUCTURES Asks: Felix Joos

In our newsletter we regularly present interviews with faculty members of STRUCTURES to give you the opportunity to get to know them better. For the current issue, we interviewed Felix Joos, Junior Professor and Emmy Noether Research Group Leader at the Institute for Computer Science (IFI), where he is heading the Theoretical Computer Science group. His research focuses on graph theory and its applications, including algorithms as well as extremal and structural questions. In 2020 he received the Lautenschläger Junior Research Prize for groundbreaking research in discrete mathematics. In the following we present our interview with him:

Q: What are you working on? What are typical questions in your research?

A: Essentially all of my research topics involve graphs and hypergraphs; that is, we have a finite set V of vertices and a collection of subsets of V, which we call edges. In case of graphs, the edges have size 2. In these structures I aim to find special substructures and in addition, I try to construct efficient algorithms computing these substructures.

Q: What fascinates you about these questions?

A: In most cases these questions are very easy to state, even explainable to non-mathematicians.

Q: How would you explain the fact that these seemingly simple problems often have very complicated solutions?

A: The questions are often so simple to state as we are considering finite objects that are easy to describe. However, the number of (hyper)graphs grows extremely fast with their size and they also exhibit a complex large scale structure. Hence in proofs this complexity has to be taken care of (which is not so simple).

Q: You have received the Lautenschläger Junior Prize for your work on the "Oberwolfach problem" and on "Kissing numbers". What are these problems about, and what did you discover?

A: The "Oberwolfach problem" posed by Ringel in the 1960s, which we solved for all large n, asks the following: given an odd number n of people and a collection of round tables with n seats in total, can one find a seat arrangement so that within $(n-1)/2$ meals *everyone* sits next to everyone else *exactly* once?
The "kissing number" in d dimensions asks for the maximum number of non-overlapping unit spheres that all touch a central unit sphere. For large d, the currently known best lower and upper bound lie exponentially far apart. We have improved the lower bound for the first time since the 1960s.

Jun-Prof Dr Felix Joos, head of the Theoretical Computer Science Group at IFI, Emmy Noether Research Group Leader. (Image credit: Felix Joos / Heidelberg University)

Q: How would you describe the relationship between "pure" mathematics and computer science in your work?

A: We often first prove structural statements about graphs and use these to find efficient algorithms solving the considered problem

Q: What are the "big challenges" or unknowns remaining in the field of graph theory and/or its applications?

A: We still do not understand how some basic (hyper)graph parameters relate to each other; this includes edge density and subgraph appearances, (algebraic) structure versus (quasi-)randomness...

We thank Felix Joos very much for his time and his interesting answers.

STRUCTURES ON THE WEB
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