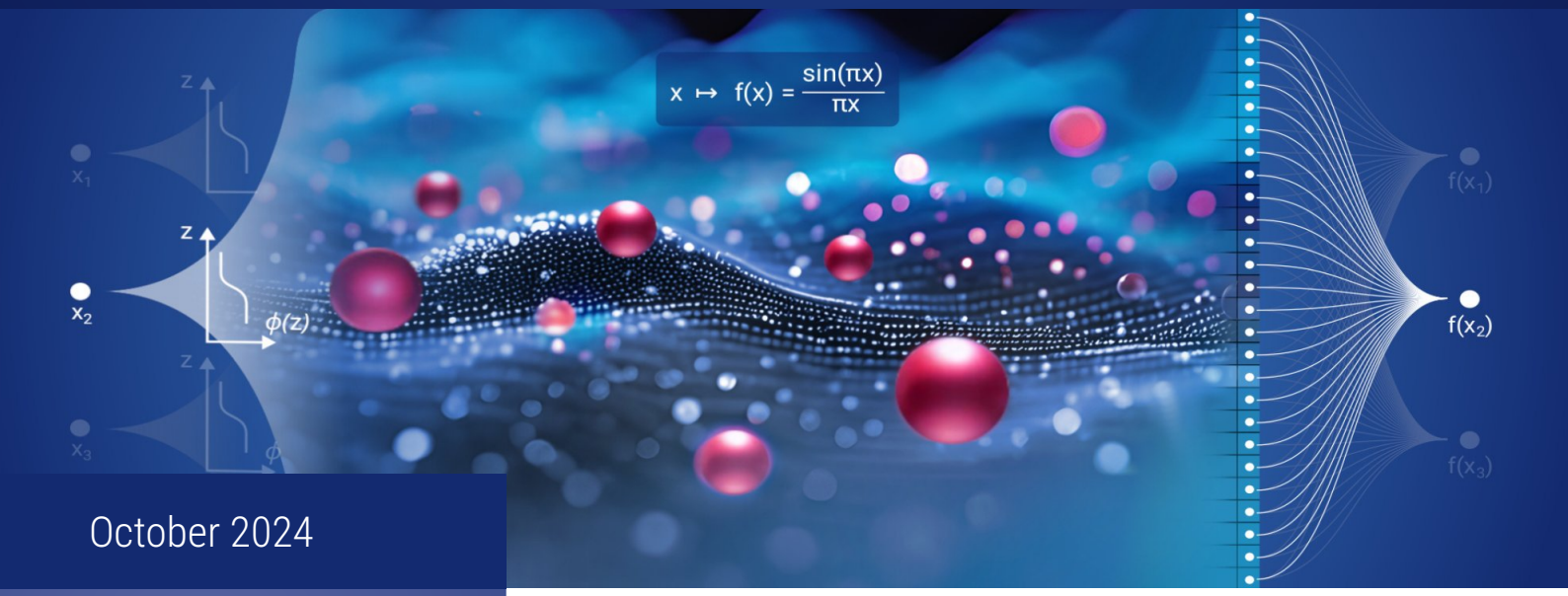
STRUCTURES | NEWS

STRUCTURES CLUSTER OF EXCELLENCE

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386



October 2024

Contents

Upcoming

Register now (for free):
Scan the QR code or visit:
structures.uni-heidelberg.de/events/2024_green/

RESEARCH

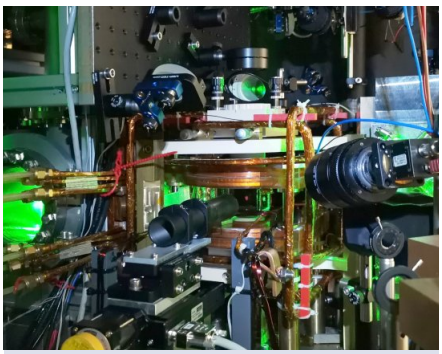
Ultracold Atoms for Machine Learning

Performing computations in physical systems has been a topic of interest since before the invention of modern computers. Here the idea is to perform computational steps in well-controlled physical systems instead of on regular, established hardware. Recently, this idea received new attention, as methods like Machine Learning have special requirements, which could therefore benefit from novel computation techniques.

Bose-Einstein Condensates (BECs), an exotic state of matter formed by a cloud of atoms at temperatures near absolute zero, are ideal systems for these purposes due to their versatility, reproducibility and excellent control over the initial state, ensuring reliable and precise experimentation.

In a new study, an interdisciplinary team of experimental physicists and mathematicians from STRUCTURES have successfully demonstrated the use of a BEC as a non-linear layer in a machine learning pipeline. Machine learning pipelines feed information through a system of connected layers, where input data is transformed to perform specific tasks. These layers form the basis of neural networks. By leveraging the inherently non-linear time evolution of the BEC to represent non-linear operations, only linear operations have to be performed on layers on classical computers.

This result became possible through the close collaboration of scientists from the groups of STRUCTURES members Christoph Schnörr at the *Institute for Mathematics (IMa)* and Markus Oberthaler at *Kirchhoff Institute for Physics (KIP)*.



BECK Experiment: This ultra-cold atom experiment creates a two-dimensional BEC of potassium-39 at temperatures of 10nK, one of the coldest known spots in the universe. *(Image by C. Viermann / Oberthaler group)*

Original Publication

M. Hans, E. Kath, M. Sparn , N. Liebster, H. Strobel, M.K. Oberthaler, F. Draxler, C. Schnörr, *Bose-Einstein condensate experiment as a nonlinear block of a machine learning pipeline*. Physical Review Research, 6, 013122 (2024). doi:10.1103/PhysRevResearch.6.013122.

STRUCTURES COMMUNITY

STRUCTURES Welcomes Eight New Members

STRUCTURES warmly welcomes its new members who have been elected by the General Assembly on June 7, 2024. We wish them all a good start and look forward to many common projects!

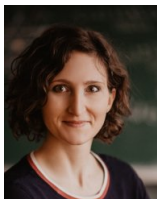
Zahra Monfared
BMBF Research Group Leader at IWR
Scientific Machine Learning, Mathem. Foundations of AI

Andreas Dreuw
Professor at IWR
Theoretical and Computational Chemistry

Dominika Wylezalek
Emmy Noether Research Group Leader at ZAH
Astrophysics: Galaxy Evolution and Active Galactic Nuclei

Holger Fröning
Professor at ZITI
Embedded Machine Learning, High-Performance Computing

Tobias Buck
Group Leader at IWR & ZAH,
Computational Astrophysics & Machine Learning



Petra Schwer
Professor at IMa
Geometry & Group Theory

Astrid Eichhorn
Professor at ITP
Theoretical Physics Quantum Gravity

Luca Amendola
Professor at ITP
Theoretical Cosmology & Astrophysics

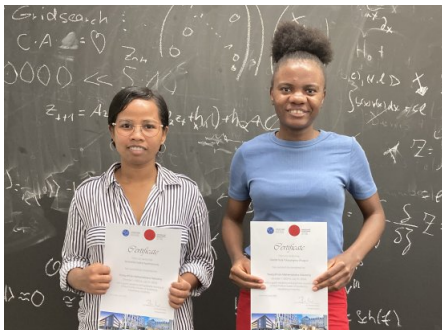
Institute abbreviations:
IWR = Interdisciplinary Center for Scientific Computing,
ZAH = Centre for Astronomy Heidelberg,
ZITI = Central Institute of Computer Engineering,
IMa = Institute for Mathematics,
ITP = Institute for Theoretical Physics

OPPORTUNITIES & FELLOWSHIPS

STRUCTURES YAM Initiative – A Year in Review and Looking Ahead

One year ago, STRUCTURES joined the *Young African Mathematicians (YAM)* initiative, an exchange programme designed to promote international collaboration and equal opportunities for early-career researchers from the Global South. YAM is a partnership between four German clusters of excellence (Bonn, Münster, Berlin and Heidelberg) and the *African Institute for Mathematical Science (AIMS)*. YAM enables outstanding graduates from the AIMS Master Programme to spend an academic year at a leading German research institution, where they conduct research under the supervision of a professor, participate in a structured course programme and immerse themselves in a rich and stimulating environment. The fellowships provide a stipend covering travel, living, and accommodation, along with extensive personal support.

In 2023/24, STRUCTURES welcomed two exceptional students, Richarlotte Razafindravola and Olivette Tchouangnou Chuagua. Supervised by STRUCTURES members Felix Joos, Roland Herzog, Hans Knüpfer, and



The 2023/24 YAM fellows at STRUCTURES: Richarlotte Razafindravola and Olivette Tchouangnou Chuagua.

YAM networking meeting, Summer 2024 (Image credit: © Mathematics Münster).

Robert Scheichl, they thrived in their research groups, benefiting from a highly skilled and international research environment, and from STRUCTURES' interdisciplinary culture bridging mathematics, physics, astronomy, and computer science. The YAM fellows attended lectures, seminars and excursions, including cluster-wide events like the STRUCTURES Jour Fixe, gaining new insights and ideas extending far beyond their own research fields. For the whole duration of their stay, they received invaluable support also from their student mentors Louise Kluge and Maximilian Siebel from the *Young Researchers Convent (YRC)*. The stay was coordinated by Hans Knüpfer, May-Britt Becker and the STRUCTURES office team.

More than just a fellowship programme, YAM represents an international community and network, fostering the exchange of ideas, experiences, and the formation of enduring connections.

In 2024/25, STRUCTURES welcomes three students: E.L.N. Mangaptche, M. A. Razanaparany and M. C. Tchoua Tchoua. They will be supervised by Christoph Schnörr, Jakob Zech and Jan Pawlowski. We wish all of them great start and a year filled with rewarding and enriching experiences!

STRUCTURES COMMUNITY

We Are STRUCTURES

In this section we regularly present short interviews with randomly picked early career researchers from STRUCTURES:

Interview with Anna-Katharina Nitschke:

Anna-Katharina Nitschke – PhD candidate, Phys. Inst. (PI), *Digital Twins in Medicine*

What are you working on? *I am introducing machine learning-based data analysis methods in public and global healthcare. Moreover, I develop algorithmic architectures for specific application requirements like a Digital Twin concept for prostate cancer patients or subpopulation identification method for people with multimorbidity of chronic non-communicable disease (NCD).*

What fascinates you about your research? *What fascinates me the most is the interdisciplinary aspect of my work, which is bridging physics with medicine, social science, and data science. By learning from one another, the given research question can be addressed in a more holistic way.*

How and when did you choose to do science? *When I studied physics in school, I decided to dedicate my life to learning and understanding the world around me. Therefore, science seemed the right path for me.*

How does one recognize you? *You might spot me with my laptop at INF 226 or sometimes even outside the building, enjoying the sun.*

Interview with Steffen Schmidt:

Steffen Schmidt – PhD student, Inst. for Mathem. (IMa), *Mathematical Physics*

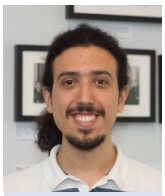
What are you working on? *I am working on the fascinating topic of the representation theory of super Lie algebras and super Lie groups, from both mathematical and physical perspectives. In particular, I investigate the structural implications of unitarity for concepts such as the superconformal index and representation categories.*

What fascinates you about your research? *Grasping the mechanisms of physical phenomena, and what it means in abstract terms, fascinates me. This includes bridging the gap between these two perspectives and using physical intuition to uncover new structures.*

How and when did you choose to do science? *I am simply a mathematician who has always loved solving all kinds of problems.*

How does one recognize you? *If you see or hear an enthusiastic runner and cyclist in the "bel étage" of the Mathematikon, it's probably me.*

Interview with Doğa Veske:



Doğa Veske – Postdoc, Inst. for Theoret. Phys. (ITP), *Cosmology group of L. Heisenberg*

What are you working on? *My work is centred around gravitational-wave (GW) observations. I work on multi-messenger follow-ups of GW with high-energy neutrinos, possible hints on dark matter, new GW detection methods and astrophysical formations of compact binary mergers.*

What fascinates you about your research? *GW astronomy is a relatively new field and it has many new opportunities for learning new things about the universe. Likewise, multi-messenger astronomy is still in its beginning. The new possibilities that they bring to find new physics is my main drive.*

How and when did you choose to do science? *I started considering doing science in high school. At the end of my second year I made my mind to be a physicist. It was mainly thanks to a book I read about relativity. My curiosity couldn't resist to studying physics after realizing that the universe behaves in ways that we cannot even imagine.*

How does one recognize you? *If you see a long curly black-haired skinny guy, it's probably me.*

TRAVEL & EXCHANGE

Insights from the *Gender in High Energy Theory (GenHET)* Meeting at CERN

In our newsletter, we occasionally feature brief travel reports by our members who have received travel funding from STRUCTURES. For this edition, YRC member Valdo Tatitscheff (IMa) kindly provided a summary of the *GenHET* meeting at CERN, which he attended in April:

GenHET is a permanent working group hosted at CERN, aiming to monitor the status of women in high-energy theoretical physics and raise awareness of gender issues in the field. GenHET organizes meetings to discuss recent developments in string theory as well as various gender-related topics. The most recent meeting, held on 29-30 April 2024 at CERN, gathered around 100 participants.

In addition to scientific talks, the agenda on April 29 included presentations of gender statistics in string theory, gender and physics within Europe, and a discussion on the special role that over-represented groups must take in order to dismantle inequity in STEM. The following day featured a panel discussion on women-only positions and quotas as well as a workshop on equity.

GenHET is open to all researchers in high energy theory, regardless of gender, career-stage, or nationality. Visit their webpage for more information: https://genhet.web.cern.ch/

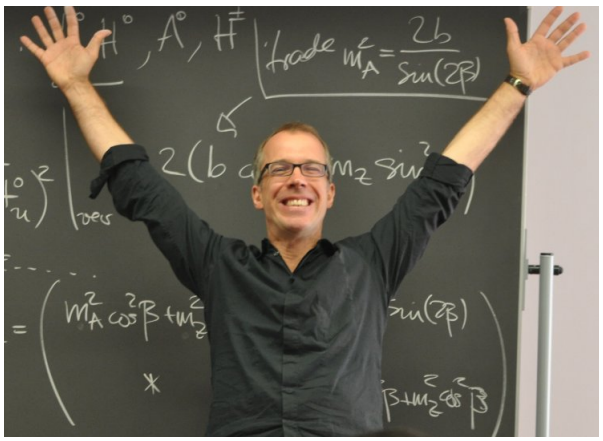
TRAVEL FUNDS

STRUCTURES members can apply for travel grants to attend scientific events such as workshops, conferences, meetings etc.

INTERVIEWS

STRUCTURES Asks: Tilman Plehn (Particle Phenomenology & Machine Learning)

For this edition of "STRUCTURES Asks," we interviewed Tilman Plehn, professor at the *Institute of Theoretical Physics (ITP)* and head of the "*Particle Phenomenology & Machine Learning*" group. His research interests include Higgs physics, QCD, and new physics at the LHC. In recent years, his team and he have been at the forefront of developing and applying modern data analysis tools, such as machine learning (ML) and information geometry, to LHC data. Tilman Plehn joined STRUCTURES in 2021, and his research aligns closely with Comprehensive Projects CP 1 (*Cosmic Structure Formation*) and CP6 (*Networks & Machine Learning*).



Tilman Plehn, Institute for Theoretical Physics (ITP)

You're working at the intersection of theory and experimental data analysis. What fascinates you about this area?

Exactly the links between quantum field theory, experimental data, and statistics. The statistics part is fun because I can enjoy mathematical precision without having to become a proper mathematical physicist.

How has machine learning changed our understanding of LHC data?

Every aspect of LHC physics is numerical in nature, experiment as well as theory. Modern ML opens so many new avenues, not just doing things faster, but also allowing us to do things we could not do before. With my statistics interest, I love the notion of optimal use of data, which we can now pursue. And CMS is playing with a trigger using an auto encoder, I am really curious what that will find.

What sparked your interest pursuing a career in science?

Two key moments – a lecture on QCD for the topic, and our research group in Madison, with lunches and great discussions by the lake, for the university career.

You are playing the bass trombone in two big bands. If you could attend a jam session with famous scientists throughout history, who would you invite?

I am not all that good, but if I were, maybe with Enrico Fermi? I do not know enough about Max Born, but he might be an interesting person, and we could reminisce about Edinburgh. Definitely, Niels Bohr on the drums, to keep us all together and in time.

Can you explain the idea of Information Geometry in two sentences? Bonus points if it involves trombones or jazz!

Not an explanation, but an application: the score defines optimal dynamics metrics, locally and globally, and they are different, so do not tell the bass trombone player that they are too loud.

What advice would you give to aspiring young researchers?

Progress is driven by methods and tools, great ideas are overrated in that respect, because they are just too rare. And even though it sounds old-school, most of us are not brilliant, but we can still make a difference if we do good work. Or as a local colleague used to say, "You cannot turn a pig into a race horse, but into a damn fast pig." And let me add, I am a very happy fast pig, and who cares about race horses?

What has been the most surprising/bizarre insight in your career?

Personally, that I can do physics every day for any number of hours, but playing music has an upper limit to the fun. Professionally, that a physics department full of big-bang-theory-like individualists, like ours, can be such a great team. Research-wise, I get lots of surprises every day...

What can you never start a day at work without?

Coffee, lots of it, and with a little bit of milk.

STRUCTURES ON THE WEB
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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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