Tobias Kühn

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OVERVIEW

I am a theoretical physicist working on applications of statistical physics to neuroscience at the university of Bern. During my PhD at the Research Centre Jülich, I have focused on the adaptation of techniques from statistical physics to neuroscience, as well as their further development. During my postdoctoral phase, I have continued this theme at ENS, Paris, and broadened my scope towards different applications, notably soft-matter physics, at Université Paris, before joining the Institut de la Vision to work on electrophysiological data from the retina and now the Institut für Physiologie at the university of Bern to study further links between information theory and neuroscience.

I am fascinated by how theoretical physics connects seemingly desperate phenomena and thereby deepens their understanding, as I am experiencing myself, for example, working on field-theory for non-Gaussian theories. Furthermore, seeing that these methods can be useful to describe phenomena in the real world, like retinal recordings, is very intriguing. It always excites me to find even more links to diverse areas, which would be invisible without theory.

In parallel to my scientific career, I was regularly involved in teaching and supervision and I am always happy when I succeed in conveying some of this fascination of theoretical physics to students.

RESEARCH PLANS

In my future research, I plan to further contribute to making statistical field theory fertile for applications to complex systems. While field-theoretical techniques have been very successfully employed in condensed-matter problems, transfering these methods to complex systems was often impeded by the fact that they imply Gaussian theories as a starting point, a restriction that due to my works is starting to be relaxed. This is important since many solvable models in the realm of complex systems are non-Gaussian, for example uncoupled Ising spins or the ideal gas. Adapting the tools from field theory will enable novel approximations and lead to new insights, especially when combined with the analysis of data. An important aspect will be to consider dynamics; for example, I would like to study the information theory of biological networks receiving dynamic stimuli or the temporal evolution of colloidal mixtures. In both fields, an appropriate field-theoretical formulation will be key to find elegant and simple derivations for new approximations.

APPOINTMENTS

Postdoctoral Fellow   May 2025 - now
Institut für Physiologie - Universität Bern, Switzerland

Postdoctoral Fellow   Apr. 2022 - Mar. 2025
Institut de la Vision - Sorbonne Université

Postdoctoral Fellow (fellowship by DAAD)   Sept. 2021 - Mar. 2022
Laboratoire de Physique - Ecole Normale Supérieure (LPENS), Paris

Postdoc (ATER)   Sept. 2020 - Aug. 2021
Laboratoire Matière et Systèmes Complexes, Université de Paris

Postdoctoral Fellow   Oct. 2019 - Aug. 2020
LPENS, Paris

Postdoctoral Fellow   Apr. 2019 - Sept. 2019
Institute for Computational and Systems Neuroscience - Research Centre Jülich

EDUCATION

PhD in Physics (Dr. rer. nat.)   Sept. 2014 - Dec. 2019
RWTH Aachen University and Research Centre Jülich (Germany)
    "Path integral methods for correlated activity in neuronal networks"
    Advisor: M. Helias

Master of Science in Physics   Oct. 2011 - May 2014
RWTH Aachen University

Bachelor of Science in Mathematics   Oct. 2009 - Sept. 2011
RWTH Aachen University
Bachelor of Science in Physics   Oct. 2008 - Sept. 2011
RWTH Aachen University

PAPERS, PRE-PRINTS AND MANUSCRIPTS [google scholar]

" * " = Authors contributed equally.

10. TK, G. Mahuas, U. Ferrari, "Diagrammatic expansion for the mutual-information rate in the realm of limited statistics.", *arxiv*   2025

9. TK, "Towards data analysis with diagrammatics.", *arxiv*   2025

8. TK, R. Monasson, "Information content in continuous attractor neural networks is preserved in the presence of moderate disordered background connectivity.", *Physical Review E (editor's suggestion)* **108** 6 2023

7. TK, F. van Wijland, "Diagrammatics for the inverse problem in spin systems and simple liquids.", *Journal of Physics A* **56** 11 2023

6. L. Tiberi*, J. Stapmanns*, TK, T. Luu, D. Dahmen, H. Helias, "Gell-Mann-Low criticality in neural networks.", *Physical Review Letters* **128** 16 2022

5. A. van Meegen, TK, M. Helias, "Large-Deviation approach to random recurrent neuronal networks: parameter inference and fluctuation-induced transitions.", *Physical Review Letters* **127** 15 2022

4. C. Keup*, TK*, D. Dahmen, M. Helias, "Transient chaotic dimensionality expansion by recurrent networks.", *Physical Review X* **11** 2 2021

3. J. Stapmanns*, TK*, D. Dahmen, T. Luu. C. Honerkamp, M. Helias, "Self-consistent formulations for stochastic nonlinear neuronal dynamics.", *Physical Review E* **101** 4 2020

2. TK, M. Helias, "Expansion of the Effective Action around Non-Gaussian Theories.", *Journal of Physics A* **51** 37 2018

1. TK, M. Helias, "Locking of correlated neural activity to ongoing oscillations.", *PLoS Computational Biology* **13 (6),** e1005534 2017

ACHIEVEMENTS

- 2025: Interviewed for a junior-research-group position at RWTH Aachen University (NRW-Rückkehrprogramm, five years)

- 2024: Interviewed for an assistant-professor position in the Department of Computing Sciences at Bocconi University, Milano, Italy

- 2023: Ranked for a junior-tenure-track position in theoretical physics at CY Cergy Paris Université

- 2023: Qualification for Maître-de-Conférence Positions in section 26 (Applied mathematics and applications of mathematics), section 28 (Dense media and materials), section 29 (Elementary constituents) and section 69 (Neuroscience)

TEACHING

In total, I have taught about **335h** in tutorials and lectures for undergradute students and I was a tutor at a summer school for graduate students.

During my own undergraduate studies, I have taught in german, later almost exclusively in english and in french. The language is indicated for every course description.

- 2021: **Tutorials/lectures (Cours-TDs) "Outils mathématiques pour la physique"** (introduction to mathematical methods, **46h**)
  Bachelor in Physics, Université de Paris, french

- 2021: **Traveaux pratiques (TP, programming tutorials) "Signaux et Systèmes"** (signal treatment with matlab, **30h**)
  Engineer's diploma, Université de Paris, french

- 2020: **Tutorials (TDs) for the Lecture "Statistical physics" (9h)**
  Master 2 ICFP, Université de Paris, Sorbonne Université, Université Paris-Saclay, Ecole Normale Supérieure, Ecole Polytechnique, english

- 2020: **TDs for the Lecture "Physics for physicians" (15h)**
  Medicine diploma (equivalent to Bachelor), Université de Paris, french

- 2020: **Tutorials/lectures (Cours-TDs) "Interactions Maths-Physique"**
  (introduction to mathematical methods, 27h)
  Bachelor in Mathematics/Math. and Computer Science (1st year), Université de Paris, french

- 2018: **Tutorials of the lecture „Statistical Physics" (4.5h)**
  MSc Physics, RWTH Aachen University (Germany), english

- 2017: **Lecture
  "Theoretical Neuroscience: Correlation structure of neuronal networks" (3h)**
  MSc Physics, RWTH, english

- 2016: **Tutor at the second „Advanced Computational Neuroscience School"**
  MPI for Dynamics and Self-organization, Göttingen, english

- 2016 - 2018: **Tutorials of the lecture „Theoretical Neuroscience: Correlation structure of neuronal networks"** (summer terms 2016, 2017 and 2018, **27h in total**)
  MSc Physics, RWTH, english

- 2016 - 2018: **Tutorials of the lecture „Statistical Mechanics of Neuronal Networks"**
  (winter terms 2016/17 and 2017/18, **18h in total**)
  MSc Physics, RWTH, english

- 2015 - 2018: **Tutorials of the lecture „Computational Neuroscience"** (winter terms 2015/16, 2016/17 and 2017/18, **4.5h in total**)
  MSc Physics and Biology, RWTH, english

- 2010 - 2014: **Tutor for diverse lectures, in mathematics for non-mathematicians (physicists, electrical engineers, chemists,...) and introduction to theoretical physics (150h in total)**
  diverse BSc in sciences and engineering, RWTH, german

SUPERVISION

- 2019: **Co-supervision of Jan Bauer, together with M. Helias**
  Learning effective data representations with restricted Boltzmann machines, Bachelor Thesis, RWTH Aachen

- 2016 - 2017: **Co-supervision of Christian Keup, together with M. Helias**
  A neuron-model-independent path-integral explored via binary assemblies, Master thesis, RWTH Aachen; contributed to the publication of Keup, Kühn et al. 2021, PRX, see above

INVITED TALKS

- Workshop "Population activity : the influence of cell-class identity, synaptic dynamics, plasticity and adaptation", CNS conference, Firenze, 2025

- Seminar of the Functional Systems Dynamics group, Université de Strasbourg, 2024

- Seminar of the group for Theoretical and Computational Neuroscience, IOB, Basel 2023

- Symposium "From synapse to transistor", INM-6, Research Centre, Jülich 2023

- Seminar zu aktuellen Fragen aus der Physik weicher Materie, Soft Condensed Matter Group, LMU, München 2023

- Seminar of the Bernstein Center for Computational Neuroscience, Neurobiology Department, LMU, München 2023

- Joint Theoretical Physics Seminar Warwick/Cergy-Pontoise, LPTM, CY Cergy Paris Université, Cergy-Pontoise 2023

- Mathematical Biology Seminar at the Czech Academy of Science, Prague, 2023

- QBio Seminar, Centre de biologie quantitative de l'ENS-PSL, Paris 2022

- CENTURI Turing Center for Living Systems, Marseille, 2020

- PhD-seminar „Cold Quantum Coffee", Theoretical Physics Department, University of Heidelberg, 2016

CONFERENCE AND WORKSHOP CONTRIBUTIONS

- StatPhys29, Firenze, 2025, Talk.

- CNS conference, Firenze, 2025, Poster.

- Journées de la Physique Statistique, Paris, 2025, Short talk.

- Bernstein Conference, Frankfurt, 2024, two Posters.

- Workshop "Information Processing, Noise, and Adaptation in Living Systems", MPI for the Physics of Complex Systems, Dresden, 2024, Talk.

- DPG Spring Meeting, Berlin, 2024, Talk.

- APS March Meeting, Virtual, 2024, Talk and poster.

- Cosyne Conference, Lisbon, 2024, Abstract for poster accepted (not attended).

- Journées de la Physique Statistique, Paris, 2024, Short talk.

- Bernstein Conference, Berlin, 2023, Poster.

- European Retina Meeting, Tübingen, 2023, Poster.

- Spring Meeting of the German Physical Society, Dresden, 2023, Talk and poster.

- Journées de la Physique Statistique, Paris, 2023, Short talk.

- Bernstein Conference, Berlin, 2022, Poster.

- Workshop „Building population models for large-scale neural recordings", Edinburgh, 2022, Poster.

- Journées de la Physique Statistique, Paris, 2022, Short talk.

- Annual Meeting of the DPG, online, 2021, Poster

- Spring Meeting of the German Physical Society, online, 2021, Talk.

- Journées de Physique Statistique of l'ENS, Paris, 2020, Short talk.

- Bernstein Conference, Berlin, 2019, Poster.

- Spring Meeting of the German Physical Society, Regensburg, 2019, Talk.

- Bernstein Conference, Berlin, 2018, Poster.

- Workshop InSpire – New Insights on Complex Neural Dynamics, Cergy-Pontoise, 2018, Poster.

- Spring Meeting of the German Physical Society, Berlin, 2018, Talk.

- Bernstein Conference, Göttingen, 2017, Poster.

- CRCNS Conference, Paris, 2016, Poster.

- Bernstein Conference, Berlin, 2016, Poster.

- 9th Bernstein Sparks Workshop, Göttingen, 2016, Poster.

- Spring Meeting of the German Physical Society, Regensburg, 2016, Talk.

FUNDING

- Short-term postdoc fellowship of the German Academic Exchange Service (Deutscher Akademischer Austauschdienst, DAAD) for **2021/2022**

- Support of M. Helias and C. Honerkamp in writing proposals („Facing the multi-scale problem in neuroscience by the functional renormalization group" and „Dynamic phase transitions in cortical networks") for the acquisition of „Exploratory Research Space"-seed funds of RWTH Aachen in **2016 and 2017**

TRAINING

- 2024: **Cargèse Summer School "Complex and Glassy Systems"**
  Cargèse, France

- 2023: **The Systems Vision Science Summer School and Symposium**
  Tübingen, Germany

- 2022: **Kavli Summer School "Mathematical Methods in Computational Neuroscience"**
  Eresfjord, Norway

- 2017: **Beg Rogu Summer School "Wind and Physics"**
  St Pierre Quiberon, France

- 2015: **Advanced Computational Neuroscience School**
  Göttingen, Germany

OTHER ACTIVITIES

- Reviewer for Journal of Physics A, Physical Review E, Reports on Progress in Physics, Machine Learning: Science and Technology, SciPost Physics, Physical Review X Life, Physical Review Letters **since 2019**

- Support of M. Helias to review for PloS Comput Biology, SIAM Journal of Applied Mathematics, Journal of Statistical Mechanics, Journal of Physics A, PNAS, **since 2016**

- Internship in the editorial department of the german newspaper „Süddeutsche Zeitung", department „Wissen" (Science), **January to March 2019**

REFERENCES

- Ulisse Ferrari Institut de la Vision, Sorbonne Université, INSERM, CNRS, Paris, France

- Rémi Monasson Laboratoire de Physics, ENS, Paris, France

- Frédéric van Wijland Laboratoire Matière et Systèmes Complexes, Université Paris Cité, France

- Moritz Helias INM-6, Research Centre Jülich and RWTH Aachen University, Germany

- Carsten Honerkamp Institute for Solid State Physics, RWTH Aachen University, Germany