Julian Arnold

Curriculum Vitae

Department of Physics
University of Basel
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Personal Information

origin	Swiss, born in Unterschächen (CH) on 7 September 1998
residence	CH-4055 Basel, Switzerland
group page	quantumtheory-bruder.physik.unibas.ch
personal page	arnoldjulian.github.io

Education and Degrees

08/2021 –present **University of Basel**, PhD Candidate in Theoretical Physics.
Thesis: "Machine Learning Phase Transitions: A Probabilistic Perspective",
supervisor: Prof. Christoph Bruder.

08/2019 –03/2021 **University of Basel**, Master of Science in Nanosciences, *final grade: 5,8/6,0*.
External Master thesis at Institute for Theoretical Physics, **ETH Zurich**: "Entropy production in ticking clocks", supervised by Dr. Mischa Prebin Woods, Prof. Christoph Bruder, and Prof. Renato Renner.

09/2016 –07/2019 **University of Basel**, Bachelor of Science in Nanosciences, *final grade: 5,7/6,0*.
Highlighted research project: "Magneto-optical trapping of ^{87}Rb using an interference filter-stabilized external cavity diode laser", supervised by Prof. Philipp Treutlein.

08/2010 –06/2016 **Kantonsschule Seetal**, Matura, Matura thesis prize (best Matura thesis in natural sciences of the year).
Matura thesis: "Influence of electrolytes on the electric properties of a dye-sensitized solar cell".

Distinctions and Awards

2024 QCQT Excellence Award

2023 Distinguished student award for the APS March Meeting

2023 Camille- and Henry-Dreyfus scholarship

2022 Best poster award for *Entropy production in ticking clocks: Fundamental limits of time-keeping*, 761. WE-Heraeus-Seminar on Entropy and the Second Law of Thermodynamics

2017 Swiss national science competition "Schweizer Jugend forscht" – Predicate: good

2016 Special award of technology, Lucerne School of Engineering and Architecture

2016 Award for the best Matura thesis in natural sciences, Kantonsschule Seetal

Funded Research

2023 – 2024 **MIT-Switzerland Lockheed Martin Seed Fund**, MIT International Science and Technology Initiatives, 22k USD, Title: Moment-Sum-of-Squares Techniques for Quantum Control (led by Dr. Frank Schäfer)

Publications

Total citations = 230+ (as of 01/2025) [Source: Google Scholar]

Preprints

[13] Difei Zhang, Frank Schäfer, and **Julian Arnold**, *Machine learning the Ising transition: A comparison between discriminative and generative approaches*, arXiv:2411.19370 (2024).

[12] **Julian Arnold**, Flemming Holtorf, Frank Schäfer, and Niels Lörch, *Phase Transitions in the Output Distribution of Large Language Models*, arXiv:2405.17088 (2024).

[11] **Julian Arnold**, Flemming Holtorf, Niels Lörch, and Frank Schäfer, *Machine learning phase transitions: Connections to the Fisher information*, arXiv:2311.10710 (2023).

Peer-reviewed Publications

[10] Flemming Holtorf, Frank Schäfer, **Julian Arnold**, Christopher Rackauckas, and Alan Edelman, *Performance Bounds for Quantum Control*, IEEE Trans. Autom. Control. **69**, 8057 (2024).

[9] **Julian Arnold**, Frank Schäfer, and Niels Lörch, *Fast Detection of Phase Transitions with Multi-Task Learning-by-Confusion*, NeurIPS 2023 Machine Learning and the Physical Sciences Workshop (2023).

[8] **Julian Arnold**, Frank Schäfer, Alan Edelman, and Christoph Bruder, *Mapping out phase diagrams with generative classifiers*, Phys. Rev. Lett. **132**, 207301 (2024) [featured in press release by MIT and University of Basel].

[7] Anna Dawid, **Julian Arnold** *et al.*, *Modern applications of machine learning in quantum sciences*, arXiv:2204.04198 (2022) [a comprehensive set of lecture notes in press as a book at Cambridge University Press].

[6] Axel U. J. Lode, Ofir E. Alon, **Julian Arnold** *et al.*, *Quantum simulators, phase transitions, resonant tunneling, and variances: A many-body perspective*, In: Nagel, W.E., Kröner, D.H., Resch, M.M. (eds) High Performance Computing in Science and Engineering '21, HPCSE 2021, Springer (2023).

[5] Juan Carlos S. V. Veliz, **Julian Arnold**, Raymond J. Bemish, and Markus Meuwly, *Combining Machine Learning and Spectroscopy to Model Reactive Atom + Diatom Collisions*, J. Phys. Chem. A **126**, 7971 (2022).

[4] **Julian Arnold** and Frank Schäfer, *Replacing neural networks by optimal analytical predictors for the detection of phase transitions*, Phys. Rev. X **12**, 031044 (2022) [featured in press release by University of Basel].

[3] **Julian Arnold**, Juan Carlos S. V. Veliz, Debasish Koner, Narendra Singh, Raymond J. Bemish, and Markus Meuwly, *Machine learning product state distributions from initial reactant states for a reactive atom–diatom collision system*, J. Chem. Phys. **156**, 034301 (2022).

[2] **Julian Arnold**, Frank Schäfer, Martin Žonda, and Axel U. J. Lode, *Interpretable and unsupervised phase classification*, Phys. Rev. Res. **3**, 033052 (2021).

[1] **Julian Arnold**, Debasish Koner, Silvan Käser, Narendra Singh, Raymond J. Bemish, and Markus Meuwly, *Machine Learning for Observables: Reactant to Product State Distributions for Atom-Diatom Collisions*, J. Phys. Chem. A **124**, 7177 (2020).

Seminar & Conference Contributions

Invited Talks

03/2024 **National University of Singapore**, Centre for Quantum Technologies, QAISG QML Seminar (organizers: Gan Beng Yee *et al.*), *Mapping out phase diagrams with generative classifiers* – online.

07/2023 **Max Planck Institute for the Science of Light**, Theory Division Seminar (organizer: Prof. Florian Marquardt), *Replacing neural networks by optimal analytical predictors for the detection of phase transitions* – Erlangen (Germany).

02/2023 **Perimeter Institute**, Perimeter Institute Quantum Intelligence Lab Group Seminar (organizer: Prof. Roger Melko), *Replacing neural networks by optimal analytical predictors for the detection of phase transitions* – online.

12/2022 **University of Basel**, QCQT Seminar (organizer: Prof. Jelena Klinovaja) *Replacing neural networks by optimal analytical predictors for the detection of phase transitions* – Basel (Switzerland).

11/2022 **University of Basel**, Seminar in Probability Theory and Statistics (organizers: Prof. Jiří Černý and Prof. David Belius), *Replacing neural networks by optimal analytical predictors for the detection of phase transitions* – Basel (Switzerland).

08/2022 **Heinrich Heine Universität Düsseldorf**, seminar in the group of Prof. Martin Kliesch, *Replacing neural networks by optimal analytical predictors for the detection of phase transitions* – Düsseldorf (Germany).

05/2022 **ultracold.org**, Journal Club for Quantum Physics and Machine Learning (organizers: MCTDH-X team), *Replacing neural networks by optimal analytical predictors for the detection of phase transitions* – online.

04/2022 **ICFO**, seminar in the group of Prof. Maciej Lewenstein, *Replacing neural networks by optimal analytical predictors for the detection of phase transitions* – online.

02/2022 **TU Delft**, seminar in the group of Prof. Eliska Greplova, *Replacing neural networks by optimal analytical predictors for the detection of phase transitions* – online.

03/2021 **ETH Zurich**, seminar in the group of Prof. Renato Renner, *Entropy production in ticking clocks* – online.

01/2021 **ultracold.org**, Journal Club for Quantum Physics and Machine Learning (organizers: MCTDH-X team), *Interpretable and unsupervised phase classification* – online.

Contributed Talks (*) indicates delivery by co-author

08/2024 **IAIFI Summer Workshop 2024**, *Machine learning phase transitions: A probabilistic perspective* – Cambridge (USA).

09/2023 **Joint Annual Meeting of SPS and ÖPG 2023**, *Mapping out phase diagrams using generative classifiers* – Basel (Switzerland).

07/2023 **JuliaCon 2023**, *Machine learning phase transitions: A probabilistic framework* – Cambridge (USA).

07/2023 **JuliaCon 2023**, *Differentiable isospectral flows for matrix diagonalization* – Cambridge (USA).

*07/2023 **JuliaCon 2023**, *Performance bounds for quantum control* – Cambridge (USA).

03/2023 **APS March Meeting 2023**, *Revealing phase diagrams of quantum systems with optimal predictors* – Las Vegas (USA).

*03/2023 **APS March Meeting 2023**, *How deep neural networks learn thermal phase transitions* – Las Vegas (USA).

03/2022 **AMLD 2022**, *Replacing neural networks by optimal analytical predictors for the detection of phase transitions* – Lausanne (Switzerland).

03/2021 **APS March Meeting 2021**, *Interpretable and unsupervised phase classification based on averaged input features* – online.

Posters (*) indicates delivery by co-author

08/2024 **IAIFI Summer Workshop 2024**, *Phase transitions in the output distribution of large language models* – Cambridge (USA).

01/2024 **Quantum Information Processing (QIP) 2024**, *Machine learning phase transitions: Connections to the Fisher information* – Taipei (Taiwan).

12/2023 **NeurIPS 2023: Machine Learning and the Physical Sciences Workshop**, *Fast Detection of Phase Transitions with Multi-Task Learning-by-Confusion* – New Orleans (USA).

*09/2023 **2023 IEEE International Conference on Quantum Computing and Engineering (QCE)**, *Sum-of-Squares Bounds for Quantum Optimal Control* – Bellevue, Washington (USA).

07/2023 **Alan Edelman's 60th Birthday Conference**, *Performance bounds for quantum control* – Cambridge (USA).

09/2022 **Arnold Sommerfeld School: Physics Meets Artificial Intelligence**, *Optimal analytical predictions of machine learning methods for the detection of phase transitions* – Munich (Germany).

07/2022 **761. WE-Heraeus-Seminar on Entropy and the Second Law of Thermodynamic**, *Entropy production in ticking clocks: Fundamental limits of timekeeping* – Bad Honnef (Germany).

02/2022 **NCCR QSIT Winter School & NCCR QSIT General Meeting**, *Optimal analytical predictions of machine learning methods for the detection of phase transitions* – Arosa (Switzerland).

09/2021 **QUSTEC Summer School**, *Interpretable and unsupervised phase classification* – Engelberg (Switzerland).

08/2021 **Summer School: Machine Learning in Quantum Physics and Chemistry**, *Interpretable and unsupervised phase classification* – Warsaw (Poland).

06/2021 **Workshop on Artificial Scientific Discovery 2021**, *Interpretable and unsupervised phase classification* – online.

Visibility in Media

05/2024 **Massachusetts Institute of Technology**, Scientists use generative AI to answer complex questions in physics. MIT press release on the paper *Mapping Out Phase Diagrams with Generative Classifiers*.

05/2024 **University of Basel**, Artificial intelligence calculates phase diagrams. University press release on the paper *Mapping Out Phase Diagrams with Generative Classifiers*.

09/2022 **University of Basel**, Computational shortcut for neural networks. University press release on the paper *Replacing neural networks by optimal analytical predictors for the detection of phase transitions*.

03/2016 **Seetaler Bote**, Mit Wissenschaft Wissen geschaffen. Local newspaper reporting on my Matura thesis on *Grätzel-Zelle – Einfluss des Elektrolyten auf die elektrischen Eigenschaften einer Grätzel-Zelle*.

03/2016 **Schweizer Radio und Fernsehen (SRF)**, Beste Maturaarbeiten ausgezeichnet. National newsstation mentions prize for my Matura thesis on *Grätzel-Zelle – Einfluss des Elektrolyten auf die elektrischen Eigenschaften einer Grätzel-Zelle*.

Supervising, Teaching, Tutoring, and Reviewing

04/2021 – present **University of Basel**, *Supervising*.

I co-supervised four Master students

- Leon Behrens: Machine learning phase transitions in diffusion models (11/2024 – present)
- Jan Neuser: Numerical quantum gate design for superconducting qubits (01/2023 – 04/2023)
- Heinz Krummenacher: Diagonalization of quantum many-body systems by flow equations (03/2022 – 01/2023)
- Benjamin Senn: Unsupervised approaches for the identification of phase transitions in the swarmalator model (04/2021 – 02/2022)

01/2022 – present **University of Basel**, *Teaching*.
During the spring term 2022 I independently conceived a 2-week intensive course on quantum computing for Bachelor and Master students. I taught the course during summer 2022 and 2023. During the spring term 2024, I developed a 2-week intensive course on contemporary machine learning for physicists which I taught in summer 2024. Moreover, I replaced Christoph Bruder in a lecture on quantum mechanics aimed at Bachelor students.

09/2021 –present **University of Basel**, *Tutoring*.
Tutoring Bachelor students from physics, computational science, and nanosciences receiving excellent evaluations:
- Classical mechanics, fall term 2024
- Classical and quantum nonlinear dynamics, spring term 2024
- Theory of superconductivity, spring term 2023
- Classical mechanics, fall term 2022
- Quantum mechanics, fall term 2021

02/2022 – present **Professional service**.
Independent peer reviews for
- Physical Review A, B, E, Research, Letters, Applied, PRX, PRX Quantum
- New Journal of Physics, Quantum Science and Technology, Machine Learning: Science and Technology [Trusted reviewer status]
- IEEE Control Systems Letters (L-CSS), American Control Conference (ACC), IEEE Conference on Decision and Control (CDC)
- NeurIPS

Practical Experience

08/2023 **University of Basel**, Organization of scientific workshop.
Co-organizing a 1-day workshop on "Scientific Machine Learning and Stochastic Optimal Control" at the Department of Physics.

04/2022 –present **University of Basel**, Computer administrator of Bruder group.
Responsible among other things for maintaining the group website, distributing software, installing Linux operating systems, ordering computers and IT accessories, and tackling security vulnerabilities.

02/2022 –present **The Julia Language**, Open-source software development.
Developing scientific open-source software packages in the Julia programming language.

Additional Qualifications

Scientific computing.
Julia, Python, Mathematica, git

High-performance computing.
Linux, Slurm, shell scripting

Professional development.
Alumni Mentoring Program (University of Basel, 2024 – present)

Languages.
German (Native), English (Fluent), French (Level B2), Spanish (Level B2)

Social Engagement and Outreach

03/2023 –present **Quantum mechanics at elementary schools**.
I regularly give a first introduction to quantum phenomena at nearby Swiss elementary schools through interactive experiments illustrating the wave–particle duality.

01/2023 –04/2023 **Climate protection initiative**, Department of Physics, University of Basel.
Member of an ad-hoc team that assesses the current CO_2 emission of the department, communicates results to the public, and proposes new sustainability policies.

Institutional Responsibilities

06/2023 –present **PhD representative**, Department of Physics, University of Basel.
Board member of the PhD Association Physics Basel responsible for representing the interests of PhD students in departmental meetings.

11/2021 –10/2022 **PhD survey**, Department of Physics, University of Basel.
Member of support group establishing a PhD survey at the department together with the graduate center of the University of Basel.