



## Philipp M. Schicho

### 1. Personal information

name Dr. Philipp Maximilian Schicho  
 born in Graz, Austria, 01 October 1991  
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### 2. Current and future position

09/2024 – 08/2028 SNSF Ambizione fellow  
 Département de Physique Théorique, Université de Genève  
 Principle investigator of SNSF project no. 215997: *Gravitational waves from cosmological phase transitions: Precision cosmology in the light of LISA* (PRECLISA)  
 09/2022 – today Postdoctoral researcher  
 Institute for Theoretical Physics, Goethe University Frankfurt  
 Advisors: L. Sagunski, J. Schaffner-Bielich

### 3. Employment history

05/2020 – 08/2022 Postdoctoral researcher  
 Helsinki Institute of Physics, University of Helsinki  
 Advisors: A. Vuorinen, K. Rummukainen  
 02/2017 – 04/2020 Doctor of Philosophy, PhD Physics (magna cum laude), 23/04/2020  
 AEC, Institute for Theoretical Physics, University of Bern  
 Advisor: M. Laine  
 Thesis: *Multi-loop investigations of strong interactions at high temperatures*, (cf. research output [4]).

- 10/2016 – 01/2017 Technical student  
CERN, Accelerator and Beam Transfer, Beam Transfer Physics  
Theoretical optimisation of slow extraction (cf. research output [6]).  
Advisors: M.A. Fraser, M. Meddahi
- 06/2015 – 08/2015 Summer student  
CERN, ABT, BTP  
Thesis: *Optimising simulation times of SPS slow extraction using MAD-X*, (cf. research output [5]).
- 07/2014 – 08/2014 Summer student (GPA 1.0/1.0)  
HEPHY, Institute of High Energy Physics, Vienna  
Advisor: R. Schöfbeck  
Thesis: *Increasing the sensitivity of a search for supersymmetry in the single lepton channel with the Transverse Mass  $M_{T2}$  (CMS)*, (cf. research output [1]).

#### 4. Education

- 07/2017 Ècole de physique des Houches  
Effective Field Theory (EFT) in particle physics and cosmology
- 03/2017 Computer algebra and particle physics (CAPP) school, DESY, Hamburg
- 09/2014 – 11/2016 Master of Science, MSc Physics (GPA 5.5/6.0), 01/11/2016  
ETH Zürich, Switzerland  
Major: Theoretical high energy physics, lattice QCD, applied mathematics  
Advisor: P. de Forcrand  
Thesis: *Inhomogeneous condensation in quark-based QCD effective models via wavelet pseudoparticles*, (cf. research output [3]).
- 07/2014 LAPP Annecy-le-Vieux, France  
Summer School in Particle and Astroparticle physics
- 08/2013 Theoretical Physics Summer school, University of Utrecht, Netherlands
- 09/2011 – 08/2014 Bachelor of Science, BSc Physics (with distinction, GPA 1.1/1.0), 12/08/2014  
Graz University of Technology, Austria  
Advisors: H. G. Evertz, C. B. Lang  
Thesis:  *$\pi$ - and  $\rho$ -Meson mass spectroscopy from Lattice QCD*, (cf. research output [2]).
- 09/2002 – 05/2010 Österreichische Reifeprüfung, Matura (with distinction, GPA 1.0/1.0)  
AHS BG/BRG Leibnitz, Austria  
Major: Physics and geometry  
Advisor: H. Scherz

Thesis: *Sonoluminescence – A bubble’s enlightenment*. A theoretical and experimental approach to the effect of Sonoluminescence.

## 5. Teaching activities

2023 – Lectures

Institute for Theoretical Physics, Goethe University Frankfurt

*Theoretische Physik 1: Mathematische Ergänzungen*

15wk×2hr

03/2022 *Phase transitions in the early universe* (exercises)

1wk×5hr

Galileo Galilei Institute for Theoretical Physics

Theoretical Aspects of Astroparticle Physics, Cosmology and Gravitation

2020 – PhD thesis mentor,

Institute for Theoretical Physics, Goethe University Frankfurt

R. Diedrichs, 10/2022 – , supervised by L. Sagunski

D. Schmitt, 10/2022 – , supervised by L. Sagunski

2021 – MSc thesis supervisor,

Helsinki Institute of Physics, University of Helsinki

S. Vihko, 06/2021 – 03/2022, co-supervised with A. Vuorinen

Thesis: *EFT methods and calculational techniques in imaginary time formalism of thermal QCD*.

2022 – BSc thesis supervisor,

Institute for Theoretical Physics, Goethe University Frankfurt

R. Baumann, 10/2022 – 09/2023, co-supervised with L. Sagunski, D. Schmitt

Thesis: *Gravitational waves in the Abelian Higgs model*

2013 – Teaching assistant

Institute for Theoretical Physics, Goethe University Frankfurt

*Astrophysics II*

AEC, Institute for Theoretical Physics, University of Bern

8832-FS2017-0	<i>Standard Model</i>
416542-HS2017-0	<i>Quantum mechanics I</i>
628-FS2018-0	<i>Quantum mechanics II</i>
7638-HS2018-0	<i>Exercises in theoretical physics</i>
430949-FS2019-0	<i>Specialist course: Introduction to BSM physics</i>
630-HS2019-0	<i>Statistical thermodynamics II</i>

ETH Zürich, D-MATH/D-PHYS

401-1652-10L	<i>Numerical analysis I</i>
401-0654-00L	<i>Numerical methods</i>
402-0063-00L	<i>Physics II</i>

Graz University of Technology, ITP/IEP

*Theoretical mechanics, physics laboratory I/II*

## 6. Event organisation

- 08/2024 Conference co-organiser, *Strong and Electro-Weak Matter 2024*, Goethe University Frankfurt
- 06/2024 Convener, *2nd Edition of the Workshop ‘Quarkonia meet Dark Matter’ (QMDM)*, Institute for Advanced Study, Technical University of Munich
- 01/2024 Conference co-organiser, *Mainz-Frankfurt-Münster CosmoCoffee*, Mainz

## 7. Outreach

- 09/2017 Public research display, University of Bern  
*Nacht der Forschung* (NdF)

## 8. Research visits

- 06/2023 CERN, Genève
- 12/2022 Kavli IPMU, Tokyo; G. White
- 09/2022 Jožef Stefan Institute, Ljubljana; M. Nemevšek
- 06/2022 SUBATECH, Nantes; J. Ghiglieri
- 10/2021 University of Basel; S. Antusch
- 10/2021 University of Bern, AEC, Institute for Theoretical Physics; M. Laine
- 08/2019 University of Helsinki, Helsinki Institute of Physics; A. Vuorinen, K. Rummukainen
- 08/2018 Universidad del Bío-Bío, Grupo de Cosmología y Partículas Elementales; Y. Schröder

## 9. Professional services

03/2022– Referee

American Physical Society's journals: Phys. Rev. **D**, Phys. Rev. **L**

Springer's journals: JHEP, Eur. Phys. J. **C**

## 10. Scientific research skills

*Theoretical* (Dimensionally reduced) effective field theories, thermal field theory, quantum field theory, Lattice QCD, simulations in physics, computer algebra techniques, general relativity, cosmology, string theory, conformal field theory, group theory

*Computational* C/C++, Python, Matlab, FORM, ROOT, FORTRAN 77, Unix, Linux, Mathematica, LaTeX, computer hardware, HTML, Office, CAD-Software

## 11. Prizes, awards, fellowships

2024 – 2028 SNSF Ambizione Fellowship, Swiss National Science Foundation (SNSF)  
CHF 810k research grant

2011 – 2014 Scholarship of excellence Graz University of Technology  
EUR 2.4k scholarship

## 12. Languages

*German* Mother-tongue

*English* Proficient C2, TOEFL 106/120 (2014), Cambridge ESOL B2 First FCE (2010)

*Spanish* Intermediate B1

*Danish* Elementary A2

*French* Beginner A1

*Latin* Very good (literal translation)

### 13. Major scientific achievements

#### Precision thermodynamics for cosmological phase transitions.

Invigorated by the first gravitational wave (GW) detections from binary mergers, I dedicated a large part of my first postdoc pushing the accuracy of the thermodynamics of cosmological phase transitions. In my first post-doctoral project, I assessed the theoretical uncertainties for cosmological phase transitions in [12]. The motivation for such a theoretical leap in precision was that leading-order (LO) calculations of thermodynamics are insufficient and render the GW spectrum ambiguous. An innocuous uncertainty at early stages has far-reaching effects in the beyond the Standard Model (BSM) – GW pipeline and put successful stochastic gravitational wave background (SGWB) observations at LISA at risk before they even begin.

The work in [12] established the current state-of-the-art precision for GW predictions. This level of precision was achieved by using methods of dimensionally reduced EFT to derive the Standard Model EFT (SMEFT) three-dimensional effective potential and its minimisation.

#### Development of automated 3d EFT framework for thermal field theories.

To improve the overall understanding of such EFT computations, we put forward a didactic review on the robust approach to thermal resummation as a combination between perturbative and non-perturbative techniques [11]. By inspecting the (dynamical) real singlet extension to the Standard Model, I computed novel contributions to the parameters of the dimensionally reduced EFT at next-to-leading order (NLO) which will be applicable for future non-perturbative lattice studies of the model. While, we demonstrated that two-loop contributions in the matching and effective potential are substantial [26, 13] for robust predictions of the thermodynamic phase transition parameters, we also devised a minimal setup [17] that combines gauge invariance and resummation and supersedes a previous scheme.

In this context, I automated the evaluation and reduction of analytically challenging sum-integrals at non-zero temperature. The automation via the corresponding **Mathematica** package **DRalgo** [21], is now successfully applied not only in QCD but also in the **most accurate predictions of gravitational waves** from cosmological first-order phase transitions in generic BSM theories.

#### Gauge-invariant framework for nucleation at finite temperature.

Theoretical uncertainties when determining the finite-temperature nucleation rate of bubbles of the new stable vacuum are still substantial. Especially in the context of radiatively induced transitions, I resolved a long-standing problem related to the unphysical gauge-dependence of the bubble nucleation rate. By employing effective theories at the nucleation scale for the Abelian Higgs model, I demonstrated for the first time [18, 15] gauge invariance of the leading order (LO) perturbative contributions in radiatively induced transitions.



## Research output list

If not specifically indicated otherwise, the following research list is in alphabetical order. In all subsequent research output, I contributed at the level of first or second author, conducted the computations, (co-)led the writing, and developed the main ideas of the project.

## Journal articles

- [27] A. Ekstedt, **P. Schicho**, and T. V. I. Tenkanen, *Cosmological phase transitions at three loops: the final verdict on perturbation theory*, (2024), [2405.18349].
- [26] M. Lewicki, M. Merchand, L. Sagunski, **P. Schicho**, and D. Schmitt, *Impact of theoretical uncertainties on model parameter reconstruction from GW signals sourced by cosmological phase transitions*, (2024), [2403.03769].
- [25] J. Ghiglieri, **P. Schicho**, N. Schlusser, and E. Weitz, *The force-force correlator at the hard thermal scale of hot QCD*, JHEP **03**, 111 (2024), [2312.11731].
- [24] C. Lwowski, K. Kaiser, J. Bucur, **P. Schicho**, and T. Kohnen, *Accuracy of using the axial length of the fellow eye for IOL calculation in retinal detachment eyes undergoing silicone oil removal*, Br. J. Ophthalmology (2023) 10.1136/bjo-2023-323581.
- [23] J. Österman, **P. Schicho**, and A. Vuorinen, *Integrating by parts at finite density*, JHEP **08**, 212 (2023), [2304.05427].
- [22] L. Sagunski, **P. Schicho**, and D. Schmitt, *Supercool exit: Gravitational waves from QCD-triggered conformal symmetry breaking*, Phys. Rev. D **107**, 123512 (2023), [2303.02450].
- [21] A. Ekstedt, **P. Schicho**, and T. V. I. Tenkanen, *DRalgo: A package for effective field theory approach for thermal phase transitions*, Comput. Phys. Commun. **288**, 108725 (2023), [2205.08815].
- [20] T. Gorda, A. Kurkela, J. Österman, R. Paatelainen, S. Säppi, **P. Schicho**, K. Seppänen, and A. Vuorinen, *Degenerate fermionic matter at N<sup>3</sup>LO: Quantum electrodynamics*, Phys. Rev. D **107**, L031501 (2023), [2204.11893].
- [19] T. Gorda, A. Kurkela, J. Österman, R. Paatelainen, S. Säppi, **P. Schicho**, K. Seppänen, and A. Vuorinen, *Soft photon propagation in a hot and dense medium to next-to-leading order*, Phys. Rev. D **107**, 036012 (2023), [2204.11279].
- [18] J. Löfgren, M. J. Ramsey-Musolf, **P. Schicho**, and T. V. I. Tenkanen, *Nucleation at Finite Temperature: A Gauge-Invariant Perturbative Framework*, Phys. Rev. Lett. **130**, 251801 (2023), [2112.05472].
- [17] **P. Schicho**, T. V. I. Tenkanen, and G. White, *Combining thermal resummation and gauge invariance for electroweak phase transition*, JHEP **11**, 047 (2022), [2203.04284].
- [16] S. Biondini, **P. Schicho**, and T. V. I. Tenkanen, *Strong electroweak phase transition in t-channel simplified dark matter models*, JCAP **10**, 044 (2022), [2207.12207].

- [15] J. Hirvonen, J. Löfgren, M. J. Ramsey-Musolf, **P. Schicho**, and T. V. I. Tenkanen, *Computing the gauge-invariant bubble nucleation rate in finite temperature effective field theory*, JHEP **07**, 135 (2022), [2112.08912].
- [14] J. Ghiglieri, G. D. Moore, **P. Schicho**, and N. Schlusser, *The force-force-correlator in hot QCD perturbatively and from the lattice*, JHEP **02**, 58 (2022), [2112.01407].
- [13] L. Niemi, **P. Schicho**, and T. V. I. Tenkanen, *Singlet-assisted electroweak phase transition at two loops*, Phys. Rev. D **103**, 115035 (2021), [2103.07467].
- [12] D. Croon, O. Gould, **P. Schicho**, T. V. I. Tenkanen, and G. White, *Theoretical uncertainties for cosmological first-order phase transitions*, JHEP **04**, 055 (2021), [2009.10080].
- [11] **P. M. Schicho**, T. V. I. Tenkanen, and J. Österman, *Robust approach to thermal resummation: Standard Model meets a singlet*, JHEP **06**, 130 (2021), [2102.11145].
- [10] M. Laine, **P. Schicho**, and Y. Schröder, *A QCD Debye mass in a broad temperature range*, Phys. Rev. D **101**, 023532 (2020), [1911.09123].
- [9] M. Laine, **P. Schicho**, and Y. Schröder, *Soft thermal contributions to 3-loop gauge coupling*, JHEP **2018**, 37 (2018), [1803.08689].

## Conference proceedings

- [8] J. Ghiglieri, G. D. Moore, **P. Schicho**, N. Schlusser, and E. Weitz. *Hard parton dispersion in the quark-gluon plasma, non-perturbatively*. In *11th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions* (July 2023). [2307.09297].
- [7] G. Aarts, J. Aichelin, C. Allton, A. Athenodorou, D. Bachtis, C. Bonanno, N. Brambilla, E. Bratkovskaya, M. Bruno, M. Caselle, C. Conti, R. Contino, L. Cosmai, F. Cuteri, L. Del Debbio, M. D’Elia, P. Dimopoulos, F. Di Renzo, T. Galatyuk, J. N. Guenther, R. Houtz, F. Karsch, A. Y. Kotov, M. P. Lombardo, B. Lucini, L. Maio, M. Panero, J. M. Pawłowski, A. Pelissetto, O. Philipsen, A. Rago, C. Ratti, S. M. Ryan, F. Sannino, C. Sasaki, **P. Schicho**, C. Schmidt, S. Sharma, O. Soloveva, M. Sorba, and U.-J. Wiese. *Phase Transitions in Particle Physics – Results and Perspectives from Lattice Quantum Chromo-Dynamics*. In (Jan. 2023). [2301.04382].
- [6] M. Fraser, D. Björkman, K. Cornelis, B. Goddard, V. Kain, **P. Schicho**, C. Theis, and H. Vincke. *Modelling the Radioactivity Induced by Slow-Extraction Losses in the CERN SPS*. In *Proc. of International Particle Accelerator Conference (IPAC’17)* (May 2017), 1897–1900.



- [5] M. A. Fraser, R. G. Alia, B. Balhan, H. Bartosik, C. Bertone, D. Björkman, J. Borburgh, N. Conan, K. Cornelis, L. Gatignon, B. Goddard, Y. Kadi, V. Kain, A. Mereghetti, F. Roncarolo, **P. M. Schicho**, J. Spanggaard, O. Stein, L. Stoel, F. M. Velotti, and H. Vincke. *SPS Slow Extraction Losses and Activation: Challenges and Possibilities for Improvement*. In *Proc. of International Particle Accelerator Conference (IPAC'17)* (Copenhagen. 2017), 611–614.

## Theses

- [4] **P. M. Schicho**, *Multi-loop investigations of strong interactions at high temperatures*, PhD thesis (U. Bern, 2020).
- [3] **P. M. Schicho**, *Inhomogeneous condensation in quark-based QCD effective models via wavelet pseudoparticles*, MA thesis (ETH Zürich, 2016).
- [2] **P. Schicho**,  *$\pi$ - and  $\rho$ -Meson mass spectroscopy from Lattice QCD*, BA thesis (TU Graz, 2014).
- [1] **P. Schicho**, *Increasing the sensitivity of a search for supersymmetry in the single lepton channel with the Transverse Mass*, Project thesis (HEPHY Vienna, 2014).

## Invited talks at workshops

- 19/03/2024 *Strong cosmological phase transitions through the EFT lens*, invited **planary** talk at *Quarkonia meet Dark Matter* at Institute for Advanced Study, Technical University of Munich, Germany
- 05/12/2022 *EFT framework for (precision) cosmological phase transition thermodynamics*, invited **planary** talk at *What the heck happens when the Universe boils?* at Kavli IPMU, Tokyo, Japan

## Contributed talks

- 14/09/2023 *Phase transition thermodynamic parameters at high precision*, contributed talk at 26th International Conference on Particle Physics and Cosmology (COSMO'23), Madrid, Spain
- 11/07/2023 *Degenerate fermionic matter at  $N^3LO$* , contributed talk at ELEMENTS Annual Conference, Bad Nauheim, Germany
- 03/07/2023 *Can EFT reveal if there was an electroweak phase transition?*, contributed talk at Cosmology from Home
- 22/06/2023 PRECLISA. *Gravitational waves from cosmological phase transitions: Precision cosmology in the light of LISA*, interview talk for the Ambizione grant of the Swiss National Science Foundation, Bern, Switzerland

- 17/05/2023 *Phase transition thermodynamic parameters at high precision*, contributed talk at How fast does the bubble grow?, DESY, Hamburg, Germany
- 05/05/2023 *Strong electroweak phase transition and simplified dark matter models*, contributed talk at Progress on Old and New Themes in cosmology (PONT) 2023, Avignon, France
- 20/06/2022 *Jet dispersion in hot QCD from the lattice*, contributed talk at SEWM 2022, Paris, France
- 06/04/2022 *(Non-)perturbative jet dispersion hot QCD*, contributed talk at Quark Matter 2022, Kraków, Poland
- 30/03/2022 *(Non-)perturbative jet dispersion hot QCD*, contributed talk at Mini workshop: Phase transitions in particle physics, Galileo Galilei Institute, Firenze, Italy
- 29/03/2021 *Soft thermal contributions to 3-loop gauge coupling*, contributed parallel talk at FunQCD (online), Barcelona, Spain
- 28/06/2018 *Fun with thermal dimension-six operators*, contributed parallel talk at SEWM 2018, Barcelona, Spain

### Seminar talks

- 10/06/2024 *Completing the perturbative program for cosmological phase transitions*, invited seminar talk at Bielefeld University, Germany
- 23/11/2023 *Impact of computational diligence on GW signals from phase transitions*, invited seminar talk at Warsaw University, Poland
- 12/10/2023 *Impact of computational diligence on GW signals from phase transitions*, invited seminar talk at University of Basel, Basel, Switzerland
- 19/09/2023 *Impact of computational diligence on GW signals from phase transitions*, invited seminar talk at Helsinki Institute of Physics, Helsinki, Finland
- 15/06/2023 *Electroweak phase diagram at finite lepton number density*, contributed talk at Thermal Field Theory meets Phenomenology, Uppsala, Sweden
- 30/05/2023 *High-temperature effective field theories: Precision phase transition thermodynamics*, seminar talk at HEP seminar, Université de Genève, Switzerland
- 10/05/2023 *Integrating by parts at finite density*, informal talk at the DMGW meeting, Goethe University, Frankfurt, Germany
- 25/01/2023 *Degenerate fermionic matter at  $N^3LO$* , invited seminar talk at Gravitation and Cosmology seminar, Utrecht University, Netherlands
- 24/01/2023 *What can EFT tell us about the electroweak phase transition?*, seminar talk at CRC-TR211 meeting and Colloquium, Bielefeld University, Germany
- 08/11/2022 *EFT framework for cosmological phase transition thermodynamics*, seminar talk at the AstroCoffee, Goethe University, Frankfurt, Germany

- 13/10/2022 *Degenerate fermionic matter at  $N^3LO$* , invited seminar talk (online) at S@INT seminar, INT, Seattle, USA
- 15/09/2022 *(Gauge independent) Bubble nucleation rate at finite temperature*, invited seminar talk at Jožef Stefan Institute, Ljubljana, Slovenia
- 24/08/2022 *Can EFT tell us if there was an electroweak phase transition?*, invited seminar talk at University of Graz, Graz, Austria
- 11/07/2022 *Soft light-cone observables from electrostatic QCD*, invited seminar talk (online) at the QCD theory seminar
- 07/07/2022 *Degenerate fermionic matter at  $N^3LO$* , invited seminar talk at the Nuclear Physics Colloquium, Goethe University, Frankfurt, Germany
- 16/06/2022 *Can EFT tell us if there was an electroweak phase transition?*, invited seminar talk at SUBATECH, Nantes, France
- 31/05/2022 *Electroweak phase transition: Combining thermal resummation and gauge invariance*, invited seminar talk at NICPB, Tallinn University, Estonia
- 24/05/2022 *Combining thermal resummation and gauge invariance for electroweak phase transition*, invited seminar talk (online) at School of Physics and Astronomy, Monash University, Australia
- 03/03/2022 *Effective theory approach to cosmological phase transitions*, invited seminar talk at Instituto de Astrofísica de Canarias, La Laguna, Spain
- 28/10/2021 *Gauge independent bubble nucleation rate at finite temperature*, invited seminar talk at University of Basel, Basel, Switzerland
- 19/10/2021 *Cosmological phase transition: Robust thermal resummation*, invited seminar talk at University of Bern, Bern, Switzerland
- 13/05/2021 *Cosmological phase transition: Robust thermal resummation*, invited seminar talk (online) at KIAS, Seoul, South Korea
- 25/11/2020 *How to be precise at the electroweak scale at finite-temperature*, invited seminar talk (online) at Kavli IPMU, Tokyo, Japan
- 13/08/2019 *3-Loop Gauge Coupling in Hot Yang-Mills*, invited seminar talk at Helsinki Institute of Physics, Helsinki, Finland
- 28/08/2018 *Fun with thermal dimension-six operators*, invited seminar talk at Universidad del Bío-Bío, Chillán, Chile