

Theoretical Seminar:

# Statistical Physics

Wintersemester 2021/22



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# Dates and structure

- Time: Mondays 9.15 - 11.00, Start: Mo 18. Oct 2021  
Venue: gHS, 1st floor, Philosophenweg 12, 69120 Heidelberg
- Prerequisites: Lectures on Quantum Mechanics, and Statistical Physics (**MKTP1**; can be attended in the same semester). Seminar language is English.
- Distribution of topics: In the 1<sup>st</sup> seminar on Oct 18 the talks will be distributed. The first 3 talks have already been distributed in advance.
- Tutors: N.N. / Prepare online test talk  $\geq$  1 week before the seminar with a colleague, or tutor.
- max. 60 min talk (beamer plus blackboard; max 40 slides) + about 15- 30 min discussion.
- pdf of slides to be submitted to GW ~1 week after the talk; appears on seminar page.
- LaTeX/ pdf extended summary for each talk  $\approx$  10-20pp, with references to the original papers (and also advanced textbooks). To be submitted ~1 week after the talk to GW; will be published on seminar page.
- 6 ECTS-Credit points for oral presentation, pdf of slides, written pdf summary, participation in discussions. Should ambitious BSc students want to participate already, 3 CPs due to reduced requirements (10pp summary etc.).
- Participation is mandatory, please send email to GW if not attending.
- **2G since Nov. 2021 . Please wear a medical mask in the building, and check in at your seat in the lecture hall (read-in QR code, fill out name, address, etc.). Immunization status will be checked at the entrance of the building.**

# List of topics

- 1) 18.10.21 Phase transitions and critical phenomena: Alexander Stoll  
slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_1.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_1.pdf)  
summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_1s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_1s.pdf)  
(please copy into your browser)
- 2) 25.10. Topological phase transitions (BKT): Eric Jacob  
slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_2.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_2.pdf)  
summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_2s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_2s.pdf)

(1.11. holiday)

- 3) 08.11. One- and two-dimensional Ising model: Anton Kabelac  
slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_3.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_3.pdf)  
summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_3s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_3s.pdf)
- 4) 15.11. Boltzmann equation and H-Theorem: Julian Mayr  
slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_4.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_4.pdf)  
summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_4s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_4s.pdf)

- 5) 22.11. Master equation, Markovian and non-Markovian processes: **Janhavi Golatkar**  
slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_5.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_5.pdf)  
summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_5s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_5s.pdf)
- 6) 29.11. Langevin- and Fokker-Planck equation: **Daniel Walter**  
slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_6.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_6.pdf)  
summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_6s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_6s.pdf)
- 7) 06.12. Thermalization of gluons in relativistic collisions: **Leena Tharwat**  
slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_7.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_7.pdf)  
summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_7s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_7s.pdf)
- 8) 13.12. Evaporative cooling and thermalization of Bose gases: **Niklas Reinhardt**  
slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_8.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_8.pdf)  
summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_8s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_8s.pdf)
- 9) [20.12. Bose-Einstein Condensate of bosonic atoms/  
Gross-Pitaevskii eq. and hydrodynamic expansion: (**cancelled, 2G**)]

10) 10.01.22 BEC of fermionic atoms, BCS-BEC transition: **Sarah Görlitz**

slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_10.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_10.pdf)

summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_10s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_10s.pdf)

11) 17.01.22 Pattern formation and self-organization in nature: **Frederik Kortkamp**

slides: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_11.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_11.pdf)

summary: [www.thphys.uni-heidelberg.de/~wolschin/statsem21\\_11s.pdf](http://www.thphys.uni-heidelberg.de/~wolschin/statsem21_11s.pdf)

(24.01.22 no seminar)

12) 07.02.22 Physical basis for the direction of time:

slides:

summary:

# General literature

## Textbooks

Kerson Huang, Statistical Mechanics, 2<sup>nd</sup> edition Wiley (2008).

Leo P. Kadanoff, Statistical Physics: Statics, Dynamics and Renormalization,  
World Scientific, Singapore (2000).

Lev Pitaevskii and Sandro Stringari, Bose-Einstein Condensation and Superfluidity,  
International series of monographs on physics, Oxford University Press (2016).

Subir Sachdev, Quantum Phase Transitions, 2<sup>nd</sup> edition, Cambridge Univ. Press (2011).

John Cardy, Scaling and Renormalization in Statistical Physics, Cambridge Univ. Press (1996).

Nick Proukakis et al.: Quantum gases - finite temperature and non-equilibrium dynamics,  
Vol. I, World Scientific, Singapore (2013).

Hannes Risken, The Fokker-Planck equation, methods of solution and applications, 3<sup>rd</sup> edition Springer (1996).

Nico G. Van Kampen, Stochastic Processes in Physics and Chemistry, 3<sup>rd</sup> edition, Elsevier (2007).

Steward Harris, An introduction to the theory of the Boltzmann equation, Dover (2004).

## **Topic-oriented literature: Original articles (selection); specific books**

### **1) Phase transitions and critical phenomena**

H.E. Stanley, Introduction to Phase Transitions and Critical Phenomena, Oxford University Press (1971).  
M.E. Fisher, The renormalization group in the theory of critical behavior, Rev. Mod. Phys. 46, 597 (1974).  
P. Papon et al., The physics of phase transitions – concepts and applications, Springer, Berlin (2006).

### **2) BKT**

J.M. Kosterlitz and D.J. Thouless, Ordering, metastability and phase transitions in two-dimensional systems, J. Phys. C: Solid State Phys. 6, 1181 (1973).

Z. Hadzibabic et al., Berezinskii-Kosterlitz-Thouless Crossover in a Trapped Atomic Gas. In: Nature 441, 1118 (2006).

J.M. Kosterlitz, Kosterlitz-Thouless physics: a review of key issues. In: Rep. Prog. Phys. 79, 026001 (2016).

### **3) Ising model**

E. Ising, Beitrag zur Theorie des Ferromagnetismus, Z. Physik 31, 253 (1925).

R. Peierls, Ising's model of ferromagnetism, Proc. Cambridge Phil. Soc., Band 32, 477 (1936).

T.D. Schultz, E. Lieb, D.C. Mattis, Two dimensional Ising model as a soluble model of many fermions, Rev. Mod. Phys. 36, 856 (1964).

S.G. Brush, History of the Lenz-Ising model, Rev. Mod. Phys. 39, 883 (1967).

### **4) Boltzmann equation and H-Theorem**

L. Boltzmann, Weitere Studien über das Wärmegleichgewicht unter Gasmolekülen, Sitzber. Akademie der Wiss. 66, 275 (1872).

English translation: L. Boltzmann, *Further Studies on the Thermal Equilibrium of Gas Molecules. The Kinetic Theory of Gases. History of Modern Physical Sciences.* 1, 262 (203), doi [10.1142/9781848161337\\_0015](https://doi.org/10.1142/9781848161337_0015). See book by E. Harris for a modern derivation.

G.B. Lesovik, A.V. Lebedev, I.A. Sadovskyy, M.V. Suslov, and V.M. Vinokur, [H-theorem in quantum physics](#), Sci. Reports. 6, 32815 (2016), doi:[10.1038/srep32815](https://doi.org/10.1038/srep32815).

## **5) Master equation, Markov processes**

W. Pauli, Über das H-Theorem vom Anwachsen der Entropie vom Standpunkt der neuen Quantenmechanik, In: Probleme der modernen Physik, Arnold Sommerfeld zum 60. Geburtstag, Hirzel, Leipzig (1928).

N. G. van Kampen (1981). [Stochastic processes in physics and chemistry](#). North Holland. [ISBN 978-0-444-52965-7](#).

C.W. Gardiner (1985). Handbook of Stochastic Methods. Springer. [ISBN 978-3-540-20882-2](#).

J. Honerkamp (1998). Statistical physics : an advanced approach with applications ; with 7 tables and 57 problems with solutions. Berlin [u.a.]: Springer. p. 173. [ISBN 978-3-540-63978-7](#)

## **6) Langevin eq., Fokker Planck eq.**

A. Einstein, Zur Theorie der Brownschen Bewegung, Ann. Physik 19, 371 (1906).

M. von Smoluchowski, Zur kinetischen Theorie der Brownschen Molekularbewegung und der Suspensionen, Ann. Physik 326, 756 (1906).

P. Langevin, Sur la théorie du mouvement brownien, C. R. Acad. Sci. (Paris) 146, 530 (1908).

A.D. Fokker, Die mittlere Energie rotierender elektrischer Dipole im Strahlungsfeld, Ann. Physik 43, 812 (1914).

M. Planck, Über einen Satz der statistischen Dynamik und seine Erweiterung in der Quantentheorie, Sitzber. Preuss. Akad. Wiss., 324 (1917).

A.N. Kolmogorov, Über die analytischen Methoden in der Wahrscheinlichkeitsrechnung, Math. Ann. 104, 415 (1931).

## **7) Thermalization of gluons in relativistic collisions**

J.-P. Blaizot, F. Gelis , J. Liao, L. McLerran, and R. Venugopalan, Bose–Einstein Condensation and Thermalization of the Quark Gluon Plasma, Nucl. Phys. A 873, 68 (2012).

J.-P. Blaizot, J. Liao and Yacine Mehtar-Tani, The subtle interplay of elastic and inelastic collisions in the thermalization of the quark–gluon plasma, Nucl. Phys. 956, 561 (2016).

G. Wolschin, Equilibration in finite Bose systems, Physica A 499, 1 (2018);  
Local thermalization of gluons in a nonlinear model, Nonlinear Phenomena in Complex Systems (NPCS) 23, 72 (2020); Aspects of relativistic heavy-ion collisions, Universe 6, 61 (2020).

## **8) Evaporative cooling and thermalization of bosonic cold quantum gases**

- O. J. Luiten, M.W. Reynolds, and J.T.M. Walraven, Kinetic theory of the evaporative cooling of a trapped gas, Phys. Rev. A53, 381 (1996).
- K. B. Davis and M.-O. Mewes and W. Ketterle, An analytical model for evaporative cooling of atoms, Appl. Phys. B 60, 155 (1995).
- G. Wolschin, Time-dependent entropy of a cooling Bose gas, EPL 129, 40006 (2020).

## **9) BEC of bosonic atoms**

- S. Bose, Plancks Gesetz und Lichtquantenhypothese, Z. Physik 26, 178 (1924).
- A. Einstein, Quantentheorie des einatomigen idealen Gases, Sitzber. Preuss. Akad. Wiss., 22, 261 (1924).
- E. P. Gross, Structure of a Quantized Vortex in Boson Systems, Nuovo Cimento 20, 454 (1961).
- L. P. Pitaevskii, Vortex lines in an imperfect Bose gas, Sov. Phys. JETP 13, 451 (1961).
- M.H. Anderson, J.R. Ensher, M.R. Matthews, C.E. Wieman, and E.A. Cornell, Observation of Bose-Einstein condensation in a dilute atomic vapor, Science, 269, 198 (1995).
- K. B. Davis, M-O. Mewes, M. R. Andrews, N. J. van Druten, D. S. Durfee, D. M. Kurn, and W. Ketterle, Bose-Einstein condensation in a gas of sodium atoms, Phys. Rev. Lett. 75, 3969 (1995).
- A. Simon, G. Wolschin, Time-dependent condensate fraction in an analytical model, Physica A 573, 125930 (2021).

## **10) BEC of fermionic pairs, BCS-BEC transition**

- C.N. Yang, Concept of Off-Diagonal Long-Range Order and the Quantum Phases of Liquid He and of Superconductors, Rev. Mod. Phys. 34, 694 (1962).
- M.W. Zwierlein, C.H. Schunck, C.A. Stan, S.M.F. Raupach, and W. Ketterle, Formation dynamics of a fermion pair condensate, Phys. Rev. Lett. 94, 180401 (2005).
- L. Salasnich, Fermionic condensation in ultracold atoms, nuclear matter and neutron stars J. Phys. 497, 012026 (2014).

## **11) Pattern formation and self-organization in nature**

Prigogine, I.; Nicolis, G. Hazewinkel, M.; Jurkovich, R.; Paelinck, J. H. P. (eds.), Self-Organisation in Nonequilibrium Systems: Towards A Dynamics of Complexity, *Bifurcation Analysis: Principles, Applications and Synthesis*, Springer Netherlands, pp. 3–12, [doi:10.1007/978-94-009-6239-2\\_1](https://doi.org/10.1007/978-94-009-6239-2_1), ISBN 9789400962392 (1985).

D. Walgraef, Spatio-temporal pattern formation, Springer, Heidelberg-Berlin-New York (1996).

S. Kondo, T. Miura, Reaction-Diffusion Model as a Framework for Understanding Biological Pattern Formation, Science 329, Issue 5999, pp. 1616-1620 DOI: 10.1126/science.1179047 (2010).

## **12) Physical basis for the direction of time**

H. D. Zeh, The Physical Basis of The Direction of Time, Springer Heidelberg Berlin (2007).

S. Carroll, and J. Chen, Spontaneous Inflation and the Origin of the Arrow of Time. arXiv: 0410270 [hep-th] (2014).

D. Lazarovici and P. Reichert, Arrow(s) of Time without a Past Hypothesis, <http://philsci-archive.pitt.edu/17468/> (2020).

More detailed literature via tutor (if available), or GW.