Theoretical Seminar:

Statistical Physics

Summer semester 2020

Georg Wolschin
Universität Heidelberg
Institut für Theoretische Physik
http://wolschin.uni-hd.de

Dates and structure

- **Time: Fridays 9.15 - 11.00, Start: Fr 24. April 2020**
  Online seminar via skype for the participants. Spokesperson and lecturer in SR 3rd floor, Philosophenweg 12, provided UHD permits it (else online only). Format may change during the semester.

- **Prerequisites: Lectures on Quantum Mechanics, and**
  Statistical Physics (MKTP1). Seminar language is English.

- **Distribution of topics: All topics have been distributed, please prepare the talks now.**

- **Tutors: N.N. / Prepare online test talk ≥ 1 week before the seminar with a colleague, or tutor.**

- **max. 60 min talk (beamer, max 40 slides) + about 15-30 min discussion (skype-seminar).**
  Should we switch to analog talks during the semester, include *blackboard session.*

- **pdf of slides to be submitted to GW > 1 day before the talk; appears on seminar page.**

- **LaTeX/ pdf extended summary for each talk ≈ 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.**

- **Participation is mandatory, please send email to GW if not attending.**

List of topics

(copy the links into your browser!)

1) 24.04. Thermalization of fermions and bosons

slides: www.thphys.uni-heidelberg.de/~wolschin/gw20.pptx

2) 08.05. Topological phase transitions (BKT): Melda Akyazi

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_2.pdf

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_2p.pptx

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_2s.pdf

(15.05. No seminar)

3) 22.05. One- and two-dimensional Ising model: Johannes Obermeyer

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_3.pdf

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_3p.pptx

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_3s.pdf

4) 29.05. Boltzmann equation and H-Theorem: Pavel Popov

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_4.pdf

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_4s.pdf

5) 05.06. Phase transitions and critical phenomena: Jonah Cedric Strauß

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_5.pdf

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_5s.pdf

(12.06. No seminar)

6) 19.06. Master equation, Markovian and non-Markovian processes: Talha Ersoy

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_6.pdf

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_6s.pdf

7) 26.06. Langevin- and Fokker-Planck equation: Parham Radpay

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_7.pdf

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_7s.pdf

8) 03.07. Thermalization of gluons in relativistic collisions: Mathieu Kaltschmidt

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_8.pdf

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_8s.pdf

9) 10.07. Evaporative cooling and thermalization of Bose gases: Tara Butler

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_9.pdf

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_9s.pdf

10) 17.07. Bose-Einstein Condensate of bosonic atoms:
Gross-Pitaevskii eq. and hydrodynamic expansion: Albert Bekov

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_10.pdf

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_10s.pdf

11) 24.07. BEC of fermionic atoms, BCS-BEC transition: Jörg Holsten

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem20_11.pdf

summary: www.thphys.uni-heidelberg.de/~wolschin/statsem20_11s.pdf

Literature (for more details contact tutor or lecturer)

Textbooks

Kerson Huang, Statistical Mechanics, 2nd 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, 2nd 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, 3rd edition Springer (1996).

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

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

Literature: Original articles (selection); specific books

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. 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.

5) 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).

6) 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

7) 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).

8) 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).

9) 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).

10) 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).

11) 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).

More detailed literature via tutor, or GW.