MITP SUMMER SCHOOL
Non-perturbative Phenomena and the Early Universe
July 22 — August 9, 2019
Erbacher Hof, Mainz, FRG

Lecture course

Holography, Finite-Temperature QFT and Hydrodynamics

Dr Andrei Starinets

References

Updated: July 2019

- **Books on Gauge-String Duality (Holography)**

  1. J. Casalderrey-Solana, H. Liu, D. Mateos, K. Rajagopal and U. A. Wiedemann, "Gauge/String Duality, Hot QCD and Heavy Ion Collisions," Cambridge U. Press, 2014 (an earlier online version is available from arXiv:1101.0618 [hep-th]).

  2. M. Ammon and J. Erdmenger, "Gauge/Gravity Duality: Foundations and Applications", Cambridge U. Press, 2015.

  3. J. Zaanen, Y. Liu, Y.-W. Sun, K. Schalm, "Holographic Duality in Condensed Matter Physics", Cambridge U. Press, 2015.

  4. H. Nastase, "Introduction to the AdS/CFT Correspondence", Cambridge U. Press, 2015.

  5. H. Nastase, "String Theory Methods for Condensed Matter Physics", Cambridge U. Press, 2017.

  6. S. A. Hartnoll, A. Lucas and S. Sachdev, "Holographic quantum matter," Cambridge U. Press, 2018 (an earlier online version is available from arXiv:1612.07324 [hep-th]).

  7. E. Kiritsis, "String theory in a nutshell," Princeton U. Press, Updated edition, 2019 (Chapters 13-15).

- **Reviews and lectures directly relevant for this course**

  D. T. Son and A. O. Starinets, "Viscosity, Black Holes, and Quantum Field Theory," Ann. Rev. Nucl. Part. Sci. **57**, 95 (2007) [arXiv:0704.0240 [hep-th]].

  P. K. Kovtun, "Lectures on hydrodynamic fluctuations in relativistic theories", 1205.5040 [hep-th].

  O. Aharony, S. S. Gubser, J. M. Maldacena, H. Ooguri and Y. Oz, "Large N field theories, string theory and gravity," Phys. Rept. **323**, 183 (2000) [arXiv:hep-th/9905111].

  A. O. Starinets, "Transport coefficients of strongly coupled gauge theories: Insights from string theory," Eur. Phys. J. A **29**, 77 (2006) [arXiv:nucl-th/0511073].

- **Reviews of Gauge-String Duality and Applications**

  J. Polchinski, "Introduction to Gauge/Gravity Duality," arXiv:1010.6134 [hep-th].

  G. T. Horowitz and J. Polchinski, "Gauge/gravity duality," In *Oriti, D. (ed.): Approaches to quantum gravity* 169-186 [gr-qc/0602037].

J. McGreevy, "Holographic duality with a view toward many-body physics," Adv. High Energy Phys. **2010**, 723105 (2010) [arXiv:0909.0518 [hep-th]].

I. R. Klebanov, "TASI lectures: Introduction to the AdS/CFT correspondence," arXiv:hep-th/0009139.

I. R. Klebanov, "From threebranes to large N gauge theories," arXiv:hep-th/9901018.

E. D'Hoker and D. Z. Freedman, "Supersymmetric gauge theories and the AdS / CFT correspondence," hep-th/0201253.

M. K. Benna and I. R. Klebanov, "Gauge-String Dualities and Some Applications," arXiv:0803.1315 [hep-th].

- **Duality in Lattice Statistical Mechanics**

R. Savit, "Duality in Field Theory and Statistical Systems," Rev. Mod. Phys. **52**, 453 (1980).

H. .P. McKean, Jr, "Kramers-Wannier Duality for the 2-Dimensional Ising Model as an Instance of Poisson's Summation Formula", J. Math.Phys., **5**, n.6, 775 (1964).

Yu. M. Zinov'ev, "Duality in Abelian gauge theories on a lattice", Theoretical and Mathematical Physics, Volume 43, Issue 3, pp 481-490 (1980).

K. Drühl and H. Wagner, "Algebraic Formulation of Duality Transformations for Abelian Lattice Models", Annals of Physics **141**, 225-253 (1982) .

S. Caracciolo and A. Sportiello, "General duality for Abelian group valued statistical mechanics models," J. Phys. A **37**, 7407 (2004), [cond-mat/0308515].

A.A.Kirillov, "Elements of the Theory of Representations", Springer Berlin Heidelberg (1976).

Y. Katznelson, "An Introduction to Harmonic Analysis", Cambridge U. Press, 2004.

R. J. Baxter, "Exactly Solved Models in Statistical Mechanics", Academic Press, London New York, 1982

A. Karch, D. Tong and C. Turner, "A Web of 2d Dualities: $\mathbf{Z}_2$ Gauge Fields and Arf Invariants", 1902.05550 [hep-th].

- **Duality in QFT**

J. A. Harvey, "Magnetic monopoles, duality and supersymmetry," In *Trieste 1995, High energy physics and cosmology* 66-125 [hep-th/9603086].

R. Rajaraman, "Solitons And Instantons. An Introduction To Solitons And Instantons In Quantum Field Theory," Amsterdam, Netherlands: North-Holland (1982) 409p.

Y. Frishman and J. Sonnenschein, "Non-Perturbative Field Theory: From Two Dimensional Conformal Field Theory To QCD In Four Dimensions", Cambridge U. Press, 2010.

- **QFT at Finite Temperature and Density**

M. Le Bellac, "Thermal Field Theory", Cambridge U. Press, 2000.

J. Kapusta and C. Gale, "Finite Temperature Field Theory: Principles and Applications", Cambdridge U.Press, 2006.

M. Laine and A. Vuorinen, "Basics of Thermal Field Theory (A Tutorial on Perturbative Computations)", Springer Verlag, 2016.

- **Uncategorised**

H. S. Dumas, "The KAM Story: A Friendly Introduction To The Content, History, And Significance Of Classical Kolmogorov-Arnold-Moser Theory ", World Scientific, 2014.

H. M. Nussenzveig, "Causality and dispersion relation", Academic Press, 1972.

- **Hydrodynamics**

  L. D. Landau and E. M. Lifshits, "Fluid Mechanics", Pergamon Press, 1987.

  P. K. Kovtun, "Lectures on hydrodynamic fluctuations in relativistic theories", 1205.5040 [hep-th].

- **Large N expansion**

  A. M. Polyakov, "Gauge Fields And Strings," Contemp. Concepts Phys. **3**, 1 (1987).

  Y. .Makeenko, "Methods of contemporary gauge theory," Cambridge, UK: Univ. Pr. (2002) 417 p

- **Black hole thermodynamics, Bekenstein-Hawking entropy and microstates counting**

  A. Sen, "Black Hole Entropy Function, Attractors and Precision Counting of Microstates," Gen. Rel. Grav. **40**, 2249 (2008) [arXiv:0708.1270 [hep-th]].

  S. Carlip, "Black Hole Thermodynamics and Statistical Mechanics," Lect. Notes Phys. **769**, 89 (2009) [arXiv:0807.4520 [gr-qc]].

  P. Fre, (ed.), V. Gorini, (ed.), U. Moschella, (ed.) and G. Magli, (ed.), "Classical and quantum black holes," Bristol, UK: IOP (1999) 348 p

- **Black branes**

  K. S. Stelle, "Lectures on supergravity p-branes," In *Trieste 1996, High energy physics and cosmology* 287-339 [hep-th/9701088].

- **The original AdS/CFT papers**

  J. M. Maldacena, "The large N limit of superconformal field theories and supergravity," Adv. Theor. Math. Phys. **2**, 231 (1998) [Int. J. Theor. Phys. **38**, 1113 (1999)] [arXiv:hep-th/9711200].

  S. S. Gubser, I. R. Klebanov and A. M. Polyakov, "Gauge theory correlators from non-critical string theory," Phys. Lett. B **428**, 105 (1998) [arXiv:hep-th/9802109].

  E. Witten, "Anti-de Sitter space and holography," Adv. Theor. Math. Phys. **2**, 253 (1998) [arXiv:hep-th/9802150].

- **Original papers relevant for the course**

  D. T. Son and A. O. Starinets, "Minkowski space correlators in AdS / CFT correspondence: Recipe and applications," JHEP **0209**, 042 (2002) [hep-th/0205051].

  P. K. Kovtun and A. O. Starinets, "Quasinormal modes and holography," Phys. Rev. D **72**, 086009 (2005) [hep-th/0506184].

- **Holography and phenomenology of heavy ion physics**

  P. Romatschke and U. Romatschke, "Relativistic Fluid Dynamics In and Out of Equilibrium – Ten Years of Progress in Theory and Numerical Simulations of Nuclear Collisions," arXiv:1712.05815 [nucl-th].

- **Books on string theory**

  M. B. Green, J. H. Schwarz and E. Witten, "Superstring Theory. Vols. 1: Introduction," Cambridge, Uk: Univ. Pr. (1987) 469 P.

M. B. Green, J. H. Schwarz and E. Witten, "Superstring Theory. Vol. 2: Loop Amplitudes, Anomalies And Phenomenology," Cambridge, Uk: Univ. Pr. (1987) 596 P.

E. Kiritsis, "String theory in a nutshell," Princeton University Press, 2007; Updated edition, 2019.

B. Zwiebach, "A first course in string theory," Cambridge U. Press, 2nd edition, 2009.

J. Polchinski, "String theory. Vol. 1: An introduction to the bosonic string," Cambridge, UK: Univ. Pr. (1998) 402 p

J. Polchinski, "String theory. Vol. 2: Superstring theory and beyond," Cambridge, UK: Univ. Pr. (1998) 531 p

- **Online lecture courses**

  J. McGreevy, MIT lectures, TASI lectures and other recordings online.

  S. Hartnoll, Nordita lectures and other recordings online.

  H. Liu, MIT lectures online.