School and conference on quantum disordered systems, Chennai, February/March 2016

Thomas Vojta
Phases and phase transitions in disordered quantum systems

Lecture notes of a previous version of these lectures can be found in:
Thomas Vojta, *Phases and phase transitions in disordered quantum systems*, arXiv:1301.7746

Prerequisistes:

I will expect the participants to have some basic knowledge of phase transitions at the level of a graduate class in statistical physics. This material will be (very briefly) reviewed in the first lecture, but those unfamiliar with topics such as first-order vs. continuous transitions, Landau theory, critical behavior, universality, and scaling should consult a text book, for example:

R.K. Pathria and P.D. Beale, Statistical Mechanics, Elsevier (2011), chapter 12
P.M. Chaikin and T.C. Lubensky, Principles of condensed matter physics, Cambridge (1995), chapter 4
J. Cardy, Scaling and Renormalization in Statistical Physics, Cambridge (1996), chapters 1 and 2
N. Goldenfeld, Lectures on phase transitions and the renormalization group, Perseus (1992), chapters 2, 3, and 5

I will also assume some basic knowledge of quantum phase transitions, see, e.g.,

S. Sachdev, Quantum phase transitions, Cambridge (1999), chapters 1, 2, and 3
T. Vojta, Quantum phase transitions in electronic systems, Ann. Phys. (Leipzig) 9, 403 (2000), arXiv:cond-mat/9910514
M. Vojta, Quantum phase transitions, Rep. Prog. Phys. 66, 2069 (2003), arXiv:cond-mat/0309604

For a quick summary of this introductory material, see Sec. 1 of the lectures notes, arXiv:1301.7746.

Lectures:

1. Phase transitions in disordered systems
   a) types of disorder (random mass and random fields)
   b) Harris criterion and the stabilty of clean critical points
   c) Imra-Ma argument and destruction of phase transitions by random fields
   d) rounding of first-order phase transitions by disorder

2. Strong-disorder renormalization group
   a) basic idea of the strong-disorder renormalization group
   b) renormalizing the random transverse-field Ising chain
   c) exotic infinite-randomness critical point

3. Griffiths phases

a) rare regions and large fluctuations
b) classical Griffiths singularities
c) quantum Griffiths singularities

4. Smeared phase transitions
a) rare regions in metallic systems (dissipation, freezing transition)
b) smearing of quantum phase transitions in metals
c) smeared transitions in system with correlated disorder

Reading material for the individual lectures:

I list both reviews (marked by *) and some influential original papers):

Lecture 1:

[4]* J. Cardy, Scaling and Renormalization in Statistical Physics, Cambridge (1996), chapter 8
[5]* T. Vojta, Rare region effects at classical, quantum, and nonequilibrium phase transitions, J. Phys. A 39, R143 (2006), section 3.1
[6] Y. Imry and S.-k. Ma, Random-Field Instability of the Ordered State of Continuous Symmetry, Phys. Rev. Lett. 35, 1399 (1975)
[7] A.B. Harris, Effect of random defects on the critical behaviour of Ising models, J. Phys. C: Solid State Phys. 7 1671 (1974)

Lecture 2:

[8]* F. Igloi and C. Monthus, Strong disorder RG approach of random systems, Physics Reports 412, 277 (2005)
[9] S.-k. Ma, C. Dasgupta, and C.-k. Hu, Random Antiferromagnetic Chain, Phys. Rev. Lett. 43, 1434 (1979)
[10] D.S. Fisher, Critical behavior of random transverse-field Ising spin chains, Phys. Rev. B 51, 6411 (1995)

Lecture 3:

[11]* T. Vojta, Rare region effects at classical, quantum, and nonequilibrium phase transitions, J. Phys. A 39, R143 (2006)
[12] H. Rieger and A.P. Young, Griffiths singularities in the disordered phase of a quantum Ising spin glass, Phys. Rev. B 54, 3328 (1996)
[13] M. Guo, R.N. Bhatt, and D.A. Huse, Quantum Griffiths singularities in the transverse-field Ising spin glass, Phys. Rev. B 54, 3336 (1996)

Lecture 4:

[14]* T. Vojta, Quantum Griffiths effects and smeared phase transitions in metals: theory and experiment, J. Low Temp. Phys. 161, 299 (2010)
[15] T. Vojta, Disorder-induced rounding of certain quantum phase transitions, Phys. Rev. Lett. 90, 107202 (2003)
[16] J.A. Hoyos and T. Vojta, Theory of smeared quantum phase transitions, Phys. Rev. Lett. 100, 240601 (2008)