Lecture on "Quantum Phase Transitions"

SoSe 18
L. Janssen
(1)

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0 Coordinates

Mo 9:20 – 10:50 Lecture
Fr 13:00 – 14:20 Lecture / exercise (in turns)

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Literature: see website

Exam:
- no written exam
- oral exam as part of rigorosum / replacement exam (doctoral degree) or Master's exam Theoretical Physics (MSc degree) possible

- exam prerequisite for MSc exam: written problem solutions, > 1/3 of points & presented in exercise class
- assessment (PL) (ungraded) for Bachelor programme possible: written problem solutions, > $\frac{1}{3}$ of points & presented in exercise class

Dates (tentative!)

1	Mo	9.4.18 (KW15)	L	
	Fr	13.4.18	L	
	Mo	16.4.18	L	
	Fr	20.4.18	E	: Landau functional for 1st ord. trans. / Two order param.
5	Mo	23.4.18	L	
	Fr	27.4.18	L	
	Mo	30.4.18	L	
	Fr	4.5.18	E	: Tricrit. point AFM / Scaling Hypothesis
	Mo	7.5.18	L	
10	Fr	11.5.18	L	
	Mo	14.5.18	L	
	Fr	18.5.18	E	: Part. function for free fields / Part. function and cont. limit
	Mo	28.5.18	L	
	Fr.	1.6.18	L	
15	Mo	4.6.18	L	
	Fr	8.6.18	E	: Scaling dimensions of higher-order op. / Perturb. to Wilson-Fisher FP
	Mo	11.6.18	L	
	Fr	15.6.18	L	
	Mo	18.6.18	L	
20	Fr	22.6.18	E	: Classical Ising chain / Rel. between gap and corr. length
	Mo	25.6.18	L	
	Fr	29.6.18	L	
	Mo	2.7.18	L	
	Fr	6.7.18	E	: Quantum Ising chain
25	Mo	9.7.18	L	
	Fr	13.7.18	L	
	Mo	16.7.18	L	
28	Fr	20.7.18	E	: Shift exponent / SM-to-CDW transition in graphene

7 exercises
21 lectures

1 Introduction

Phase (a definition attempt): Equilibrium state of matter whose qualitative characteristics do not change upon small change of external parameters ("stable")

$\Rightarrow$ thermodynamic potential varies analytically

Phases are:

- characterized by symmetry of $\rho = \sum_j p_j |\psi_j\rangle\langle\psi_j|$ (density operator)
- separated by phase transitions

Phase transition: Point in parameter space at which equilibrium properties of a system change qualitatively ("unstable")

$\Rightarrow$ thermodynamic potential nonanalytic

Phase transitions can:

- be continuous or discontinuous
- occur at finite T ("thermal") or $T=0$ ("quantum")

Quantum phase transition (QPT): Phase transition at $T=0$, which occurs upon varying non-thermal control parameter (pressure, magnetic field, chemical composition, ...)

$\Rightarrow$ ground-state energy nonanalytic in control parameter

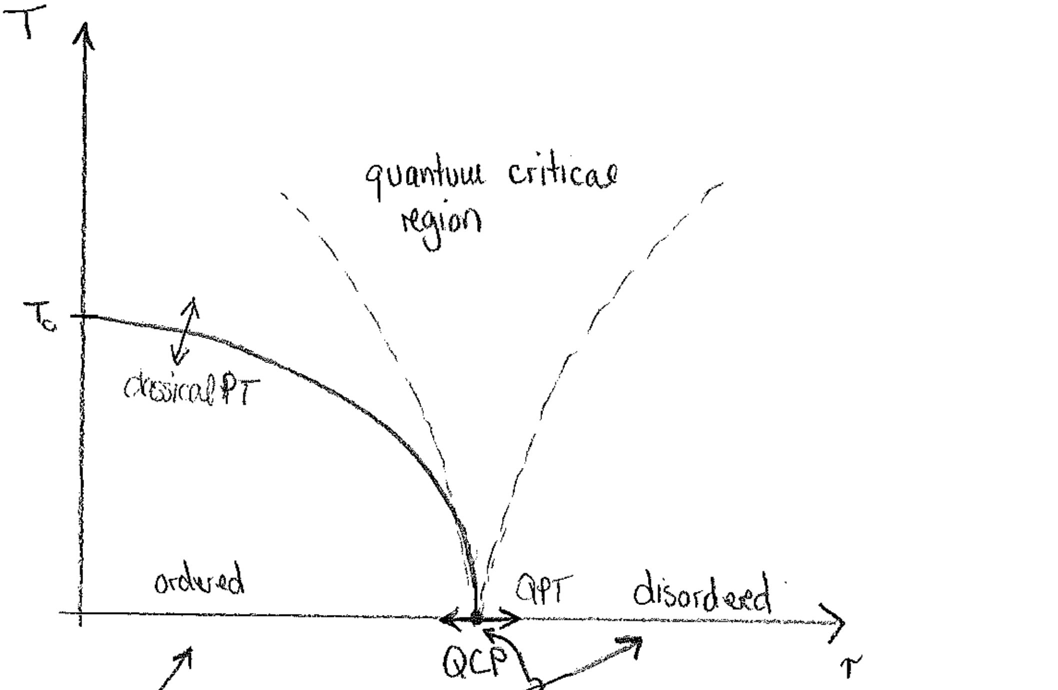
Remark: QPT apparently driven by "quantum fluctuations"

Disclaimer: $T=0 \Rightarrow$ quantum described by single phase-coherent (many-body) wavefunction

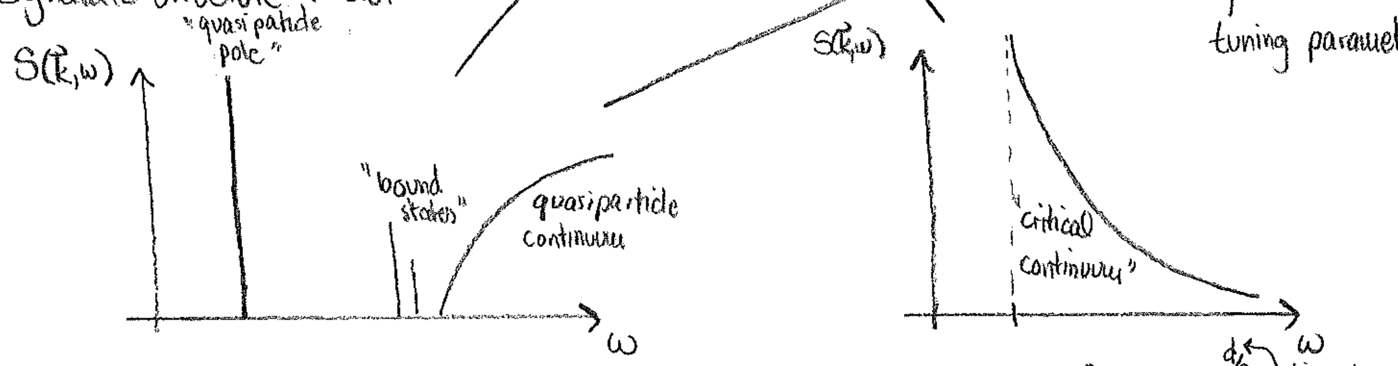
"fluctuations": deviations from a reference state (e.g., ordered magnet)

Experimental relevance:

Quantum phase diagram:



Dynamic structure factor:



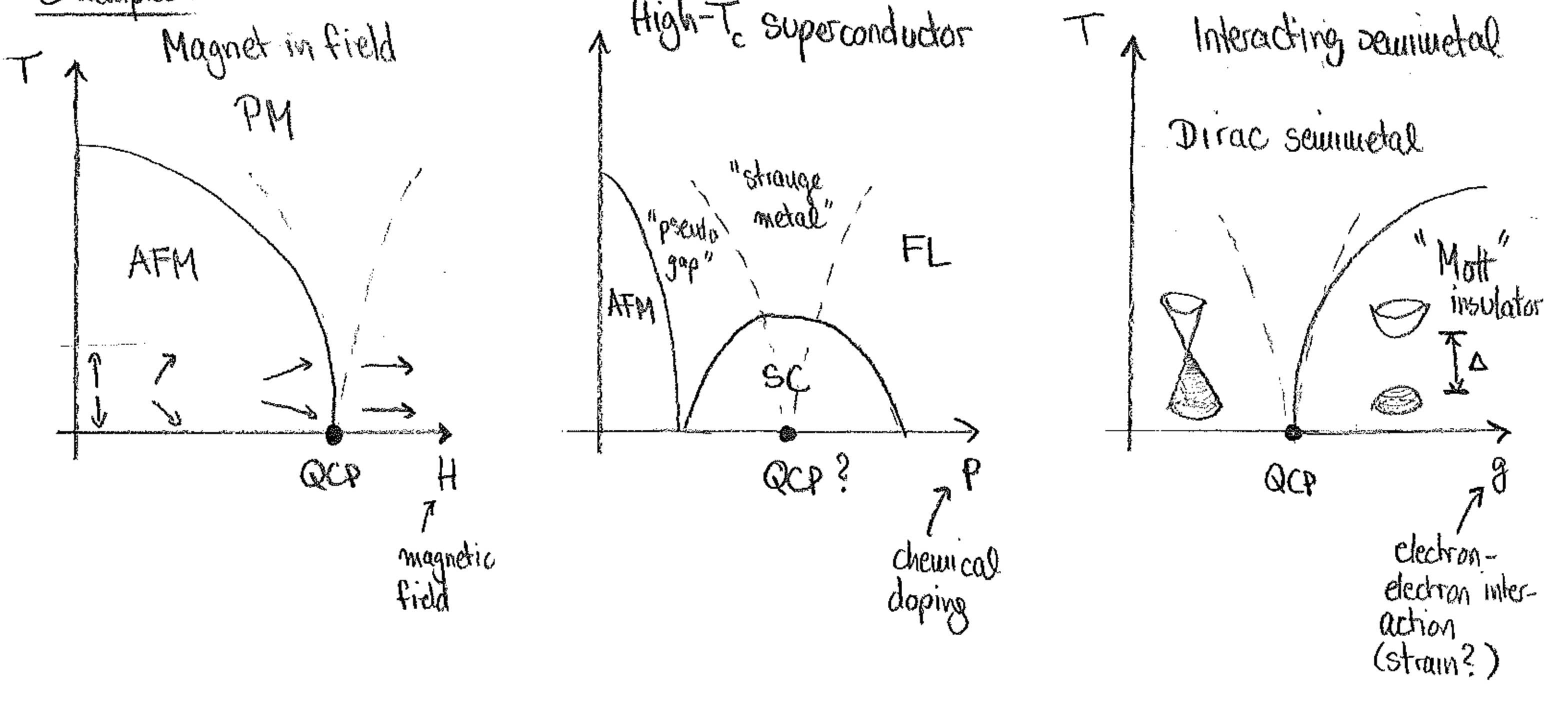
e.g., Fermi liquid: $C_V \sim T$

gapped magnet: $C_V \sim \frac{1}{T} e^{-\frac{\Delta}{k_B T}}$ ← gap

e.g., $C_V \sim T^{d/z}$ ← d: dimension; z: "dynamical critical exponent"

"novel state of matter"

Examples:



Other examples:

- disordered system ("Anderson transition")
- cold atoms on an optical lattice
- quark matter ("chiral symmetry breaking" in QCD)