Advanced Topics in Condensed Matter

Lecture 14: Mermin-Wagner Theorem

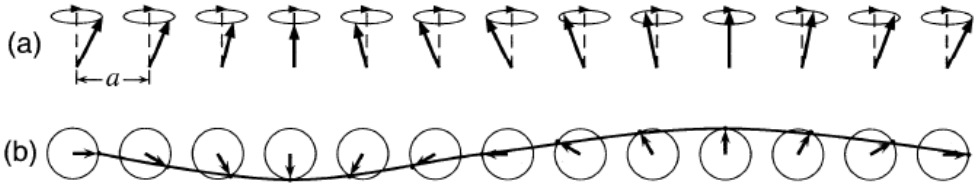
Dr. Ivan Zaluzhnyy

Prof. Dr. Frank Schreiber

Mermin and Wagner, Phys. Rev. Lett. 17 (1966) 1133
other relevant names Kosterlitz, Thouless, Halperin, Nelson, Young (KTHNY)
Hohenberg, Landau, …
see also Nobel prize 2016

EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

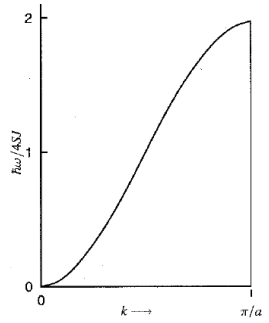
Strategy for theory of excitations



- determine ground state
- establish equations for excitations,

  e.g., equations of motion for atoms or magnetic moments
- dispersion, i.e. energy or frequency depending on wavevector $\omega(k)$
- density of states (DOS) depending on $\omega(k)$ and dimension D
- thermal statistics of excitations,

  e.g. Bose-Einstein statistics for phonons or magnons
- integral over excitations



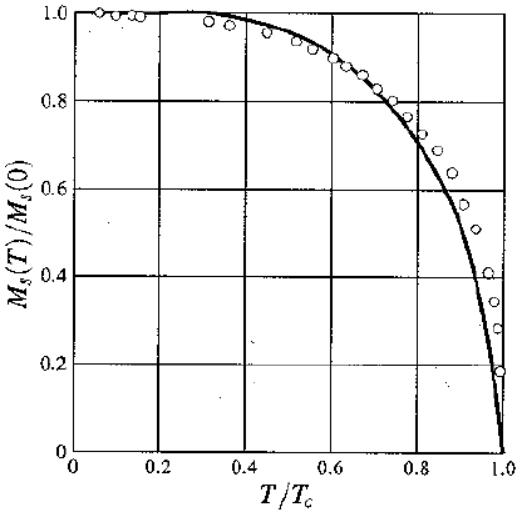
→ Observables ...

magnetization M(T)

internal energy U(T)

heat capacity c(T)

...



Magnetism in two dimensions and Mermin-Wagner theorem

by Frank Schreiber

Question: Does a lower dimension (e.g., 2D instead of 3D), i.e. "less neighbouring spins" change the ordering behaviour ?

Answer: Yes.

Fundamental statement

> "At any non-zero temperature, a one- or two-dimensional isotropic spin-S Heisenberg model with finite-range exchange interaction canc be neither ferromagnetic nor antiferromagnetic."
>
> see Mermin / Wagner, Phys. Rev. Lett. 17 (1966) 1133

See pdf under
https://www.soft-matter.uni-tuebingen.de/teaching/

What to remember

Mermin-Wagner theorem — Phys. Rev. Lett. 17 (1966) 1133

- no magnetic order for T > 0 in 2D
- for isotropic Heisenberg model with finite-range interaction

- the assumptions are important; if violated, strict statement no longer holds

- if assumptions are approximately correct, tendency to reduce T_c
  i.e. magnetic order in thin films can break down at lower T than bulk

- implications for other forms of order, including crystalline order
  e.g. graphene (not flat, i.e. not really 2D, without substrate)

- other relevant names Kosterlitz, Thouless, Halperin, Nelson, Young (KTHNY)
  Hohenberg, Landau, …
  see also Nobel prize 2016