Theory of

Frustrated Magnetism

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(9. Quantum criticality and frustration)

Literature

K. Yosida, Theory of Magnetism

A. Auerbach, Interacting Electrons and Quantum Magnetism

E. Fradkin, Field Theories of Condensed-Matter Systems

S. Sachdev, Quantum Phase Transitions

H.T. Diep (Ed), Frustrated Spin Systems

C. Lacroix et al, (Ed) Introduction to Frustrated Magnetism

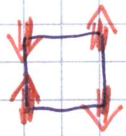
1. Introduction and motivation

Frustration describes a situation

- where not all constraints can be simultaneously satisfied
- where not all contributions to the (potential) energy of a physical system can be simultaneously minimized

Example: Ising spins with antiferromagnetic nearest-neighbor coupling

vs.



6 degenerate inequivalent lowest-energy states (frustrated)

2 degenerate symmetry-equivalent lowest-energy states (unfrustrated)

Frustration tends to suppress (conventional) magnetic order.

Experimentally:

$$f = \frac{|\Theta_{CW}|}{T_N} \quad \text{(„frustration ratio") \underline{large}}$$

$\Theta_{CW} \hat{=}$ Curie-Weiss temperature $\left(\chi = \frac{C}{T-\Theta_{CW}}\right)$

$|\Theta_{CW}|$ measures magnitude of exchange interaction between moments

$T_N \hat{=}$ Néel temperature (ordering temperature)

Unfrustrated systems have $T_N \simeq |\Theta_{CW}| \curvearrowright f \approx 1$.

Alternative view: Soft fluctuations destroy order.

Frustration leads to massively degenerate ground-state manifolds at classical level.

Perturbation (e.g. quantum effects) then produce nontrivial states.

(Compare Quantum Hall effect: Landau level highly degenerate; interactions produce fractional QHE)

Why is frustrated magnetism interesting?

- Frustrated magnets can host a plethora of novel (exotic, interesting) states, both ordered and disordered. Many of those states have exotic excitations. (eg. spinons, monopoles, anyons, ...)

- Frustrated magnets can display interesting forms of topology (topological order, emergent gauge fields, long-range entanglement)

  2016 Nobel prize for topological physics

- Theory has found/proposed many non-trivial phases. Materials have been found/synthesized to realize those. Prospects for applications exist. (topological quantum computing, information storage, ...)

- Fertile links exist to other fields of research:
  Mathematical physics (→ topology),
  Statistical mechanics,
  High-temperature superconductivity.

Global challenges of the field

Systematic understanding of interacting topological phases

Diagnosis of topological / exotic phases

Finding / designing materials

Tuning materials and phenomena (eg. Mott FET)

Designing application concepts