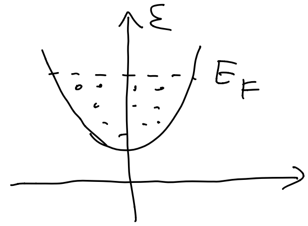
Introduction

The many-body problem

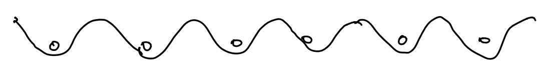


Electrons in material

↑ ↑ ↑ ↑ ↑

Spin systems

Cold Atoms in optical lattices



Tunable, dimensionality

"Synthetic quantum systems"

* N spins ½
* Locality of interactions

$$H = \sum_{\langle ij \rangle} \underline{\underline{J_{ij}^{\alpha\beta}}} \, \sigma_i^\alpha \sigma_j^\beta$$

↑ nearest-neighbors

$$J(r) \sim e^{-r/a} \;, \quad r \to \infty$$

* Variety of collective phenomena

  Superconductivity, magnetism, fractional quantum Hall

* <u>Goal</u>: ground state, excitations above it, quasiparticles

  Phase transitions when H parameters are changed

* Recently: highly non-equilibrium dynamics

* N spins-$\frac{1}{2}$ $\underline{\dim(N) = 2^N}$

* Classical computers not good for quantum many-body systems

* Quantum simulators: cold atoms, superconducting qubits...

* Field theory .. renormalization

* <u>These lectures</u>: entanglement of many-body states
  Locality of interactions important

* Connections to quantum information, math. physics, complexity theory, powerful algorithms (tensor networks)

Plan:

① Role of locality. Lieb-Robinson bounds → structure of many-body states

② Entanglement of many-body states

③ Dynamics & entanglement