

# Frustrated kinetics of spinless fermions

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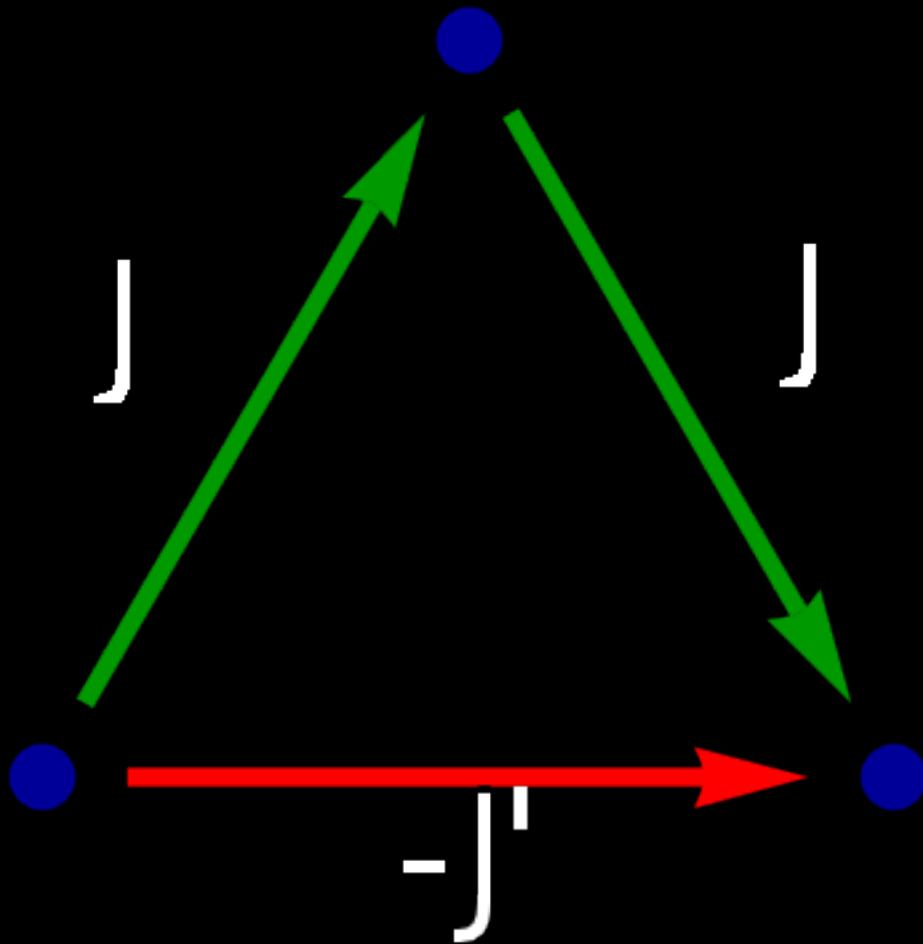
Institute for Theoretical Physics, Utrecht, the Netherlands

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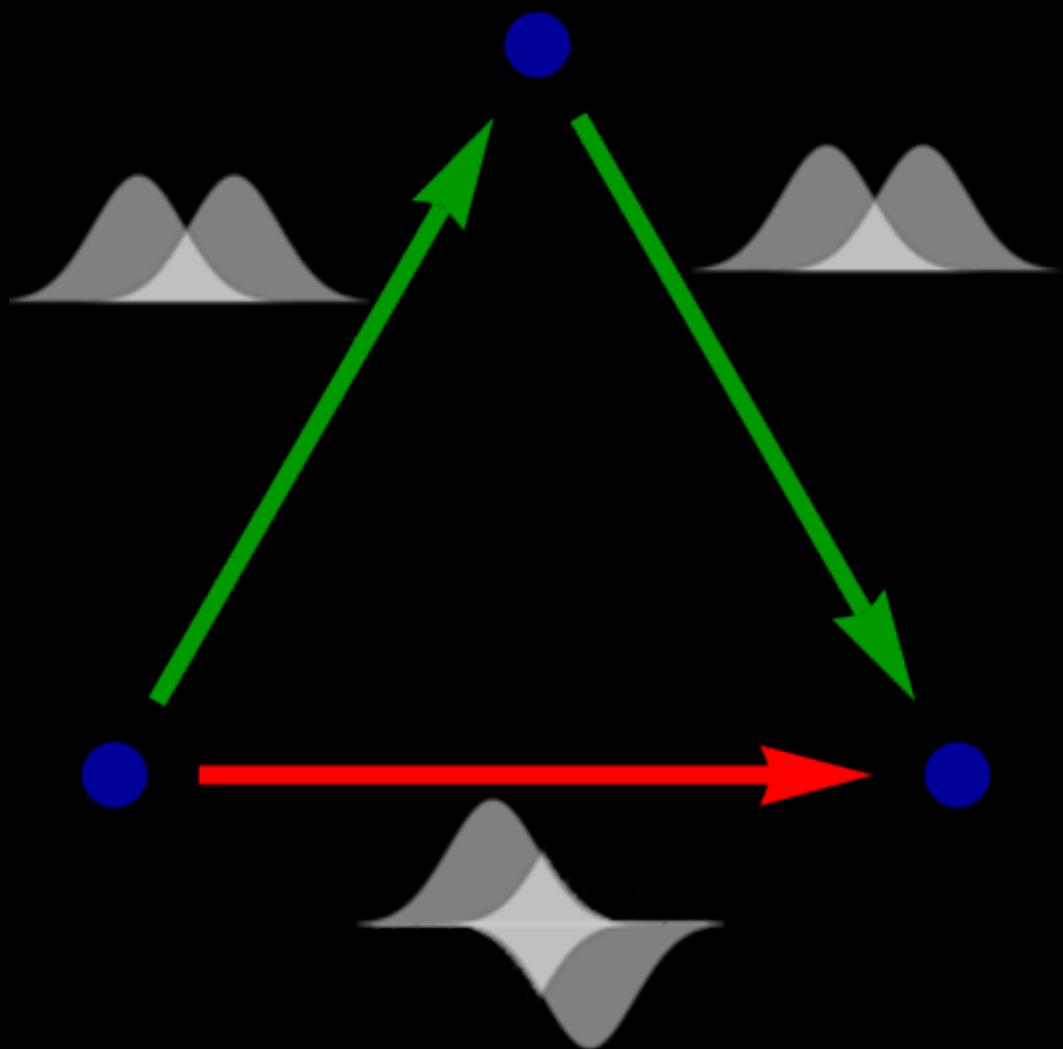
# Overview

- Frustrated kinetics
  - Here: triangular lattice
- Repulsively interacting spinless fermions
- Time-reversal symmetry breaking
- Experimental realisation?
- Summary

# Frustrated kinetics

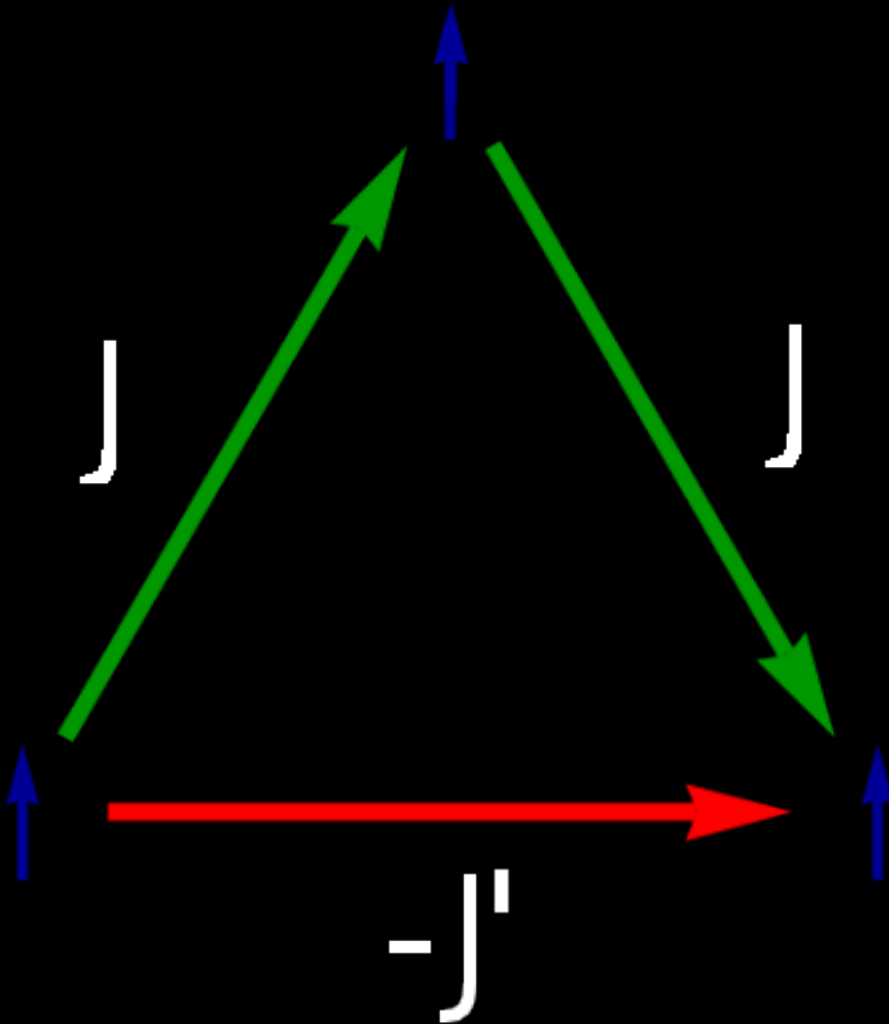


# Frustrated kinetics



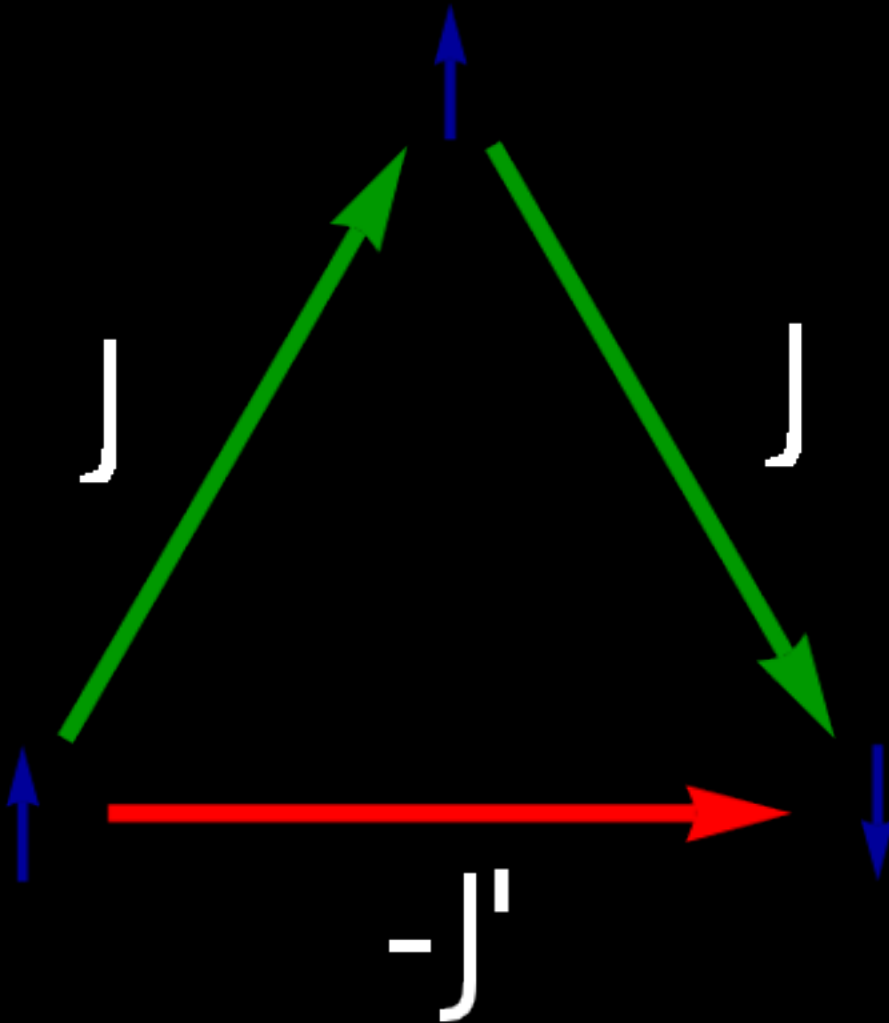
# Frustrated kinetics

- Wavefunction phase as (classical) spin: frustrated ferromagnet
- Depending on frustration: (A)FM, chiral states

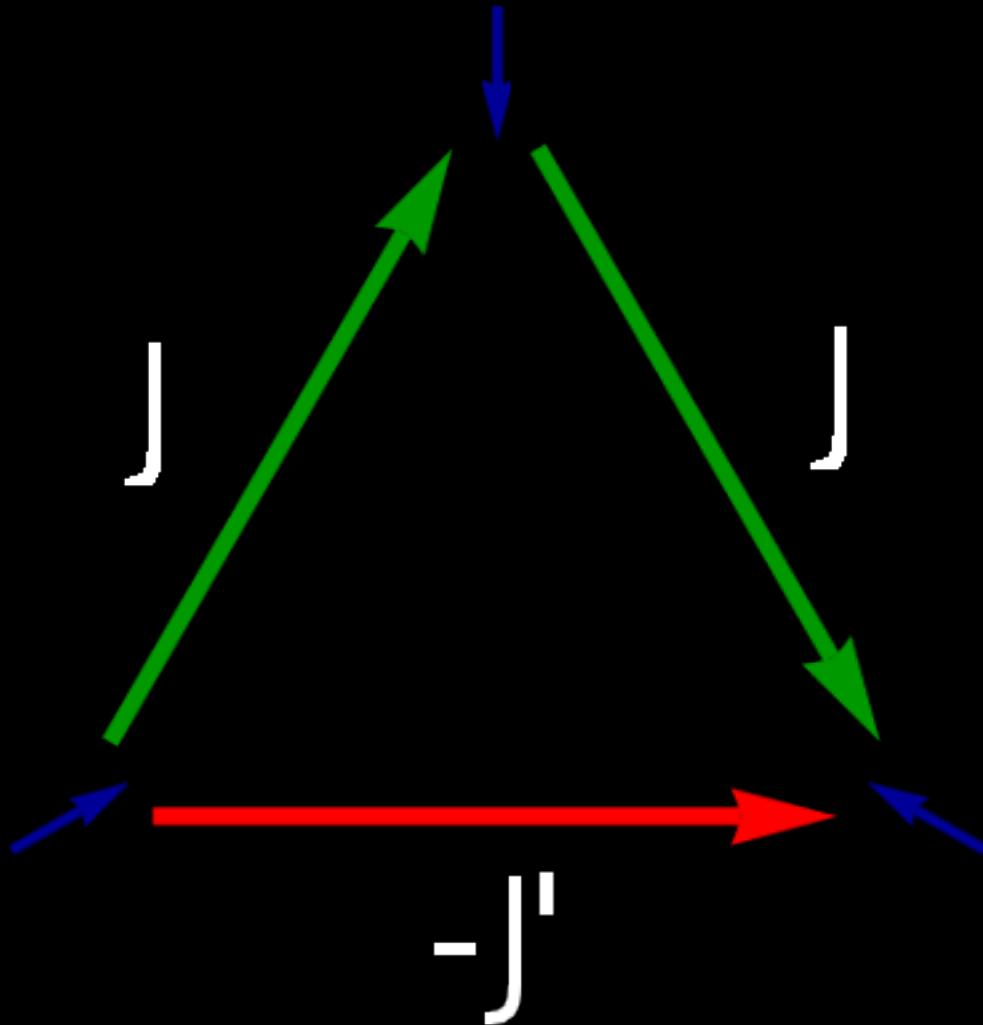


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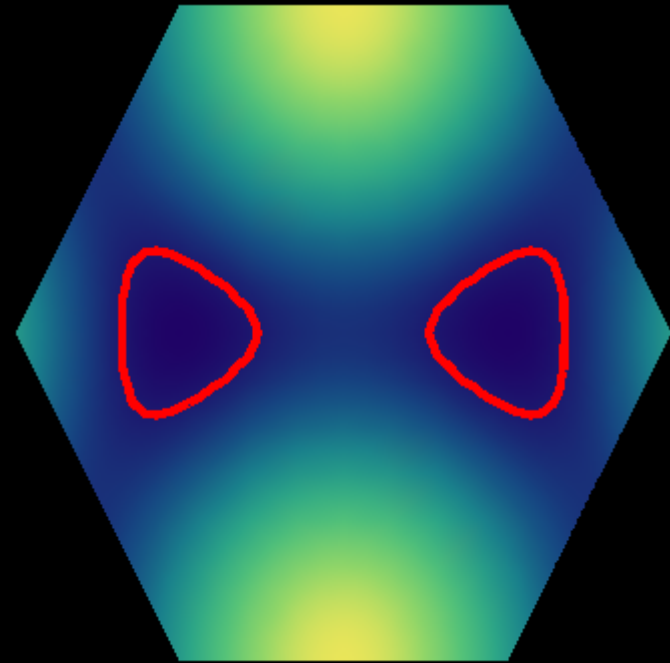
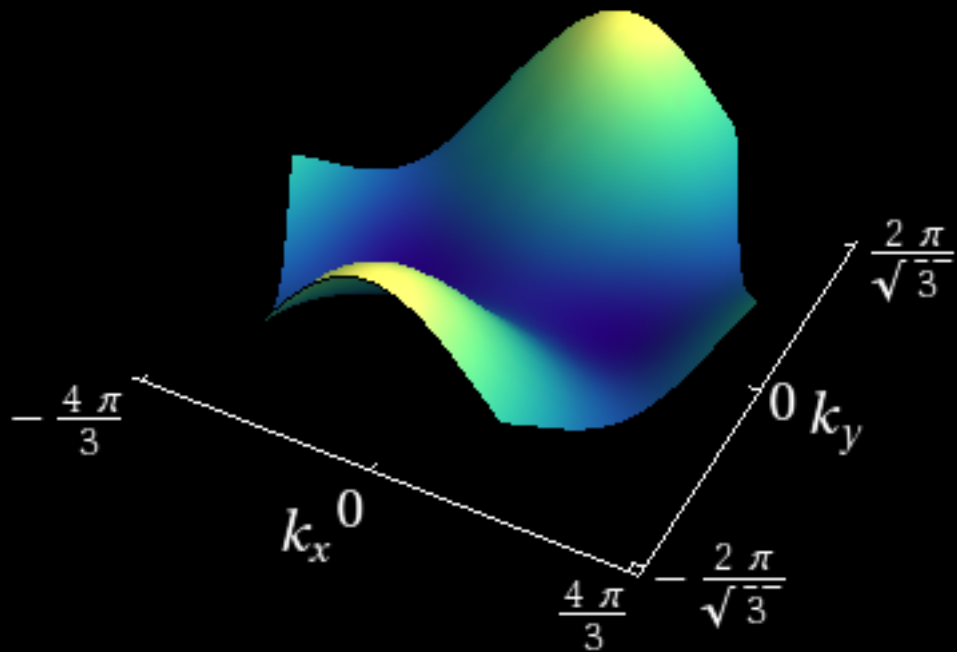


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# Frustrated kinetics



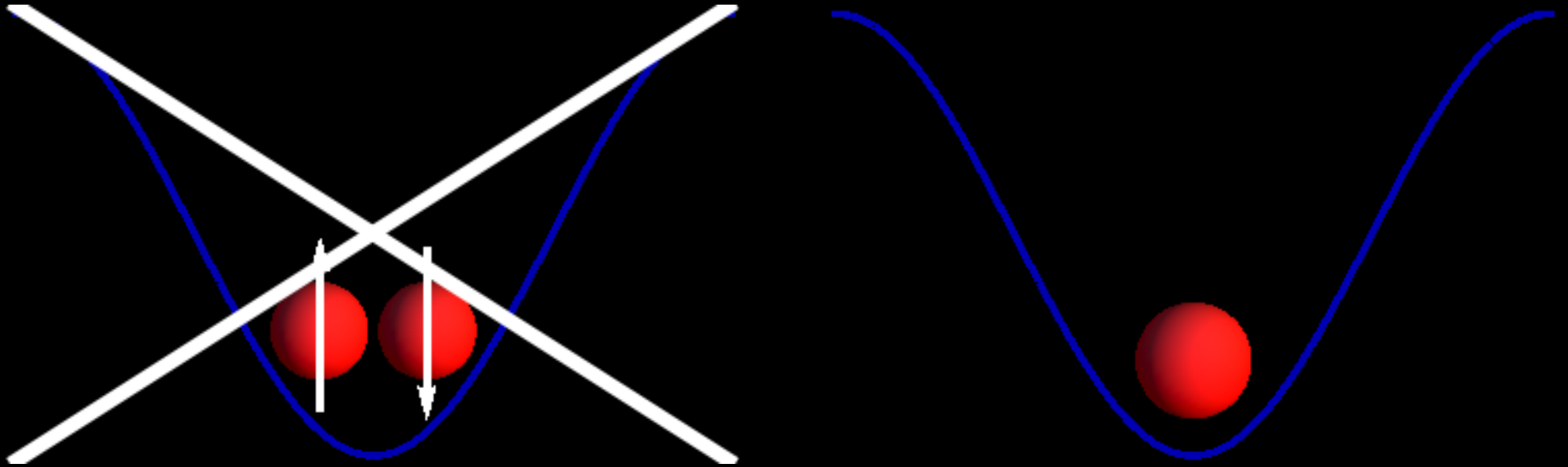
$$|J'| = |J|$$

$$\mu = 0.5 J$$

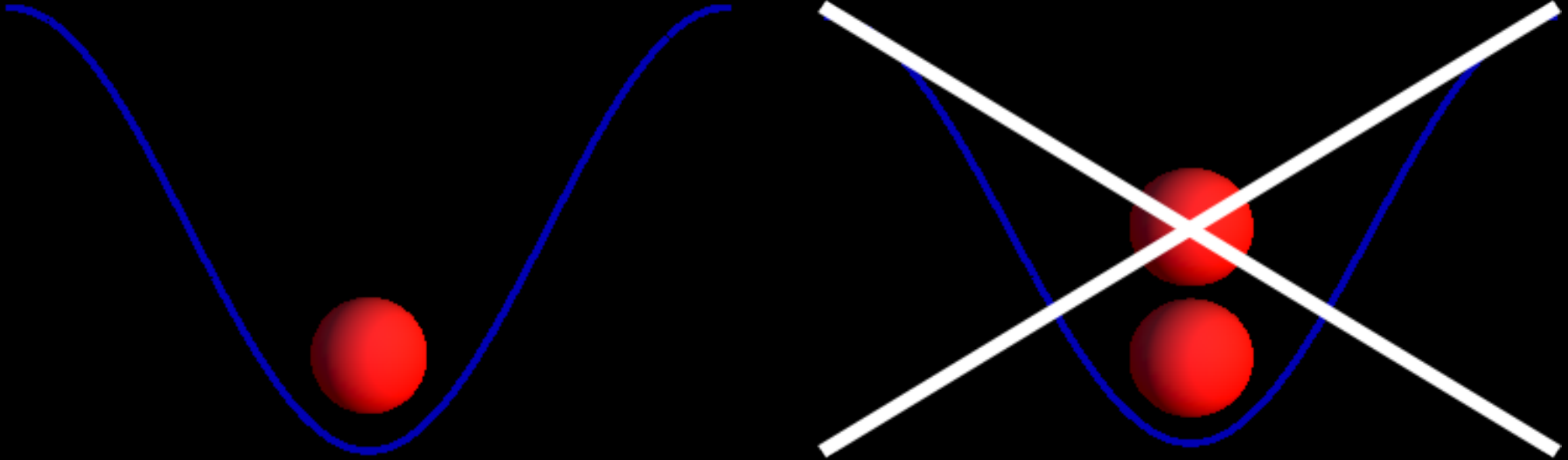


Now: interactions

# Spinless fermions

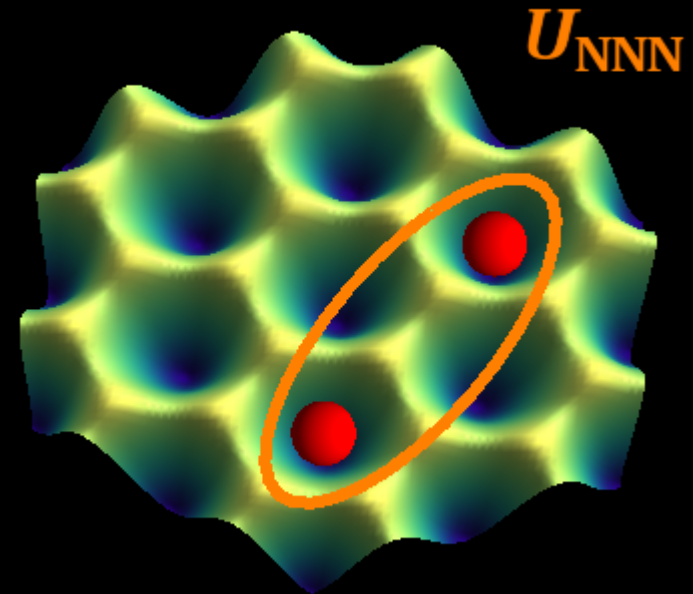
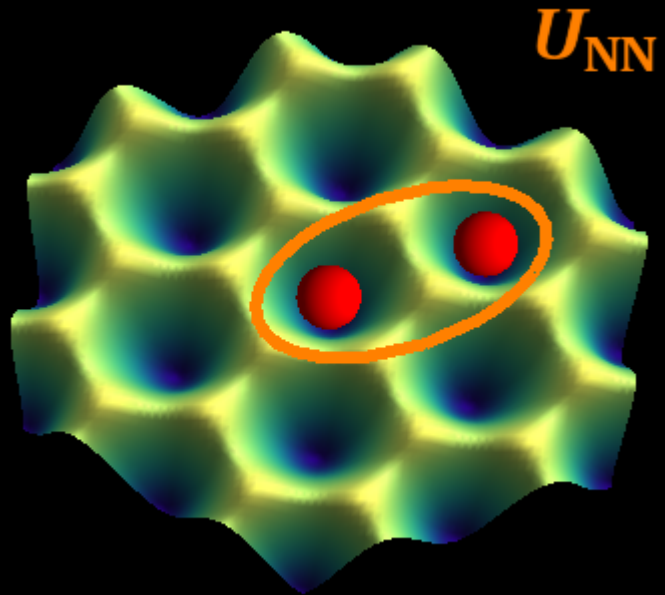


# Spinless fermions



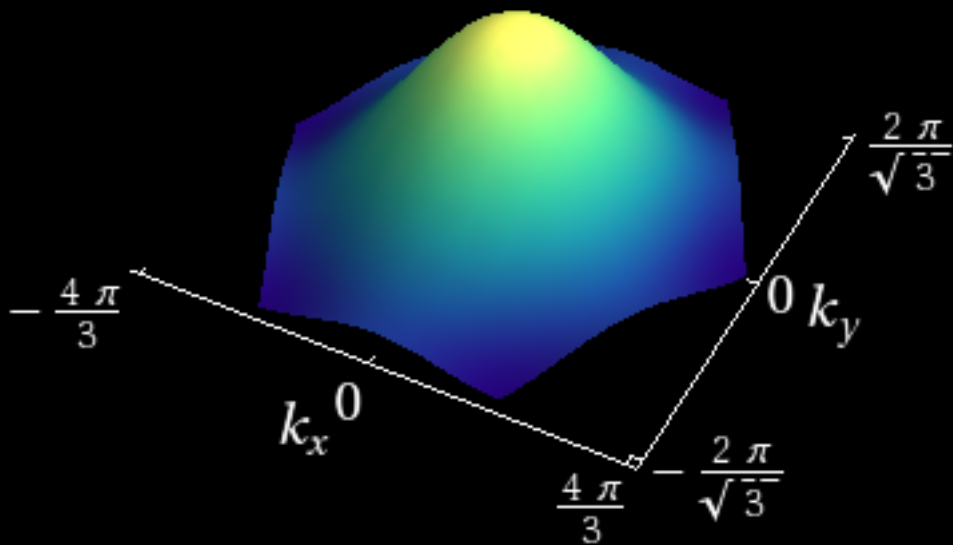
No on-site interactions

# Spinless fermions



Only “long-range” interactions

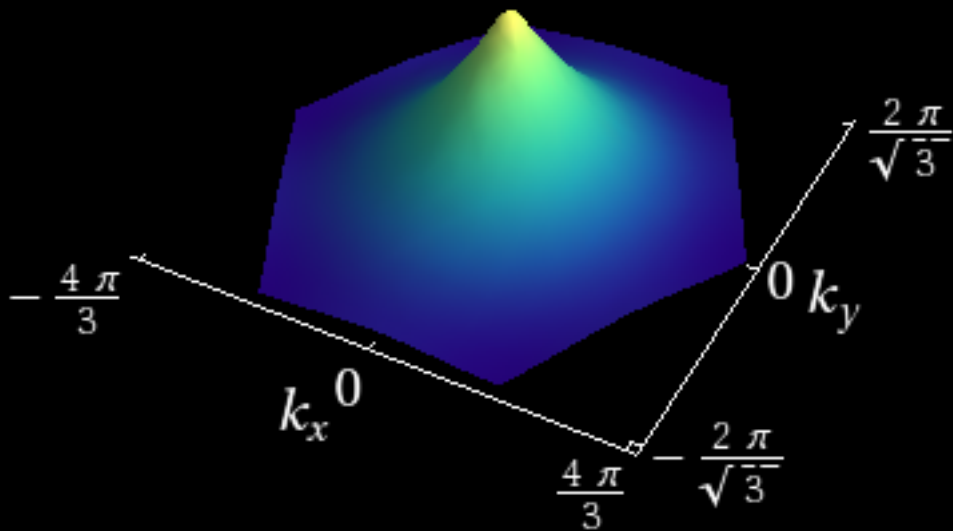
# Interactions: momentum-dependent



NN repulsion

- Non-local interactions depend on the relative momentum
- Examples: NN repulsion, dipolar, Yukawa

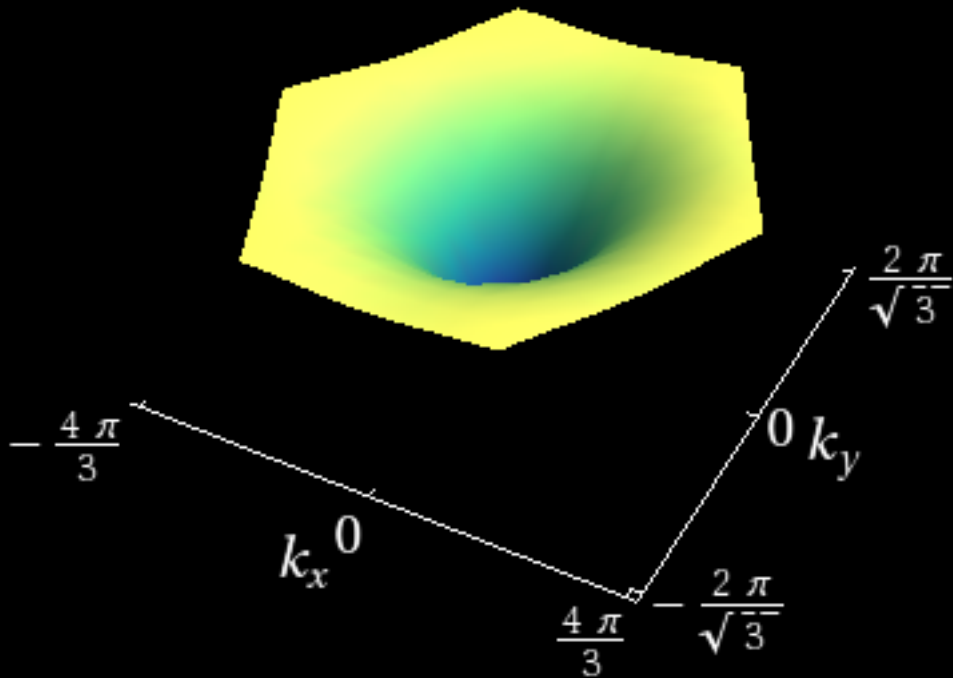
# Interactions: momentum-dependent



Dipolar repulsion

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# Interactions: momentum-dependent



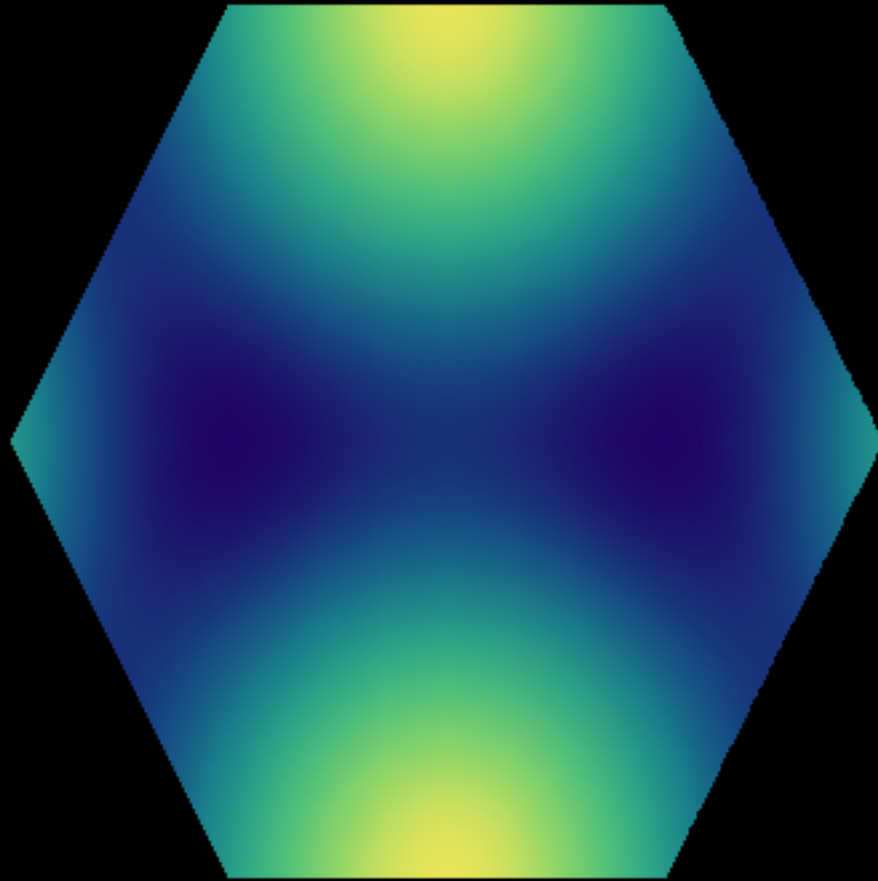
Yukawa attraction

- Non-local interactions depend on the relative momentum
- Examples: NN repulsion, dipolar, Yukawa

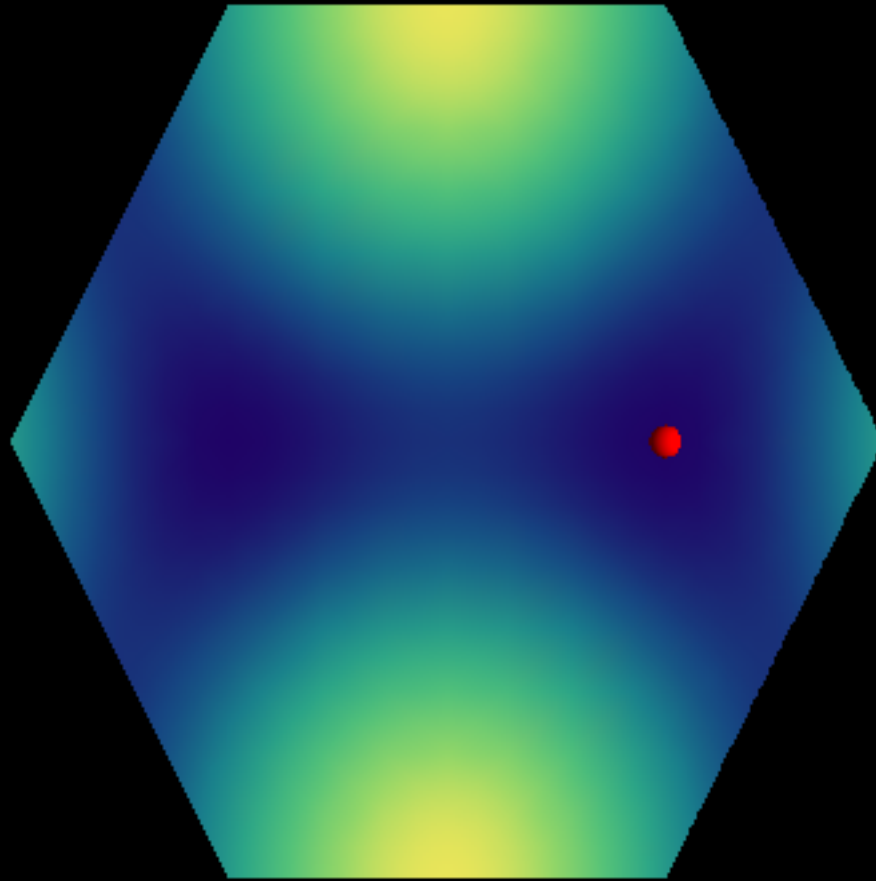
What do repulsive long-range interactions do to our system?



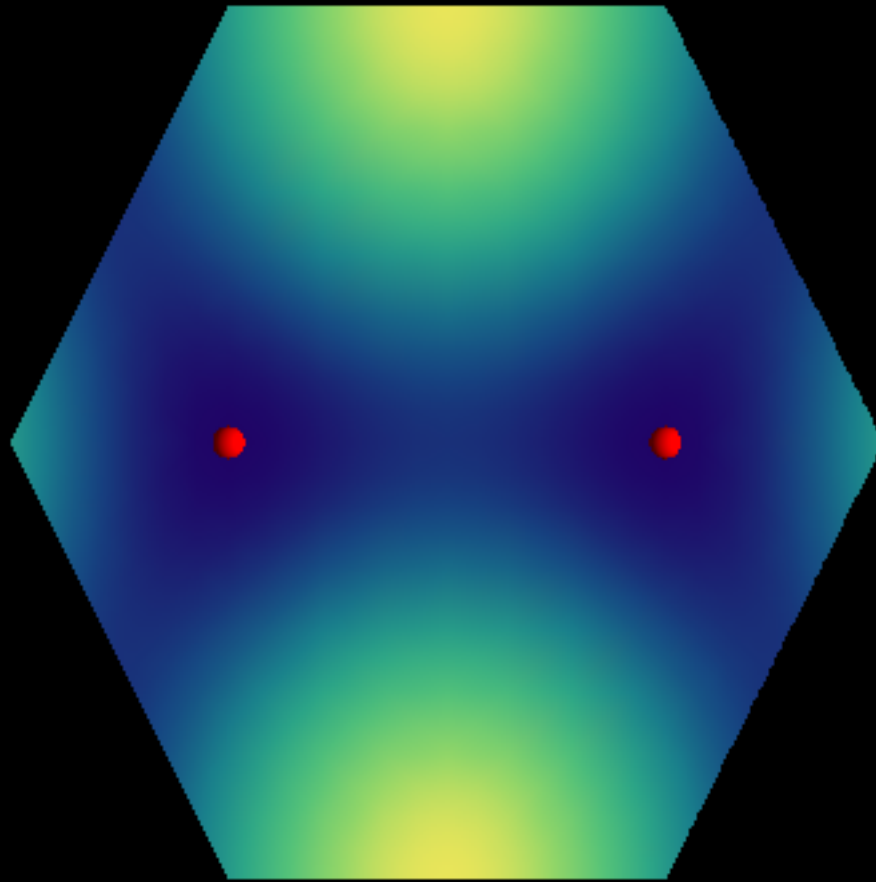
# Two interacting particles



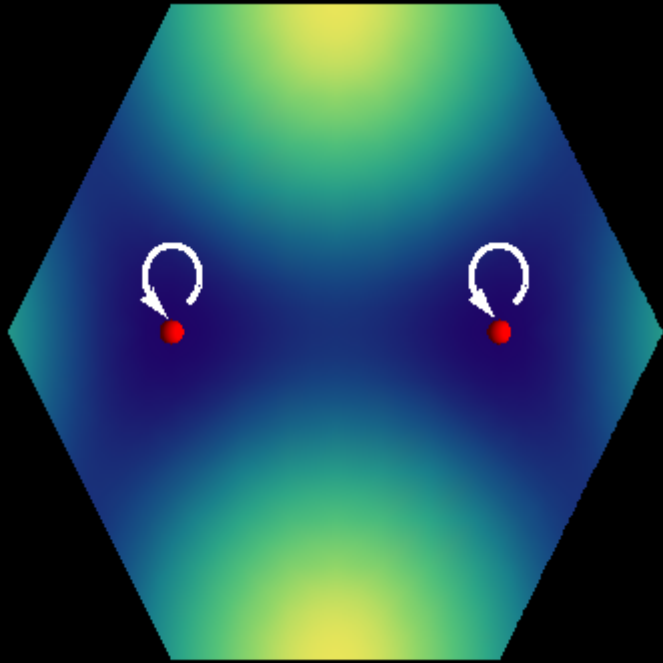
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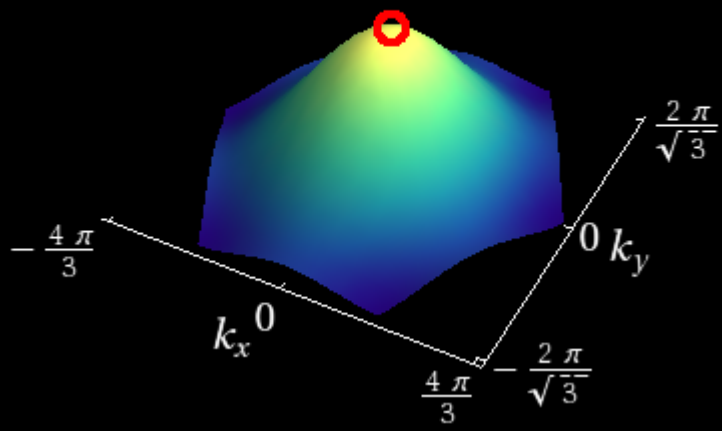
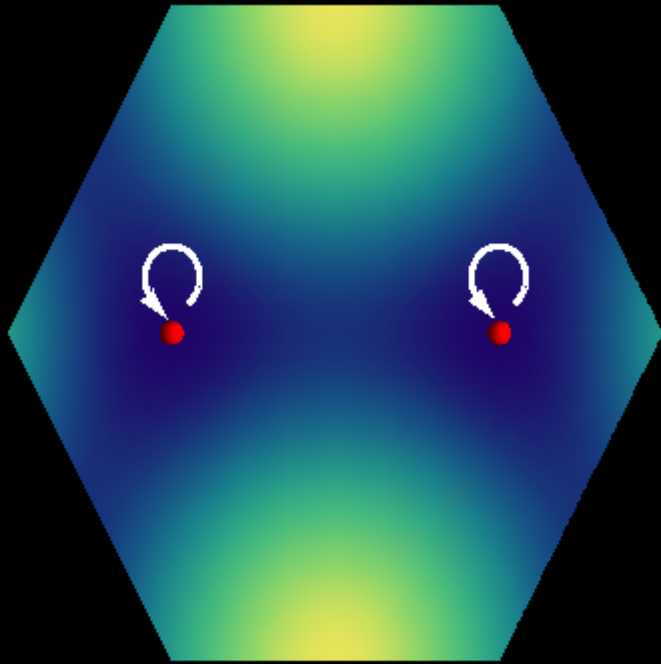
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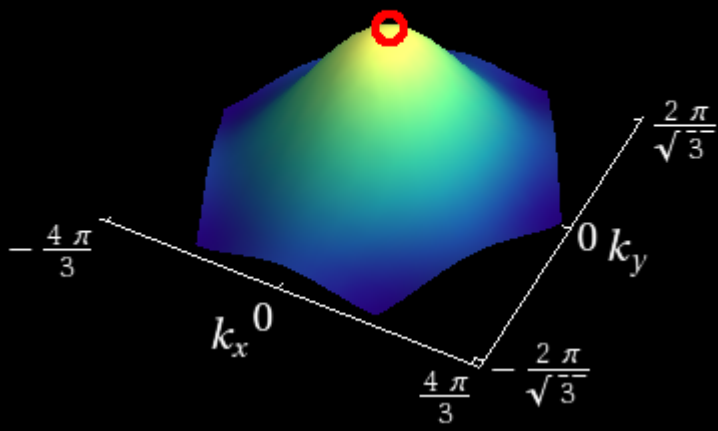
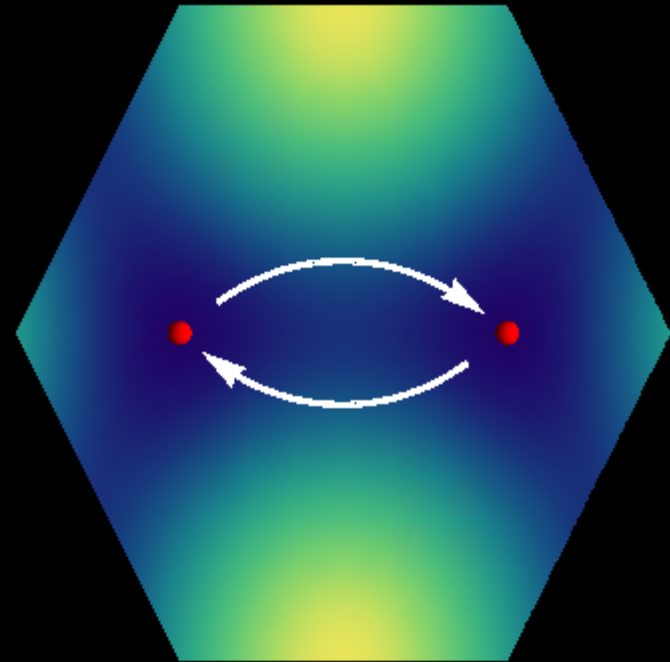
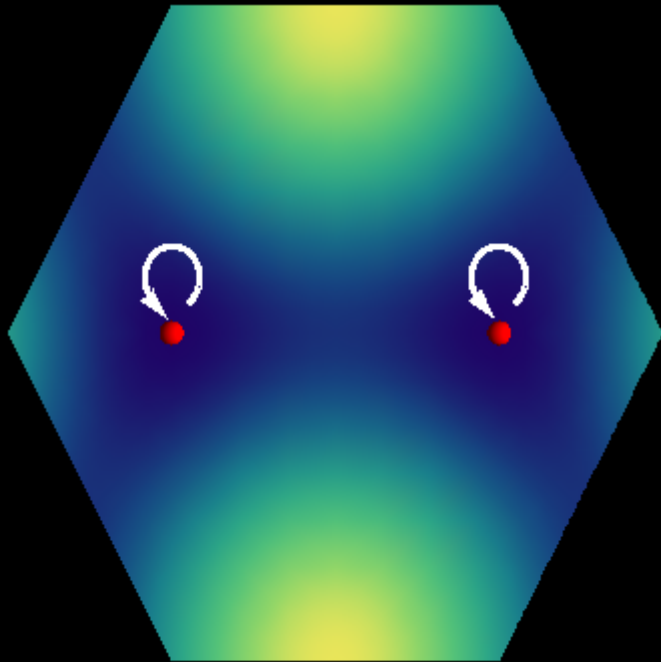
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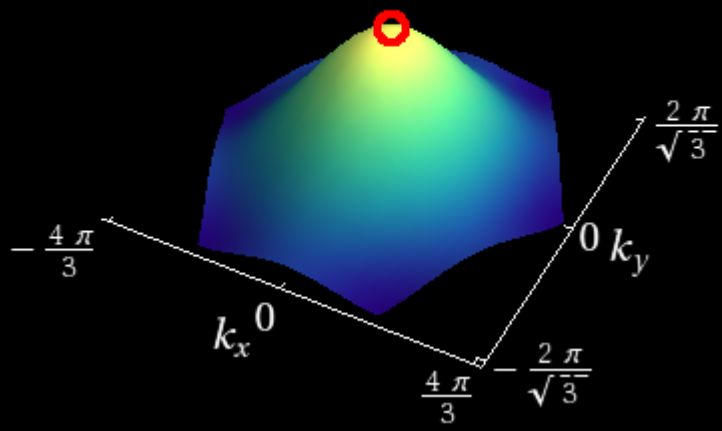
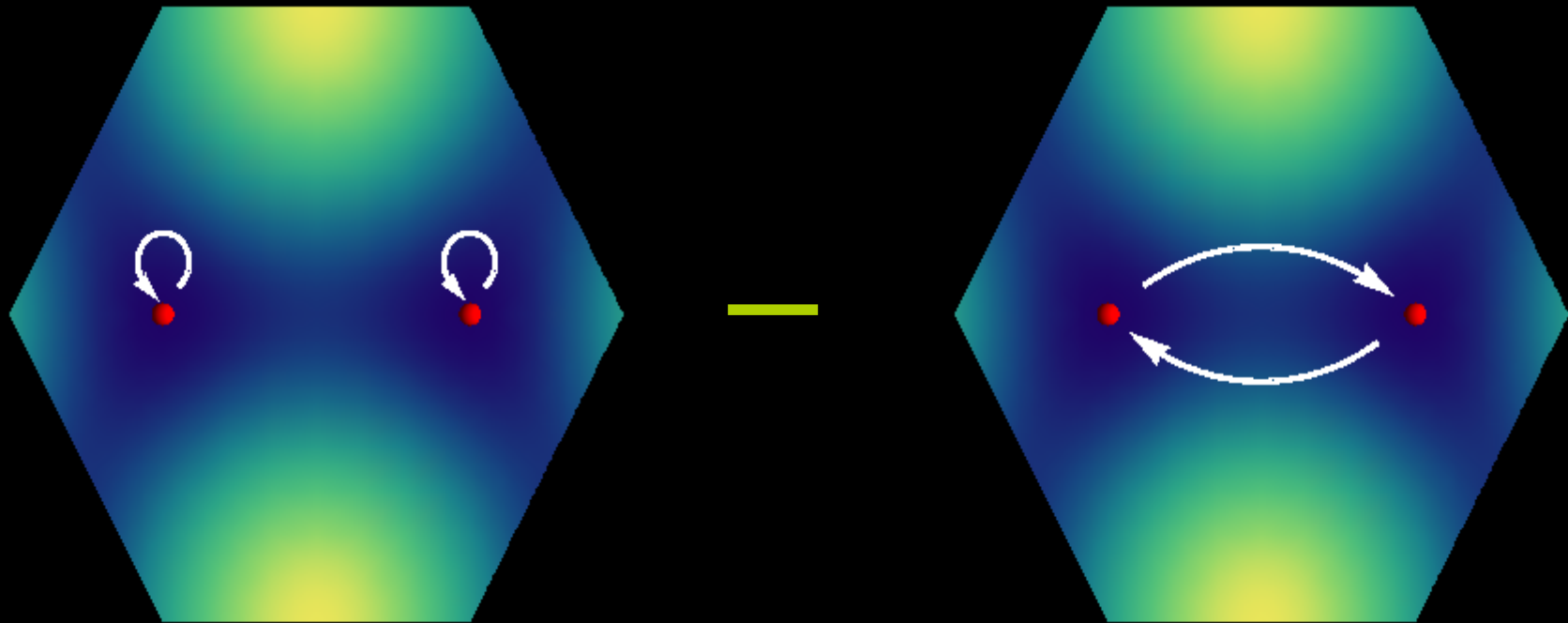
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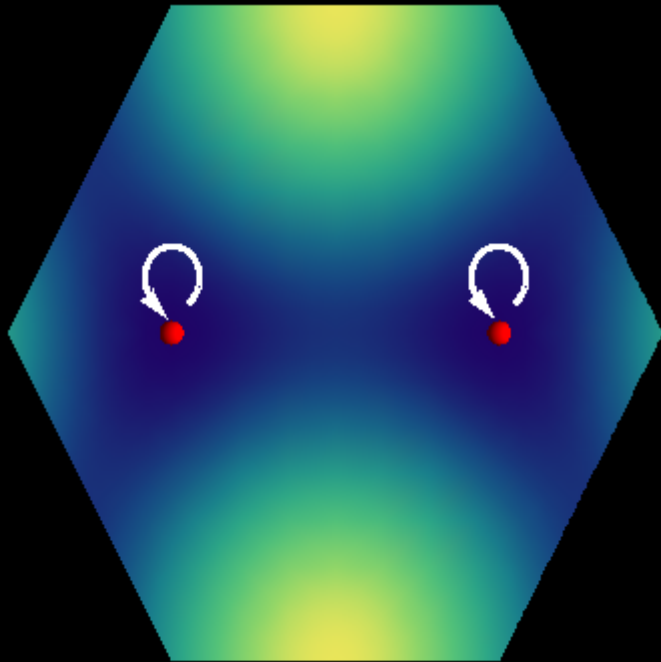
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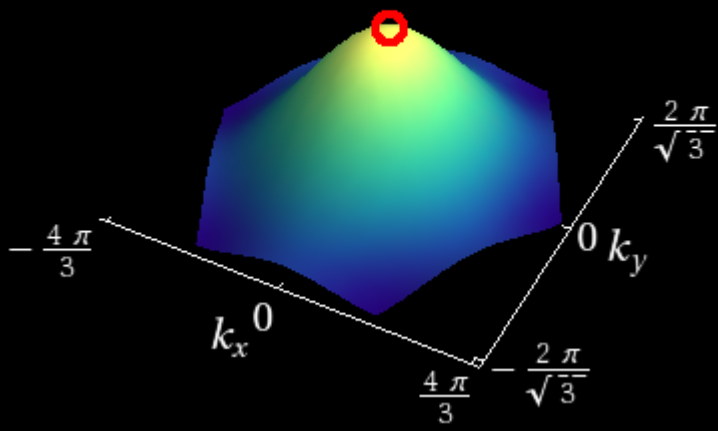
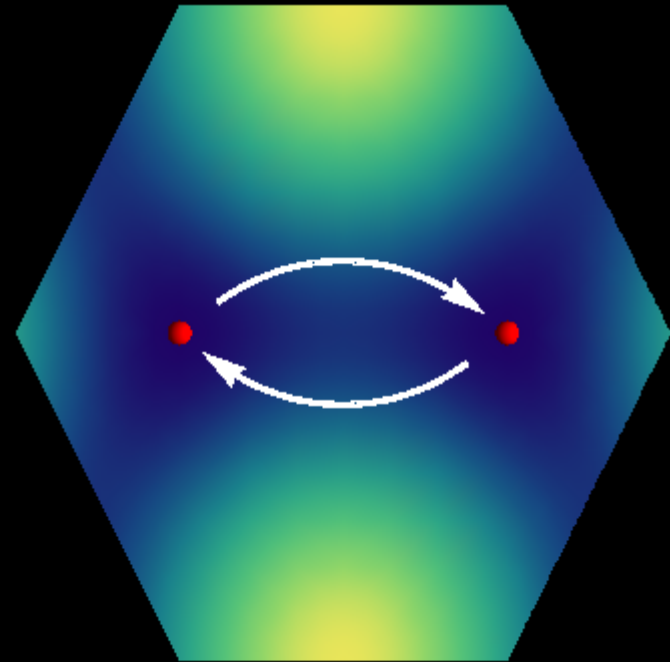
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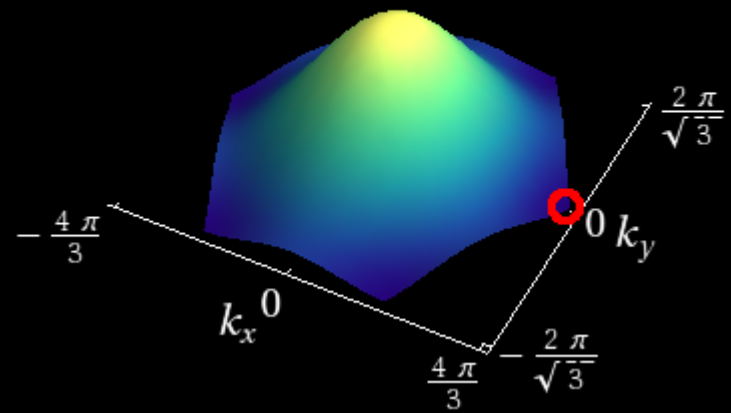
# Two interacting particles



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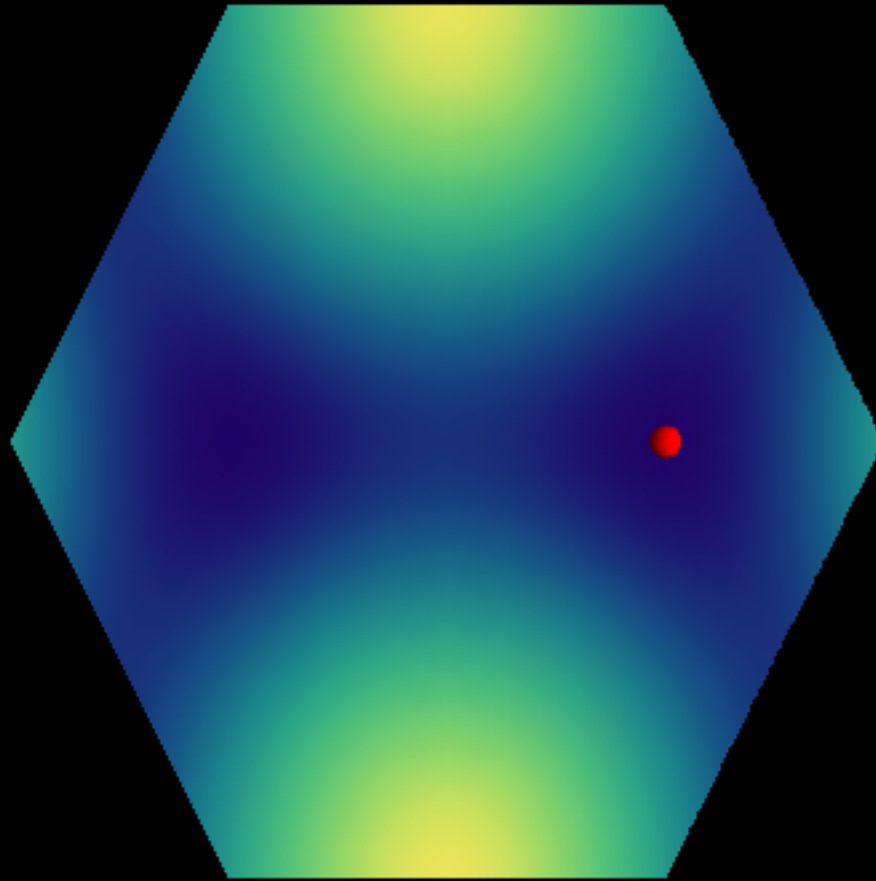


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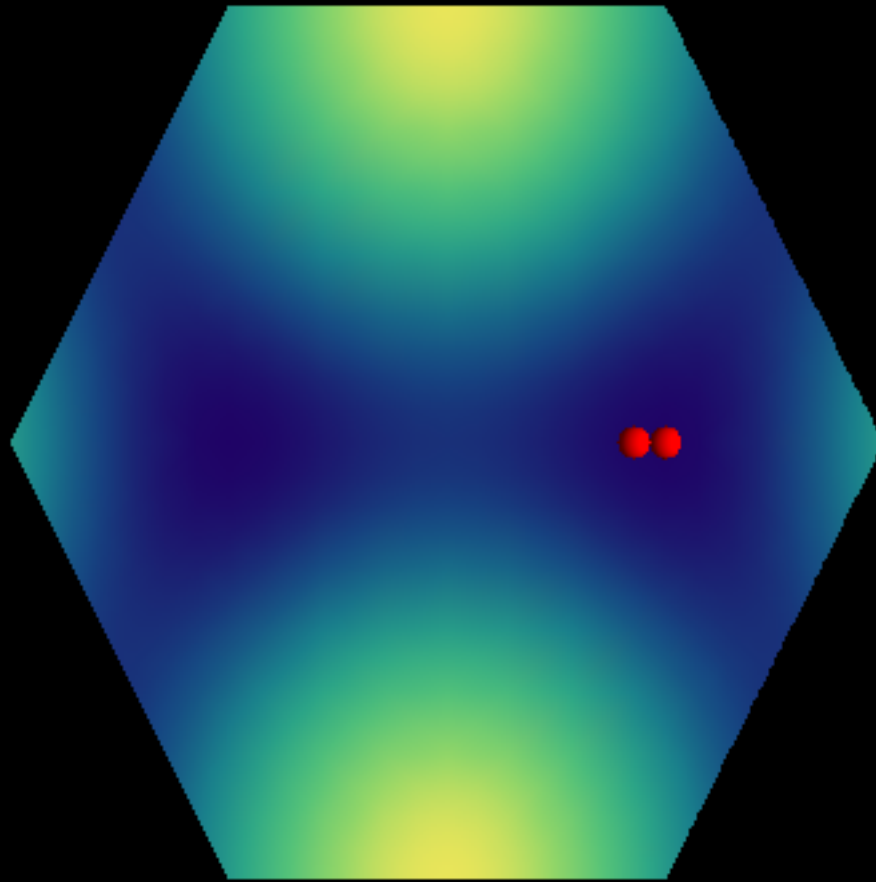




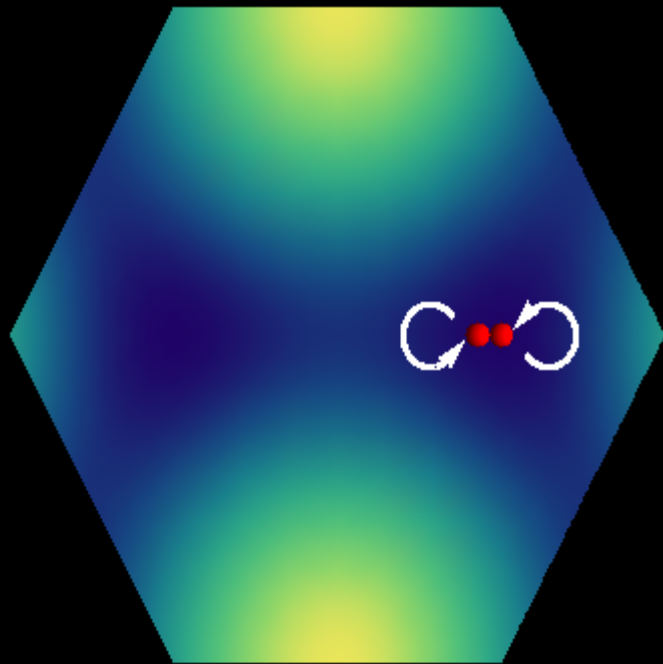
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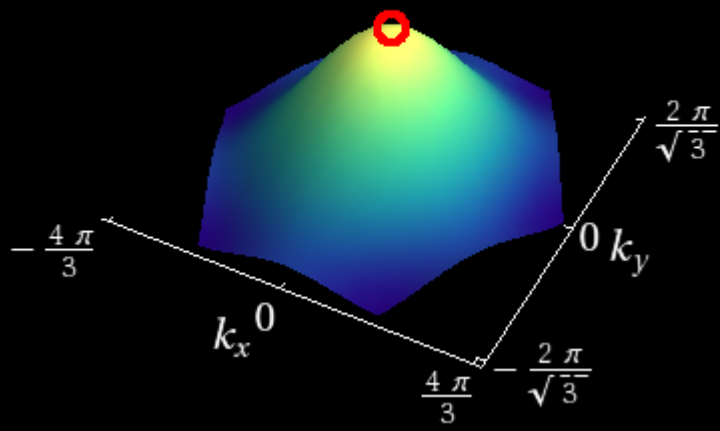
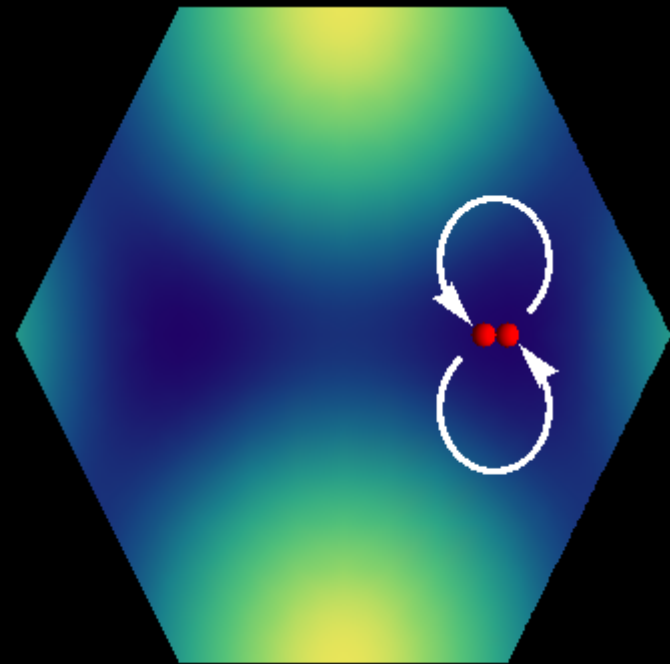
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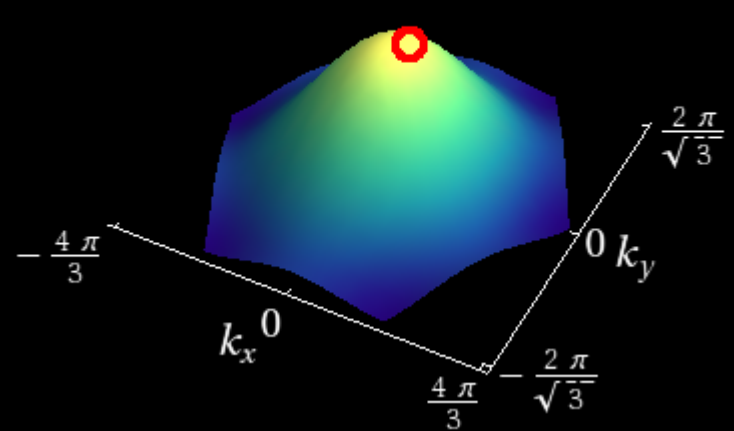
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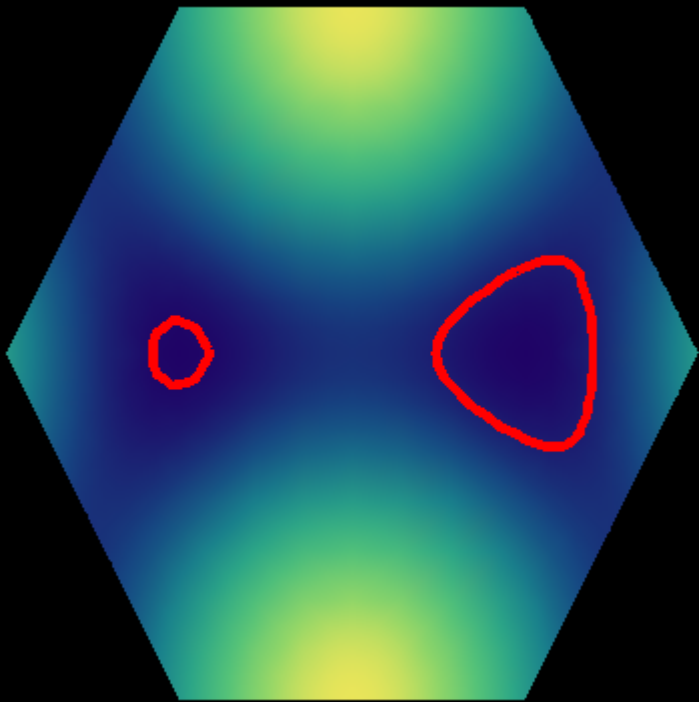
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# Mean-field theory

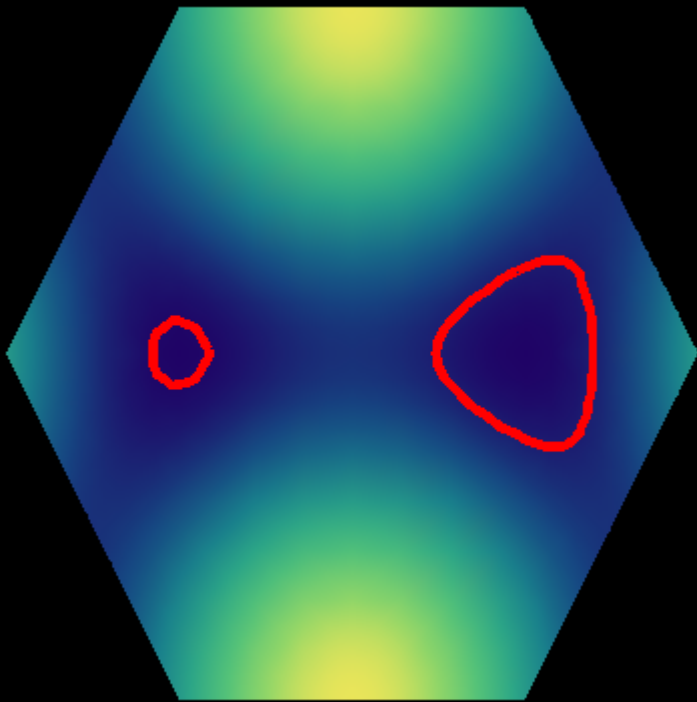
- Assume Gaussian ground state
- Decompose interaction term by Wick's theorem
  - Anomalous averages vanish due to repulsion
- Calculate corresponding free energy
  - Assume spatial homogeneity
  - Minimise
- Result: effective non-interacting theory
  - Shifted single-particle dispersion

# Time-reversal symmetry breaking

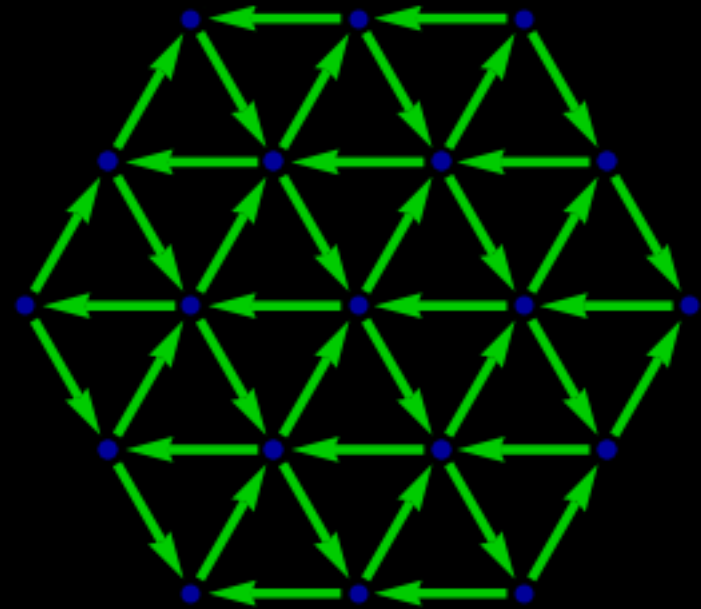


Momentum space

# Time-reversal symmetry breaking

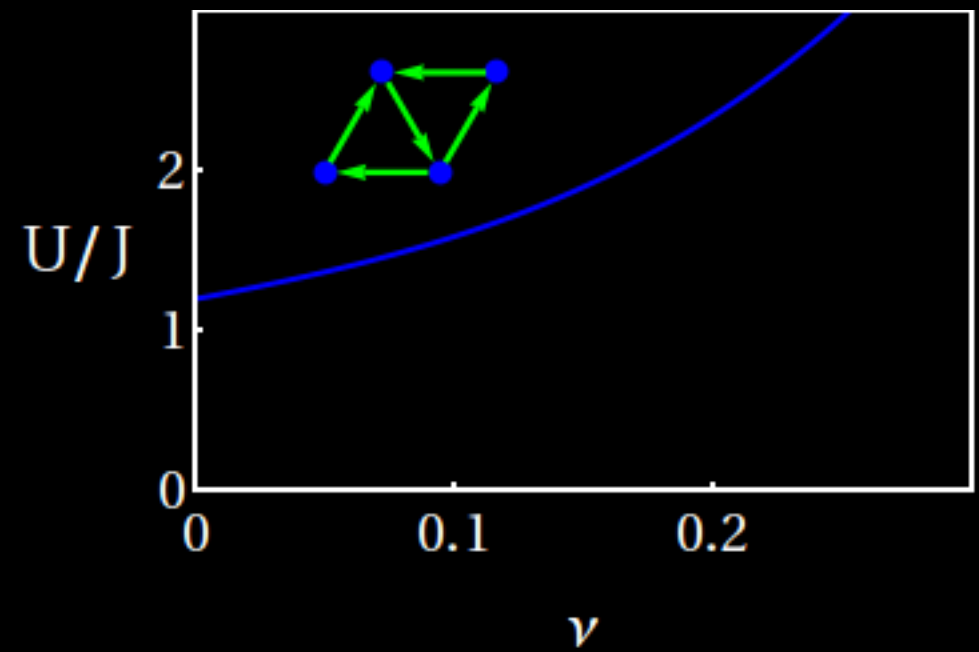
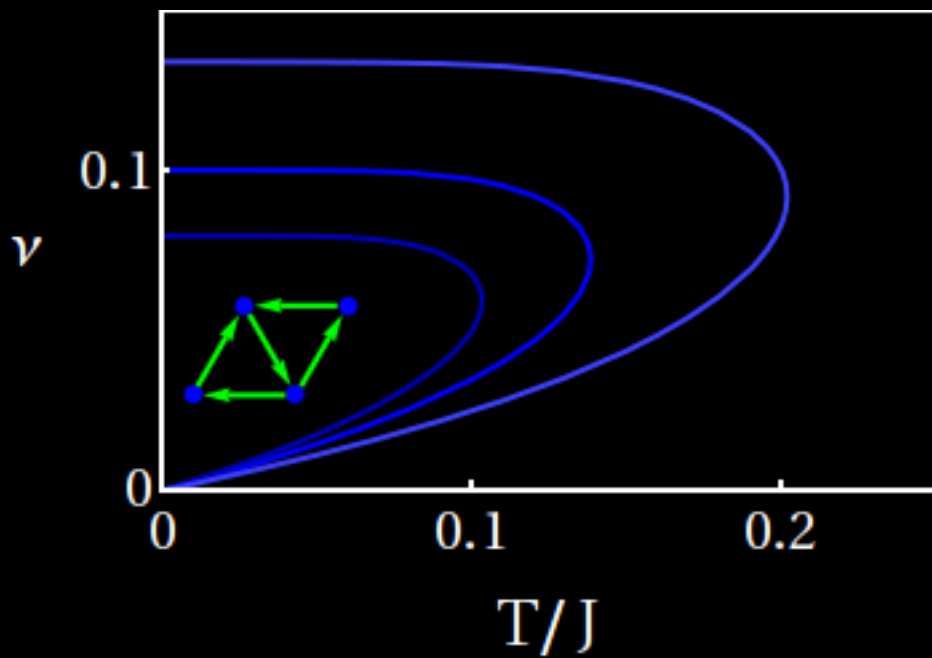


Momentum space

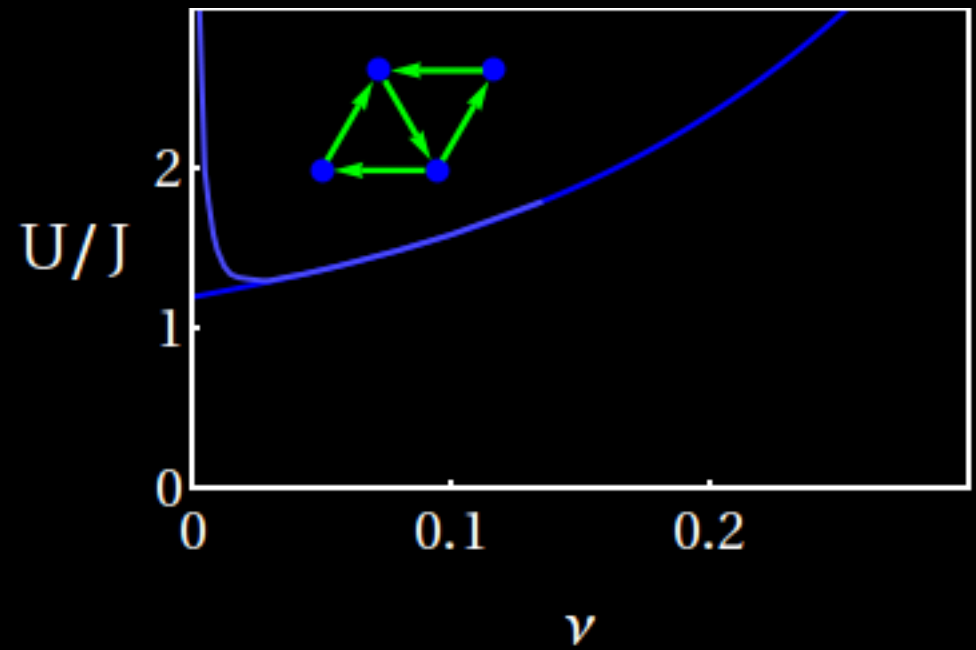
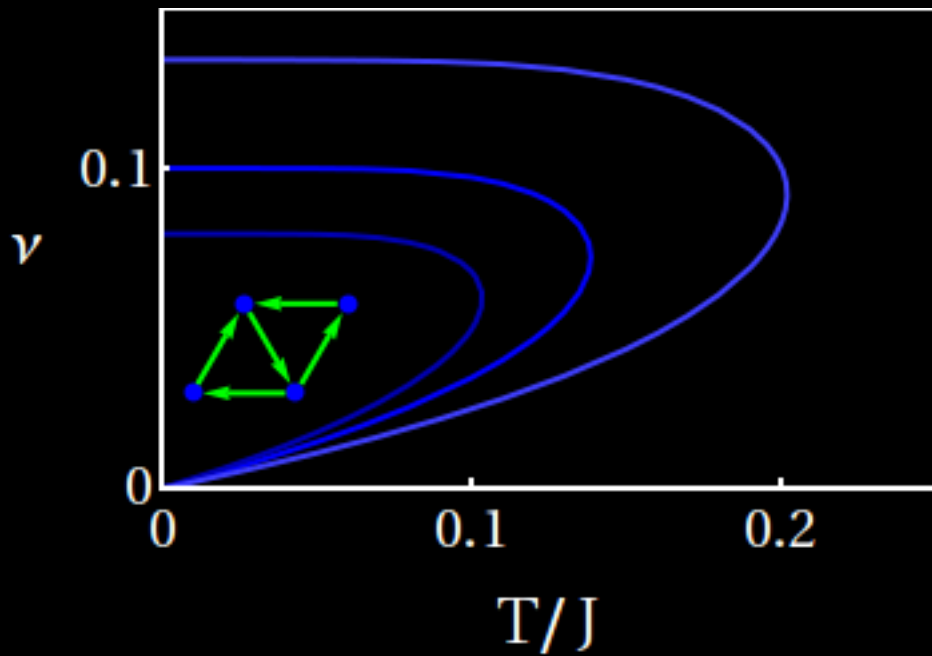


Real space

# Time-reversal symmetry breaking



# Time-reversal symmetry breaking





frustrated kinetics  
repulsive long-range interactions

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time-reversal symmetry breaking



The theory is nice; how about  
experiments?

# How to realise such a system?

- Frustrated hopping:
  - Elliptically shake triangular lattice
  - Triangular lattice at high filling: holes
  - Diagonally shake square lattice (certain types)
- Repulsive long-range interactions:
  - Dipolar
  - Exchange-induced

# Summary

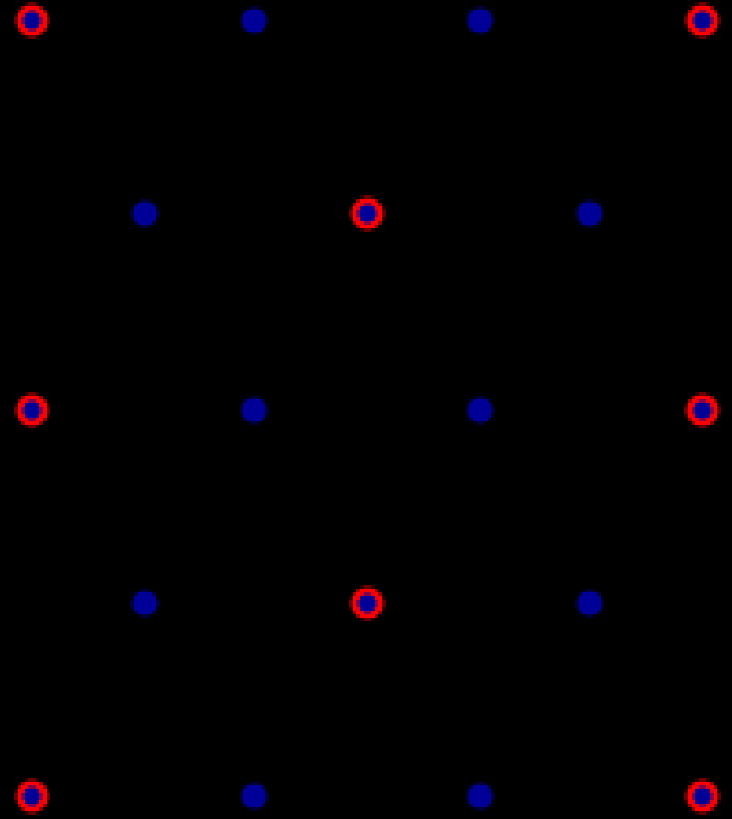
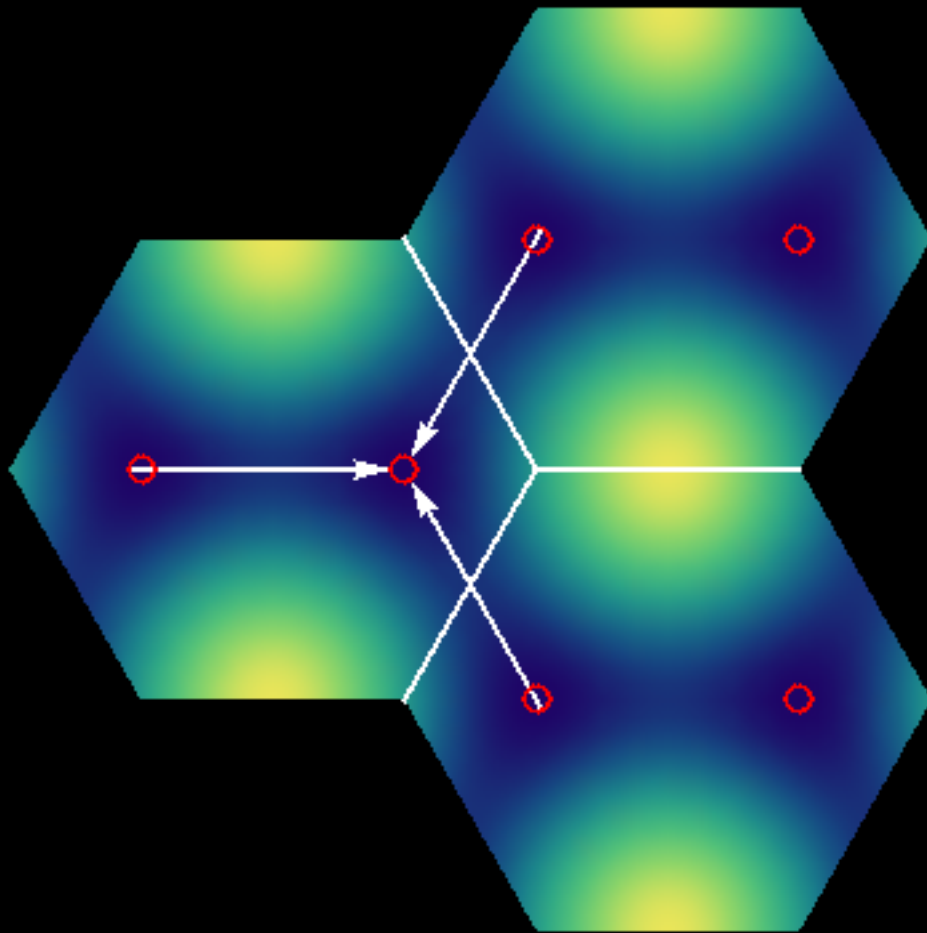
- Ingredients:
  - Spinless fermions
  - Frustrated kinetics
  - Repulsive interactions
- Outcome:
  - Time-reversal symmetry breaking

The end

Thank you for your attention :)

Interactions can also break the  
lattice symmetry

# Charge-density wave



# Charge-density wave

