# FRUSTRATION OF BEING ODD

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Humboldt College SCIENCE AND EDUCATIONAL CHALLENGES FACING EUROPE IN THE NEXT DECADE
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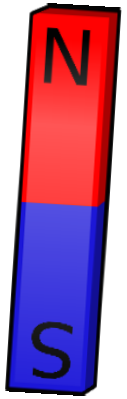
# Outline

- Frustration in magnetic systems
- Research problem: Frustration and Quantum Mechanics
- Examination of particular models
- Conclusions

FERROMAGNETS

- ancient Greece
- spins like to point in the SAME direction



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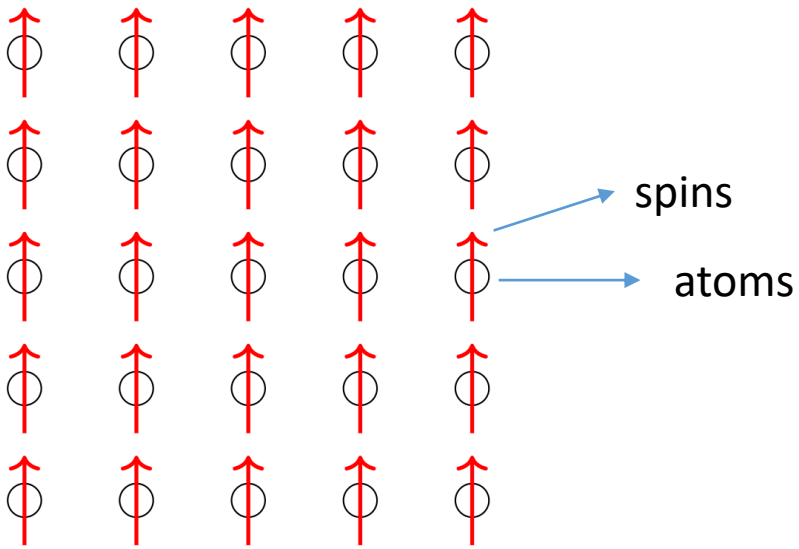

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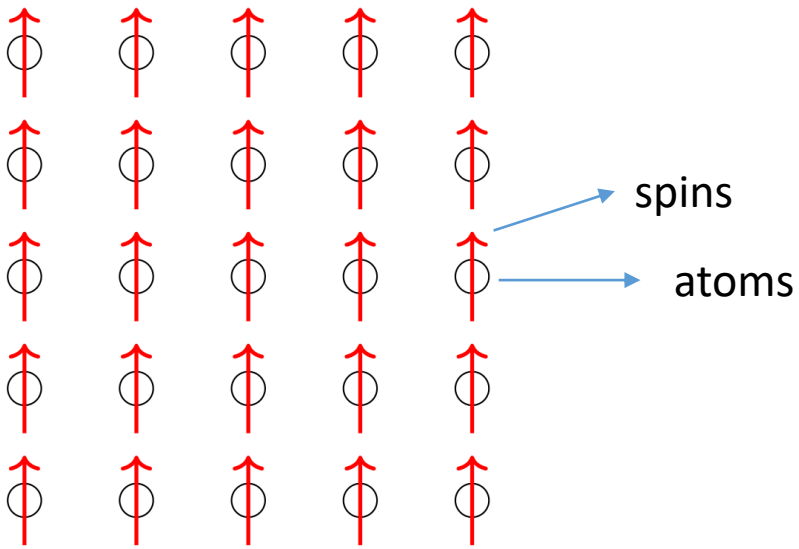
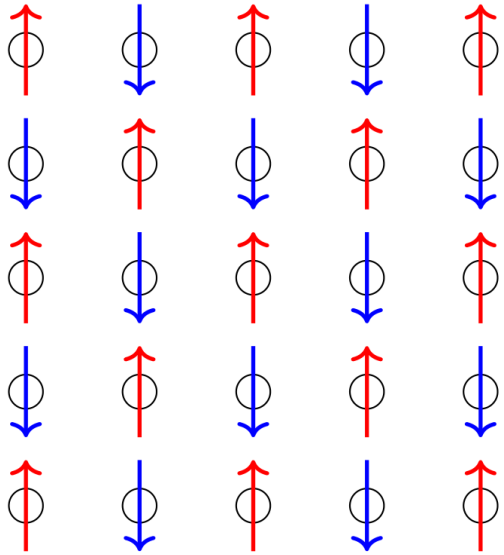


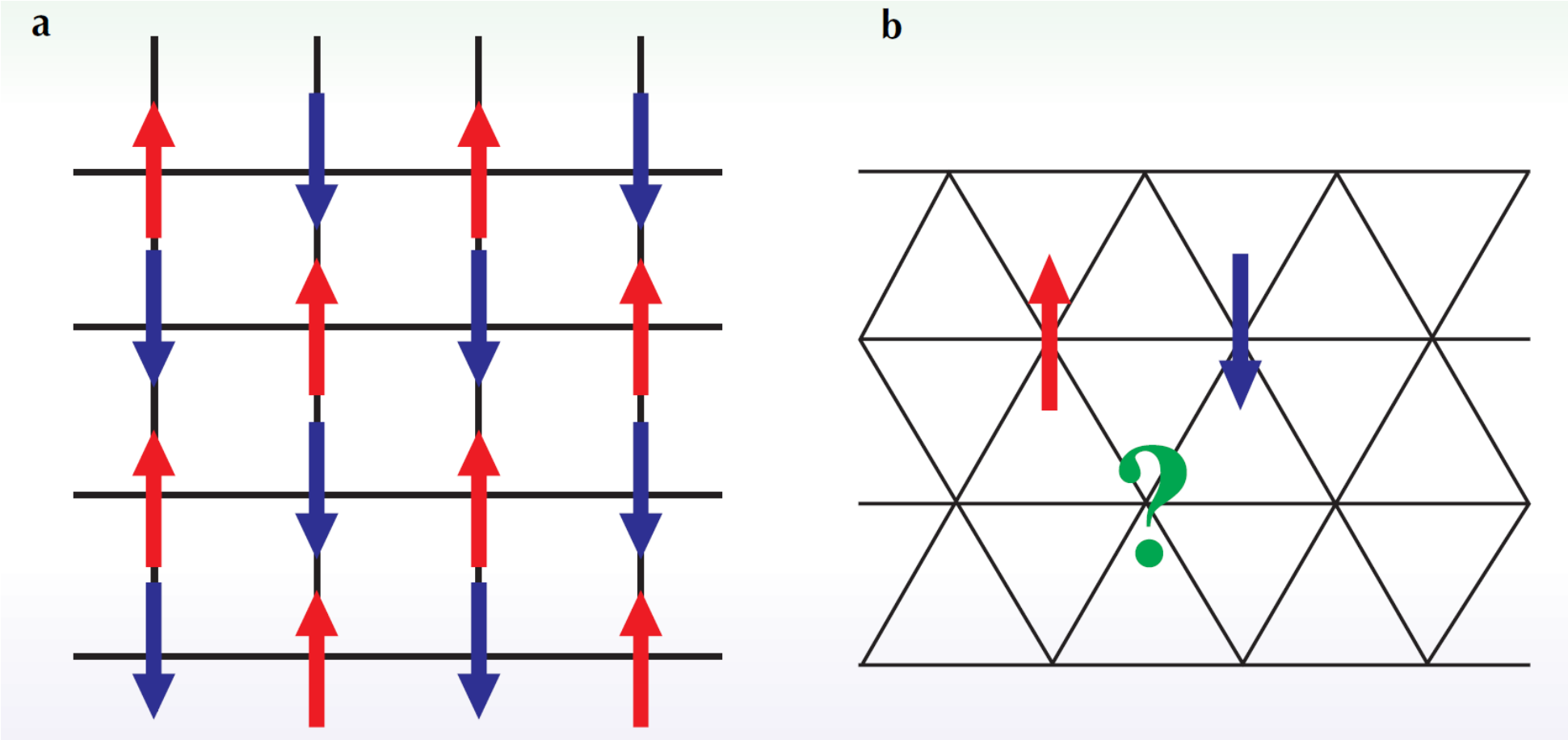

ANTIFERROMAGNETS

- 20th century
- spins like to point in the OPPOSITE directions



# Frustration

- interactions in conflict




Picture taken from [Moessner,Ramirez 2006]

# Interest

## Applications

Materials with new properties

- Quantum technologies

## Fundamental Side

- Organization of matter
- Spin ices, spin liquids
- Ability of such condensed matter systems to mimic different systems (e.g. Artificial light)

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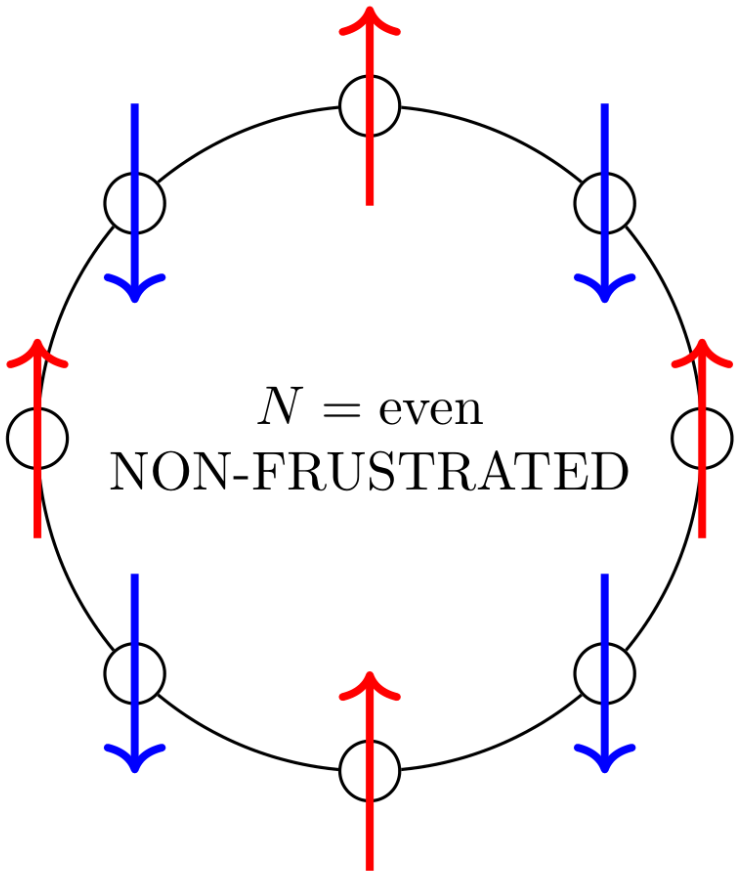
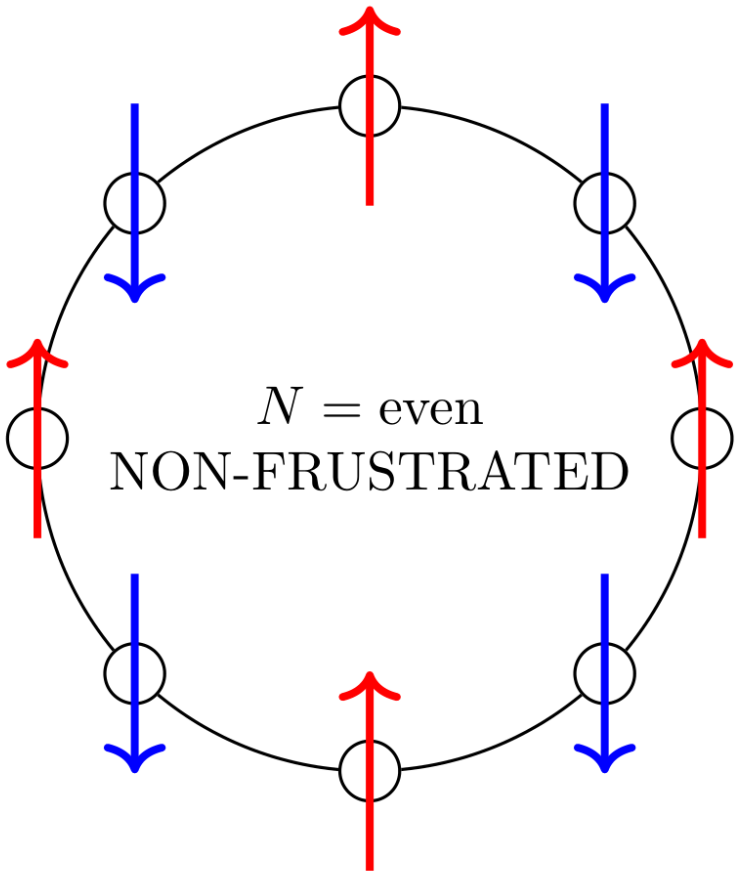
Frustration + Quantum Mechanics?

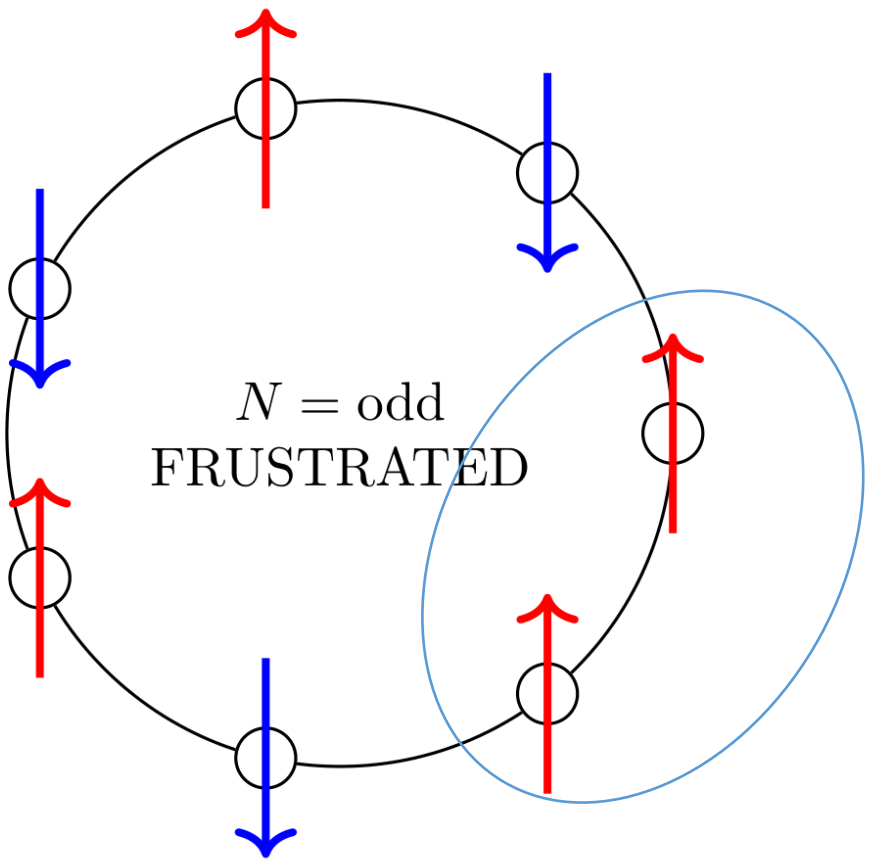
# One dimensional systems



# One dimensional systems

- Frustration of being Odd
  - periodic boundary conditions and odd system size



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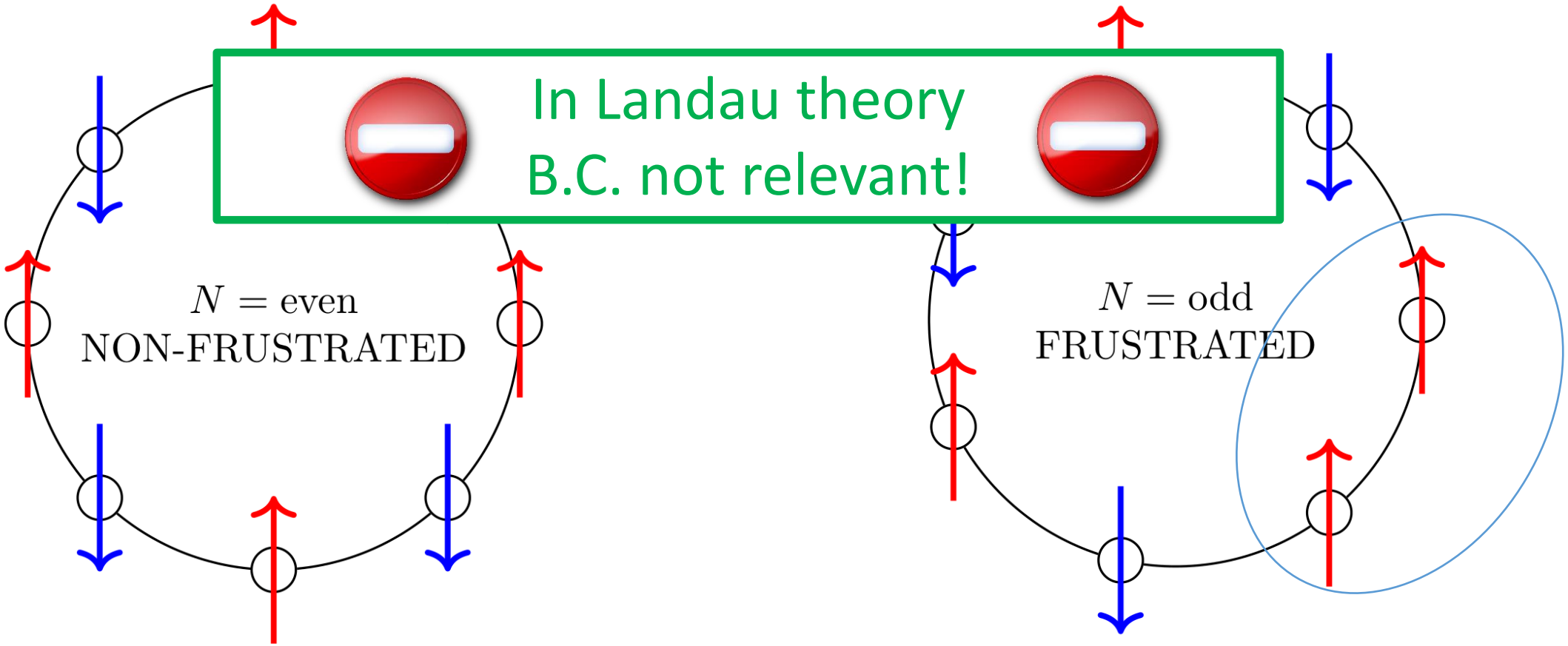
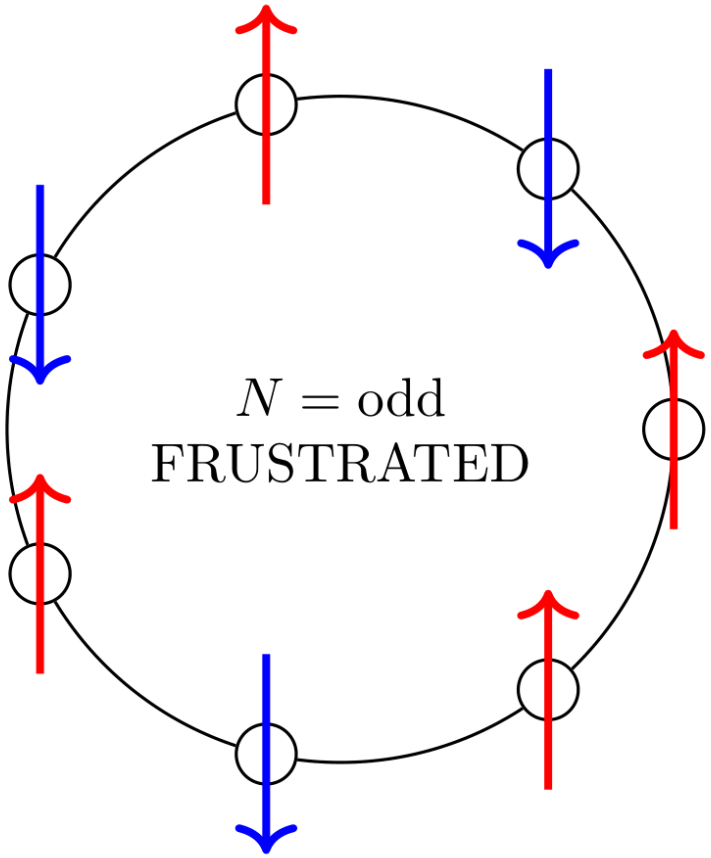


System described by the Hamiltonian (XY chain)




$$H = \sum_{j=1}^{N} \sigma_j^x \sigma_{j+1}^x - \lambda \sum_{j=1}^{N} \sigma_j^y \sigma_{j+1}^y \ , \ \lambda \in (0,1)$$

Magnetization? (average value)

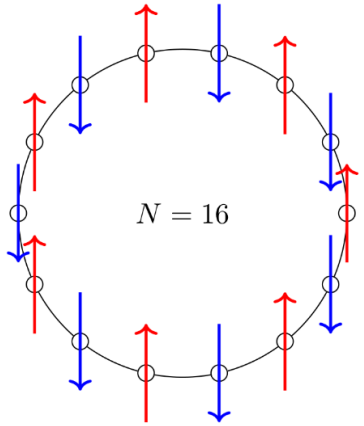
$$\langle \sigma_j^x \rangle = ?$$

- Combination of analytical and numerical methods

# Results

<u>Without frustration</u> (System size *N*=Even):

- Magnetization antiferromagnetic



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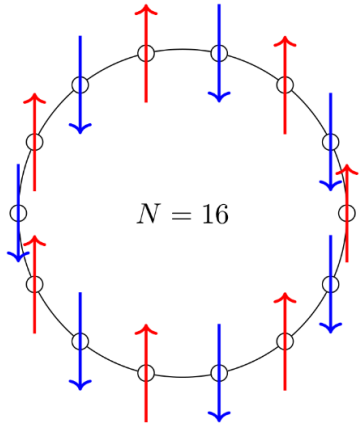
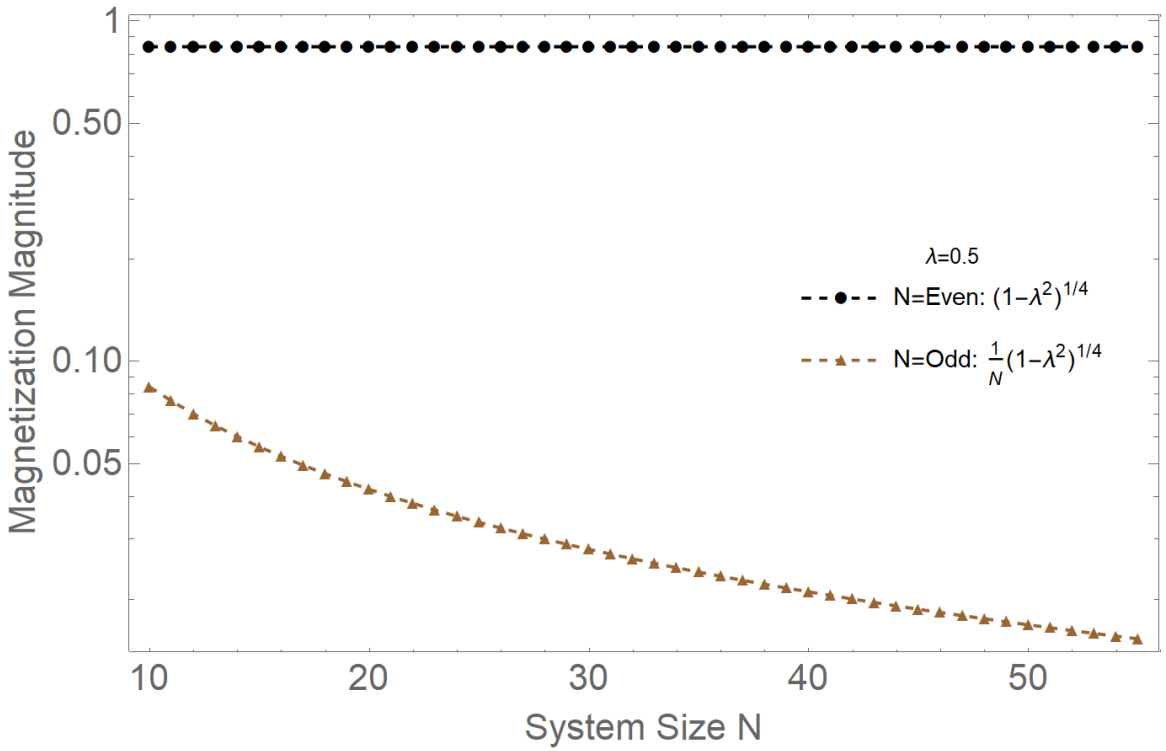
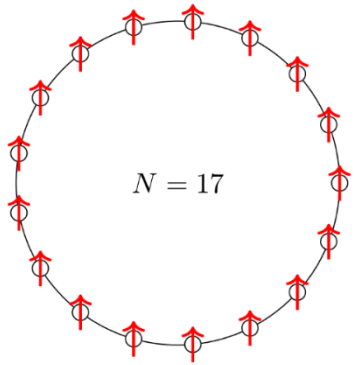



## With frustration (*N*=Odd):

- Magnetization decreases to zero with the system size
- Magnetization ferromagnetic




*Mesoscopic Ferromagnetic Order*

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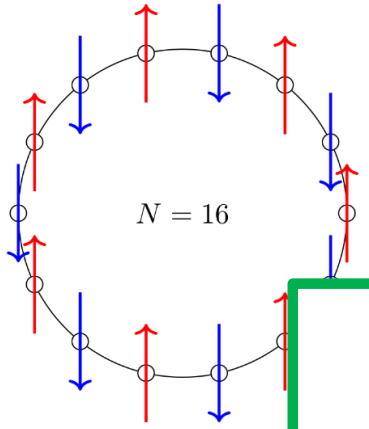


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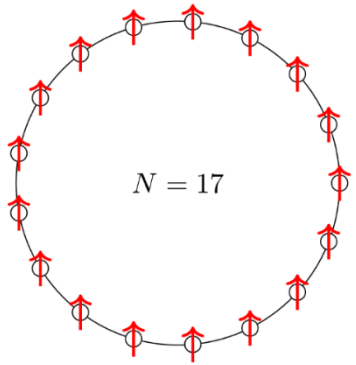
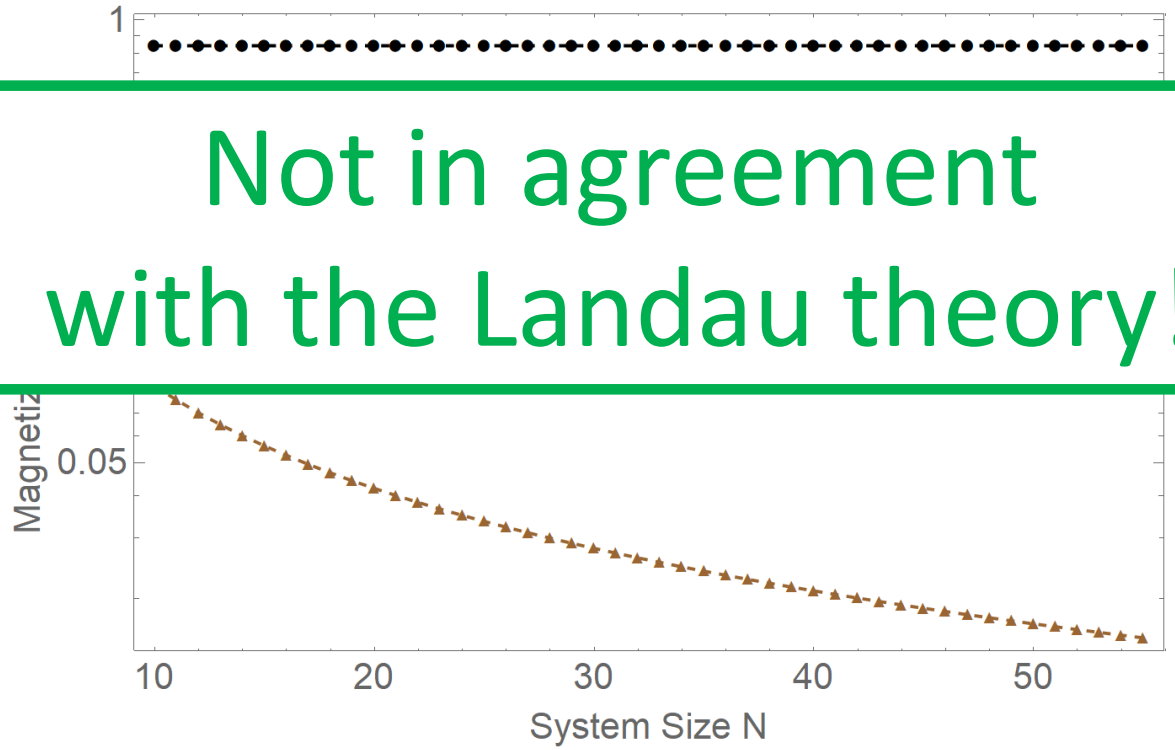
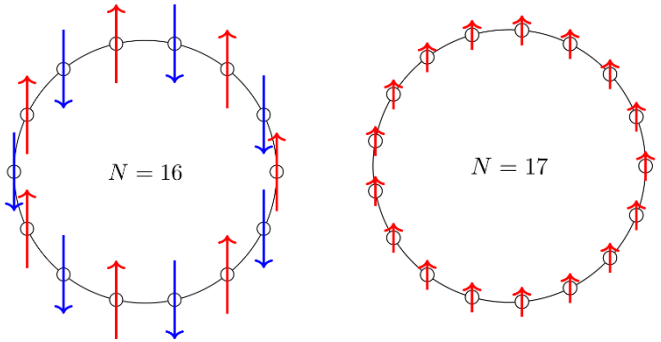



Not in agreement with the Landau theory!

*Mesoscopic Ferromagnetic Order*

# Conclusions




- Frustration with Quantum Mechanics destroys the antiferromagnetic order.
- Different behavior of systems of even and odd size, however large they are. (Importance of the boundary conditions.)
- Incompletness of the Landau theory.

Reference: V. Marić, S. M. Giampaolo, D. Kuić, and F. Franchini. “The Frustration of being Odd: How Boundary Conditions can destroy Local Order”. arXiv:1908.10876, 2019.

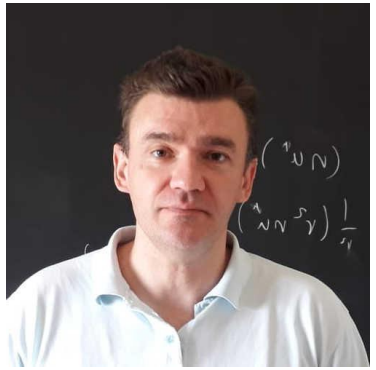
- Results are generalized to other models, in some a new type of order is found (breaking of translational symmetry).

Reference: V. Marić, S. M. Giampaolo, D. Kuić, and F. Franchini. In preparation.

# People involved in the project

Fabio Franchini

Salvatore Marco Giampaolo



Domagoj Kuić