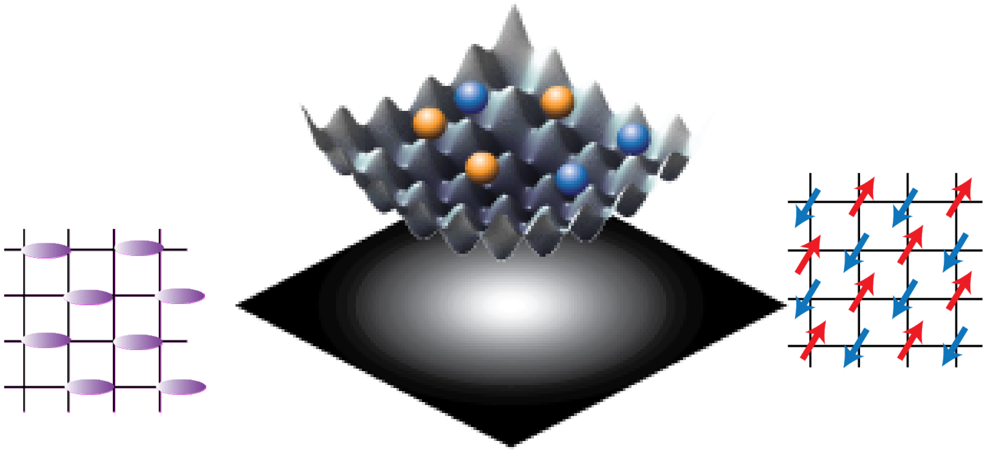
Novel approach to Quantum Spin Liquids: Random Boundary Conditions



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Our Problem:

Quantum fluctuations + frustration → Exotic phases of matter

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Quantum Spin Liquids

- Very elusive both theoretically and experimentally
- No local order
- Current theoretical methods: VMC, PEPS,Mean field,... have no consensus in detecting some QSL phases

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What we propose:

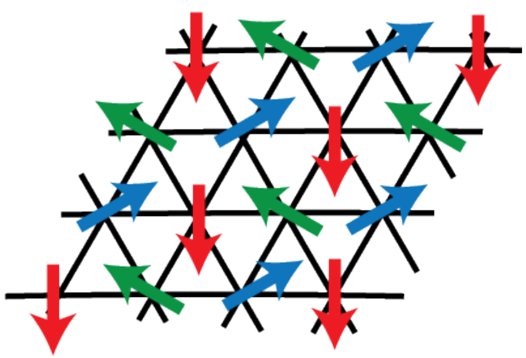
Simulate the disorder of the system with the boundary conditions:

Random Boundary Conditions

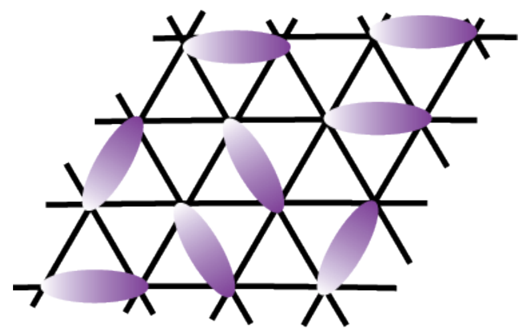
Quantum Antiferromagnets and Spin Liquids

$$\hat{H}_{AF} = |J| \sum_{i,j} \vec{S}_i \cdot \vec{S}_j$$

Strong competition between possible ground states



classical **Néel state**

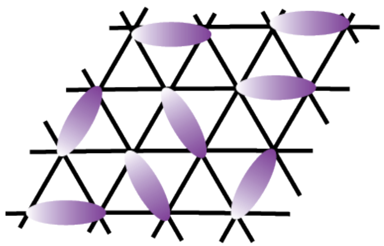


Valence Bond solid

competition strongly depends on the lattice geometry!

 $= |s_{ij}\rangle = \frac{1}{\sqrt{2}}(|\uparrow_i\downarrow_j\rangle - |\downarrow_i\uparrow_j\rangle)$

Quantum Antiferromagnets and Spin Liquids



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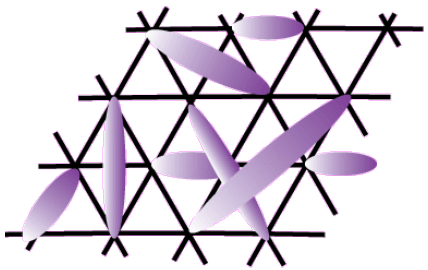


+....

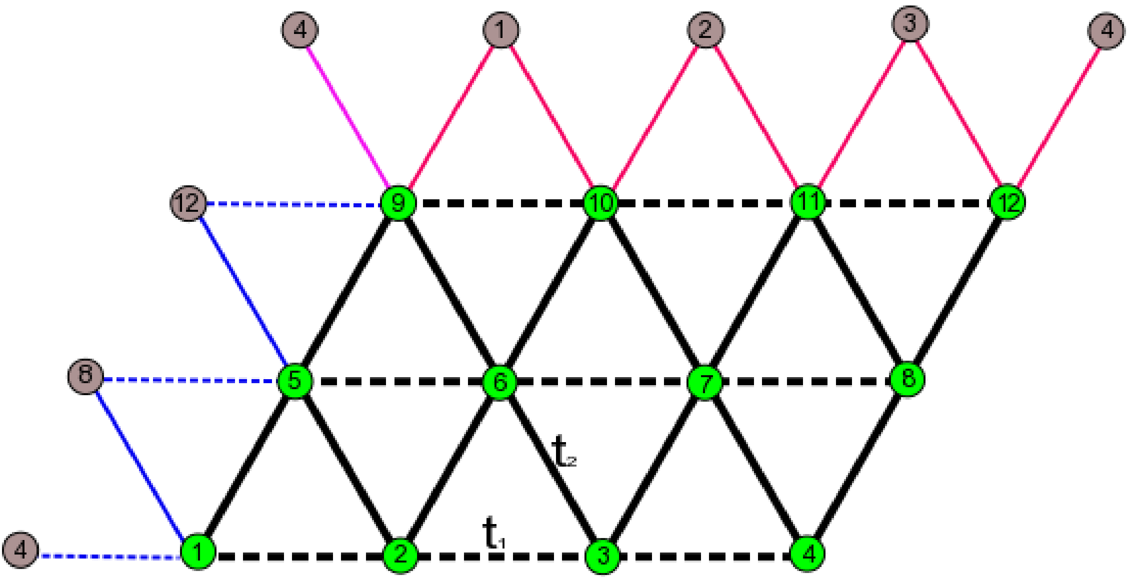
- ***Negative definition:*** a spin liquid cannot break any local symmetry (no local order)

They cannot be detected or distinguished by using a **local measurement**

- They can be distinguished globally (possess some hidden global order)
- They can be distinguished by the **topological entanglement** entropy

SPIN 1/2 in the Spatially Anisotropic Triangular Lattice (SATL)

$$H_s = \sum t_{ij} (S_i^x S_j^x + S_i^y S_j^y)$$

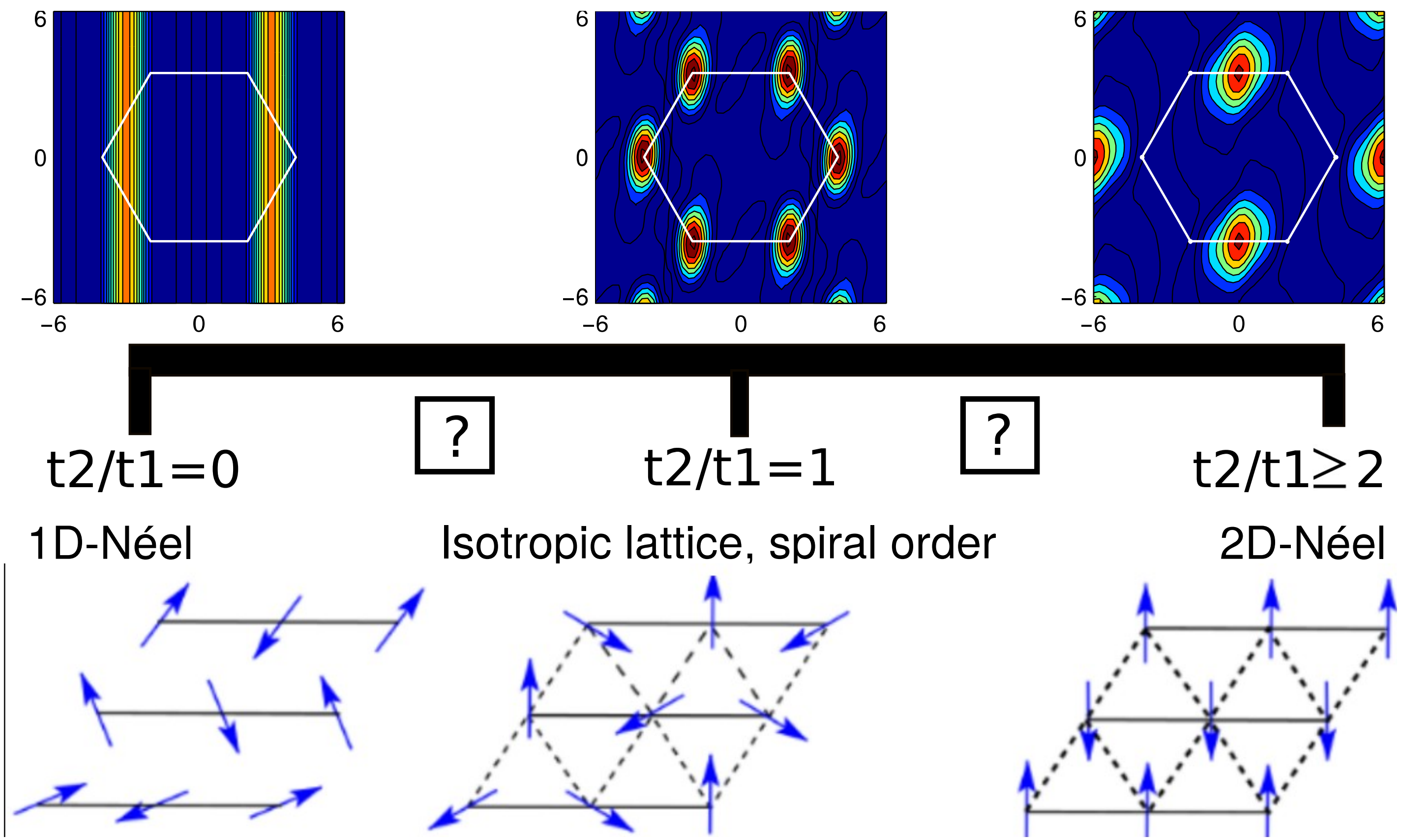


Anisotropy:

- t_2 (diagonal bounds)
- t_1 (horizontal bounds)

Spin 1/2 in the Spatially Anisotropic Triangular Latice (SATL)

$$S(k) = \sum_{i,j=1}^{n} \langle S_i \, S_i \rangle e^{ik(r_i - r_j)}$$



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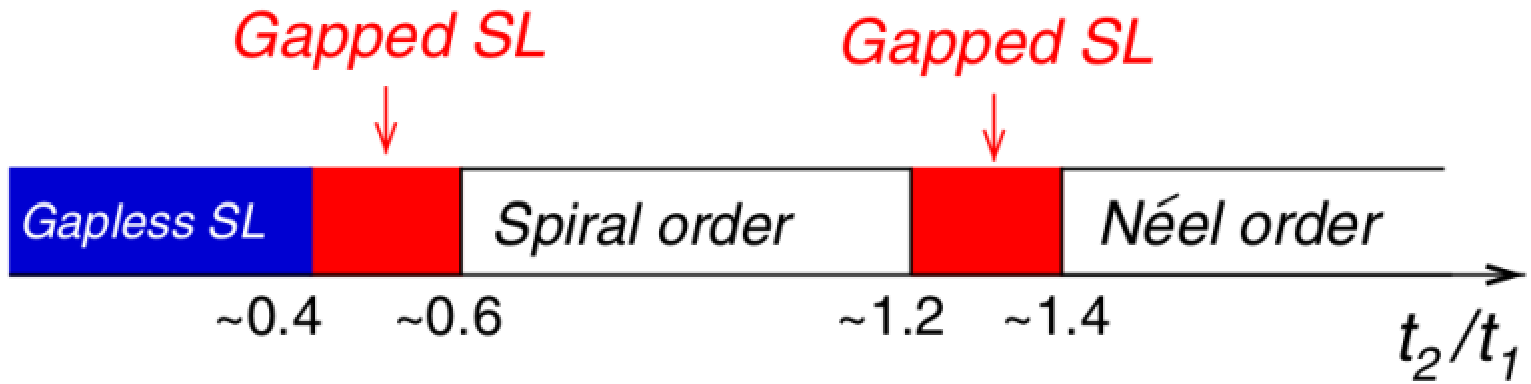
Schmied,et al. 2008 (PEPS)



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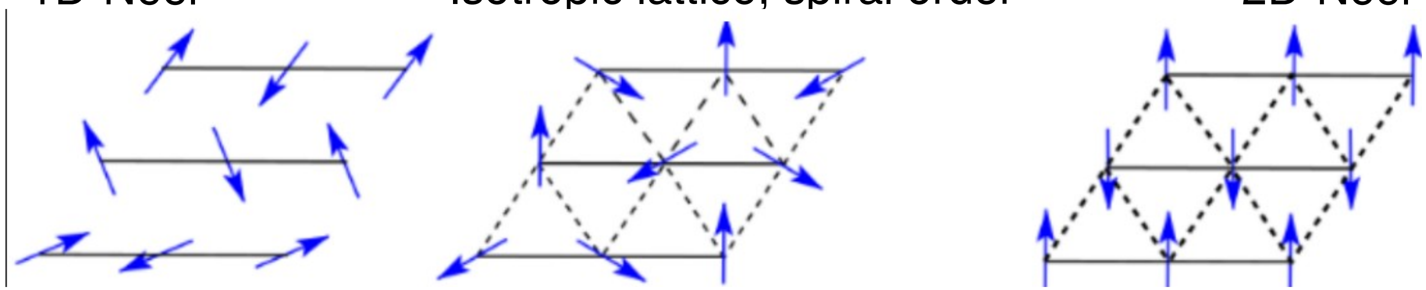
t2/t1=0 — t2/t1=1 — t2/t1≥2

1D-Néel — Isotropic lattice, spiral order — 2D-Néel

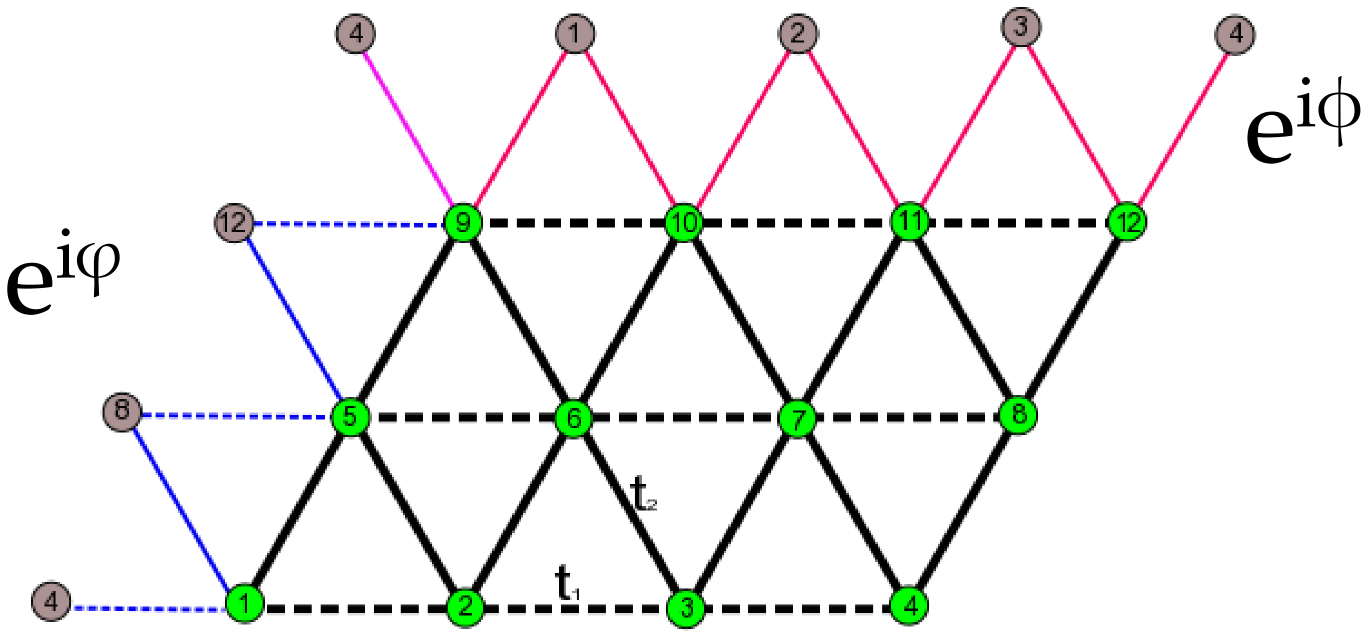


IDEA: IF SL = DISORDERED QUANTUM SYSTEM…

•Disordered systems are treated by performing averages over the different disorder realizations.

• When a spin tunnels with a random phase it gets twisted.

•Every disorder realization adds different “artificial” symmetries.



How many random phases give an energy which is close to the minimal one?

Roughly speaking

- **Ordered phases**: if the random phase implement the correct symmetries, we get a minimal energy. When not, the energy rises.
- **Minimum!**
-
- **Disordered phases,** the system can energetically adapt to many random configuration.
- **Maximum!**

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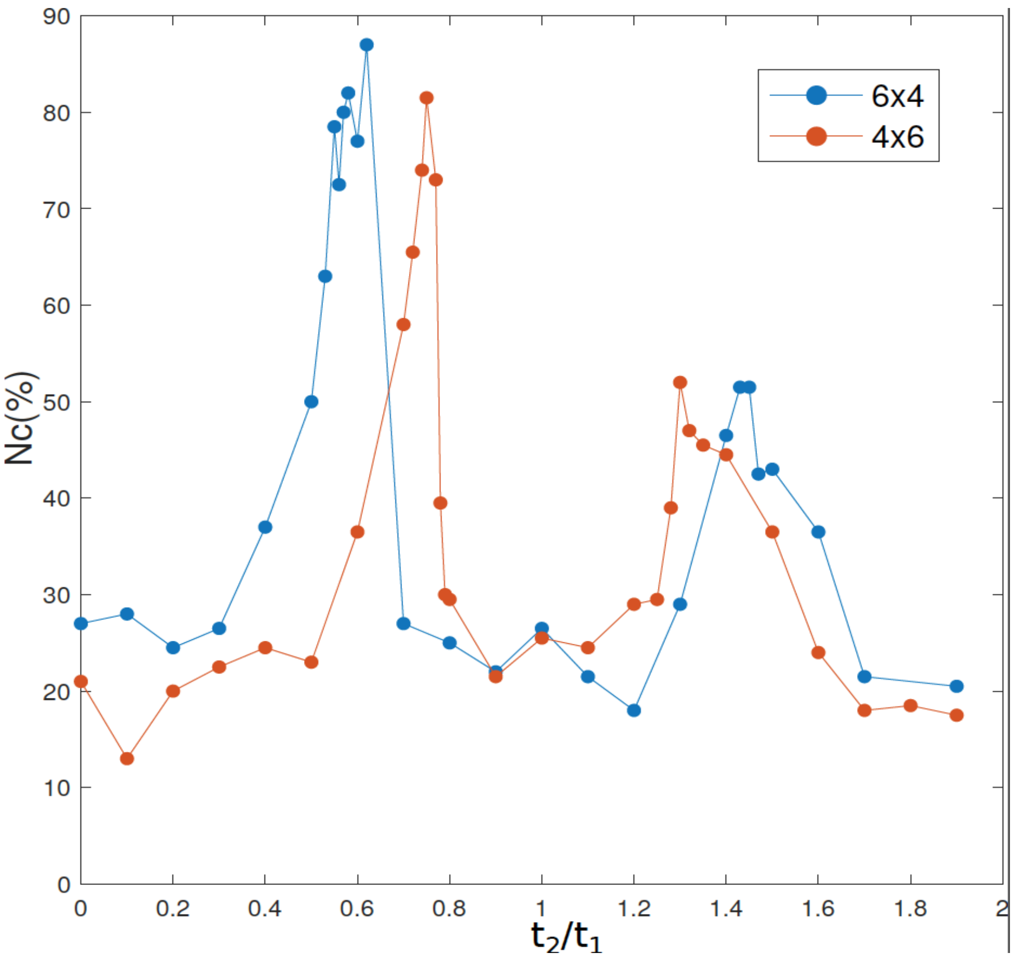

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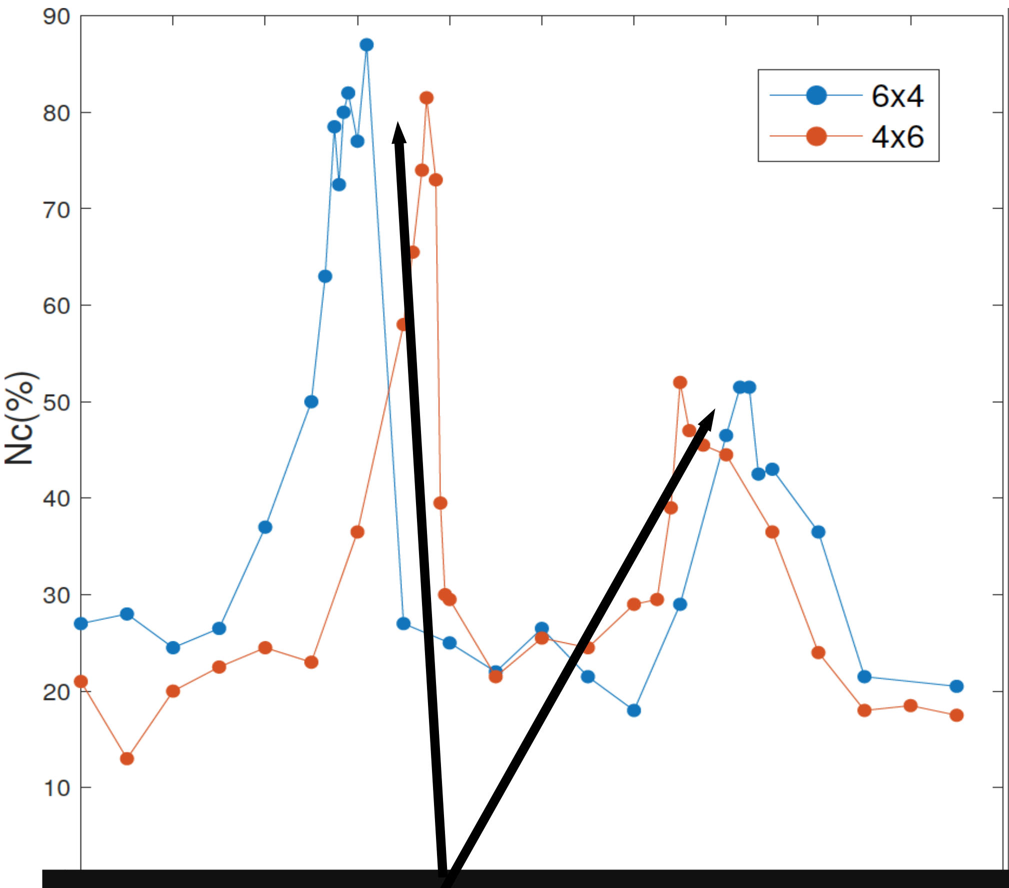

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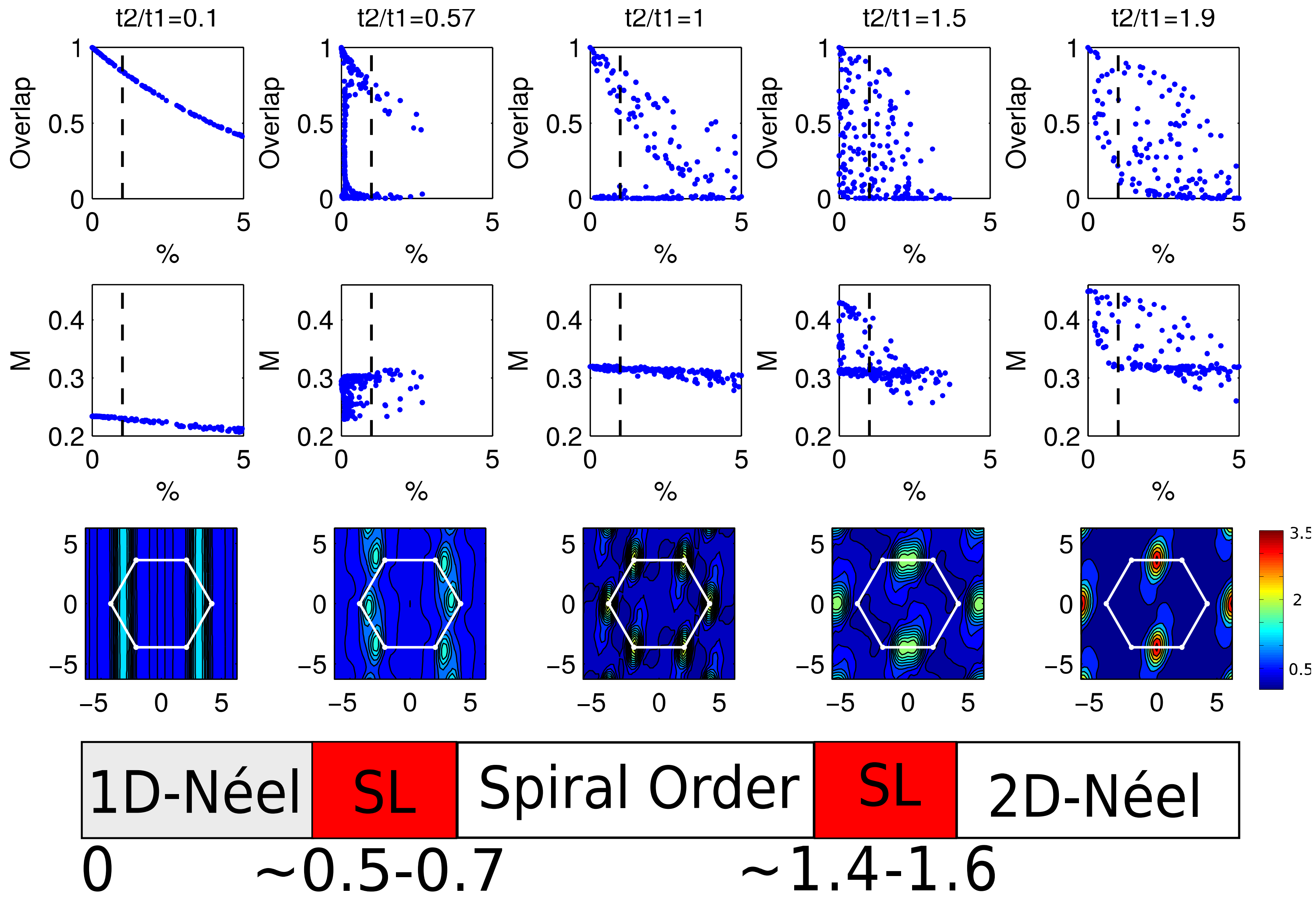
Next Question:

How are these ground states which are very close in energy?



t2/t1=0.1
t2/t1=0.57
t2/t1=1
t2/t1=1.5
t2/t1=1.9
Overlap
M
%
1D-Néel
SL
Spiral Order
SL
2D-Néel
0
~0.5-0.7
~1.4-1.6

Conclusions

•Exotic phases of matter as QSL are very difficult to study with current technology.

•We propose RBC as a way to simulate disorder by changing the geometry of the cluster.

•We have successfully detected the QSL phases in the XY model in the SATL.

•RBC may open the door to **solving some other open problems in the study of quantum disordered phases** of matter and could be applied in other numerical techniques which rely on periodic boundary conditions with **a modest computational cost.**