UNIVERSITÉ DE LYON

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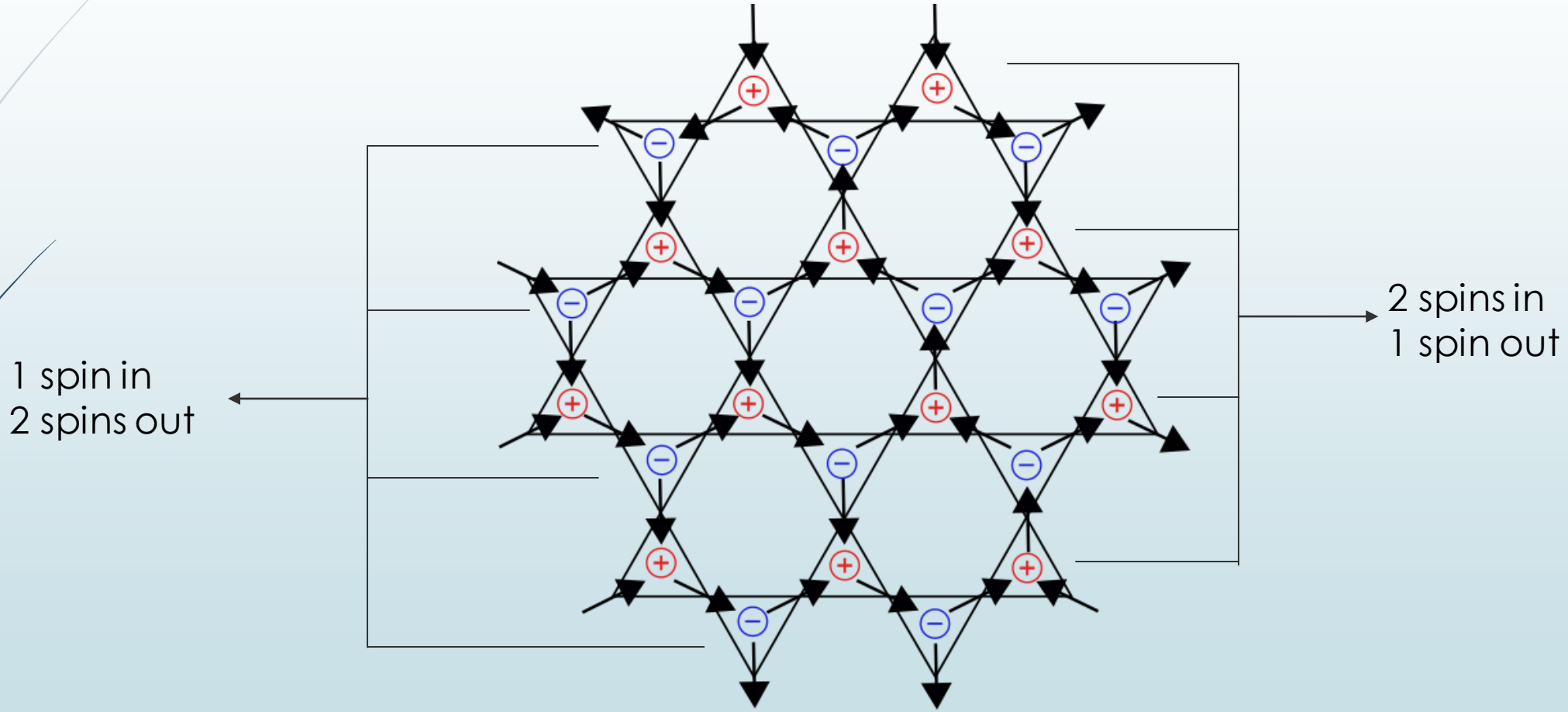
AGENCE NATIONALE DE LA RECHERCHE

ANR

Phase transitions in topologically constraints kagome lattice

G. Haeseler, P.C.W. Holdsworth

K11 phase of kagome ice [1,2]



1 G. Möller and R. Moessner. "Magnetic multipole analysis of kagome and artificial spin-ice dipolar arrays". In: PRB. 80 (14 Oct. 2009)
2 Gia-Wei Chern, *et al*. "Two-Stage Ordering of Spins in Dipolar Spin Ice on the Kagome Lattice". PRL.106 (20 May 2011)

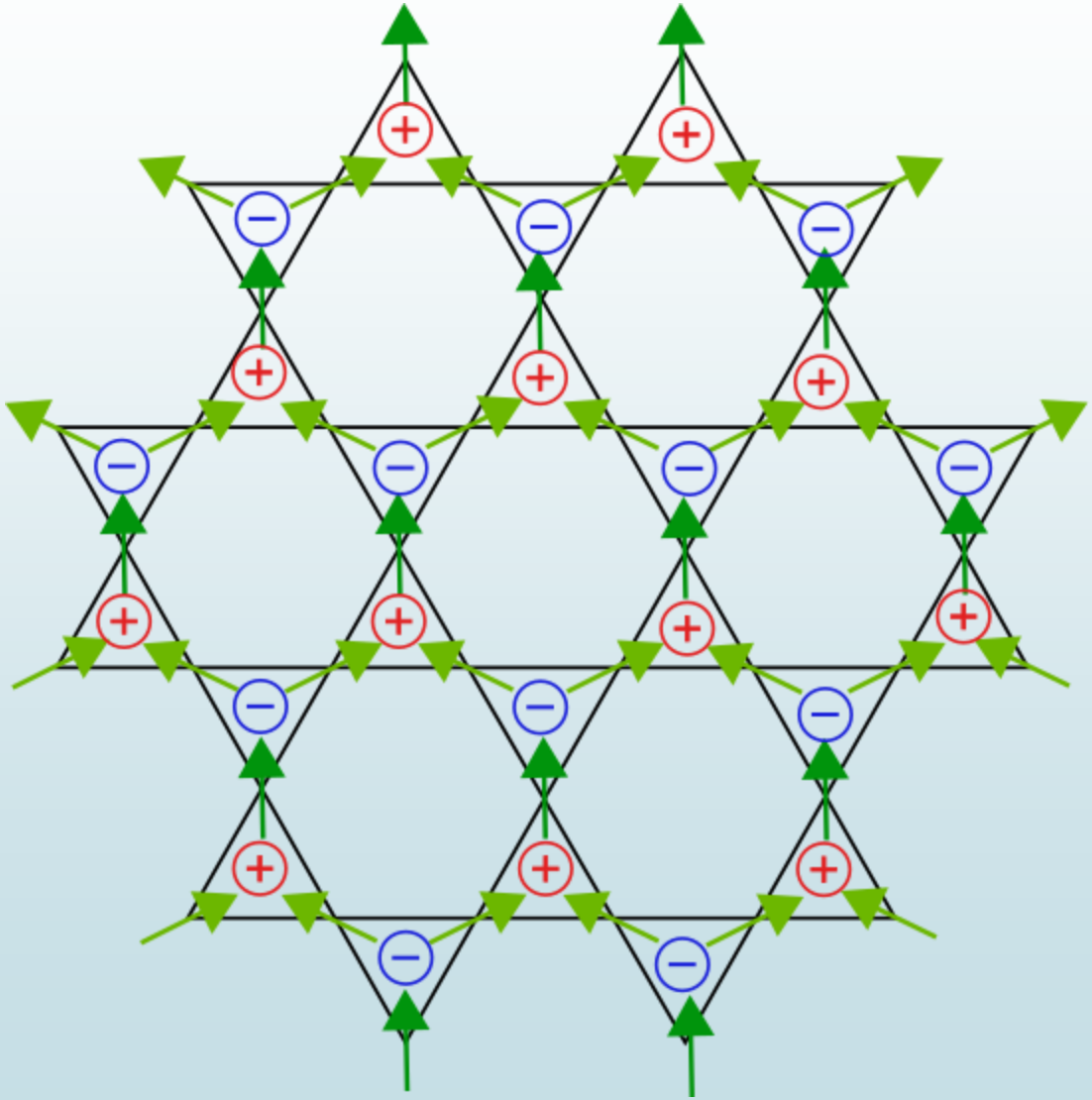
Outline

- Kasteleyn transition with field in the y direction
  - Ground state
  - Excitations
  - Topological sectors
  - Results
- BKT transition with diagonal term of quantum dimer model
  - Ground state
  - Excitations
  - Results
- Full phase diagram

Kasteleyn transition[1,2]

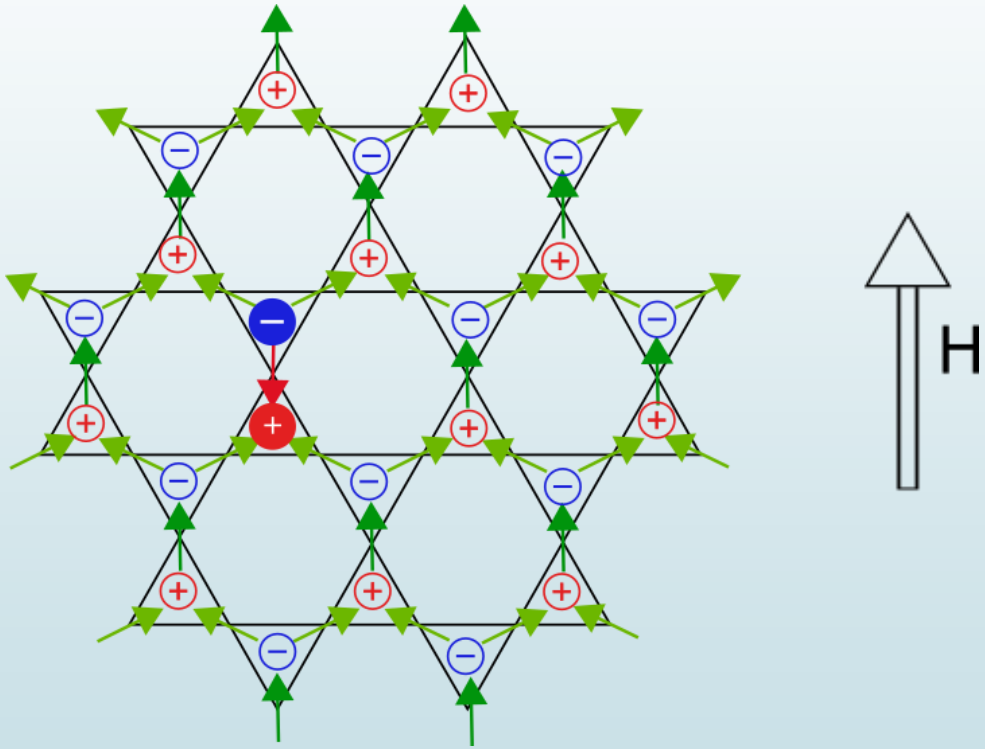
1 R. Moessner and S. L. Sondhi. “Theory of the [111] magnetization plateau in spin ice”. In:Phys. Rev . B68 (6 Aug. 2003), p. 064411. doi:10.1103/ Phys-RevB.68.064411
2 A. A. Turrini, A. Harman-Clarke, G. Haeseler, T. Fen- nell, I. G. Wood, P. Henelius, S. T. Bramwell, and P. C. W. Holdsworth, Tunable critical correlations in kagome ice, Phys. Rev . B 105, 094403 (2022)

We apply a magnetic field on the K11 phase of kagome ice

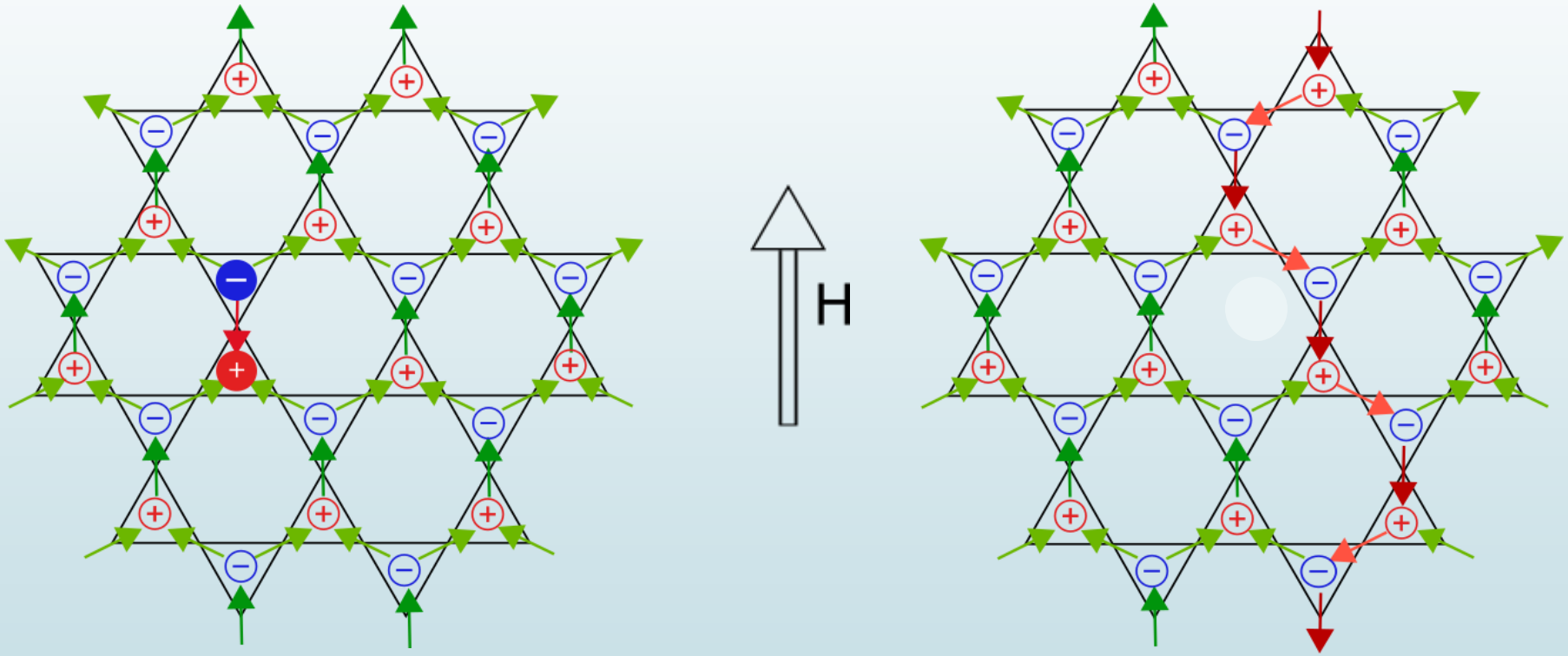


$$H = H_0 - \vec{H} \sum_{i=0}^{N} \vec{S_i}$$

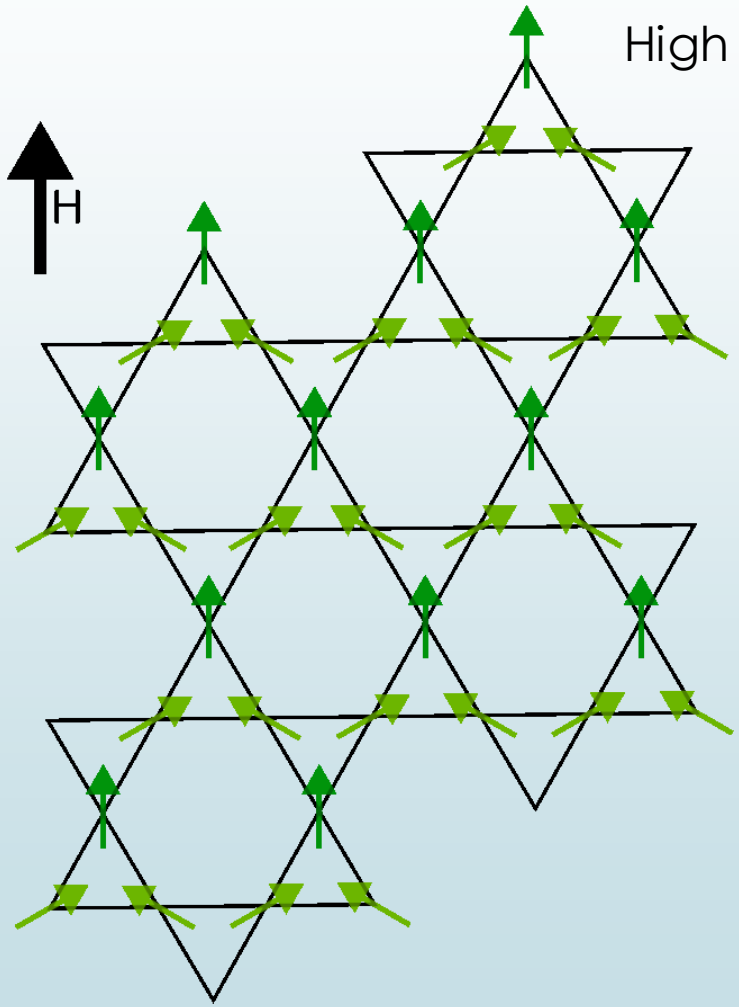
Flip a spin is not an allowed move. It would break the constrain.

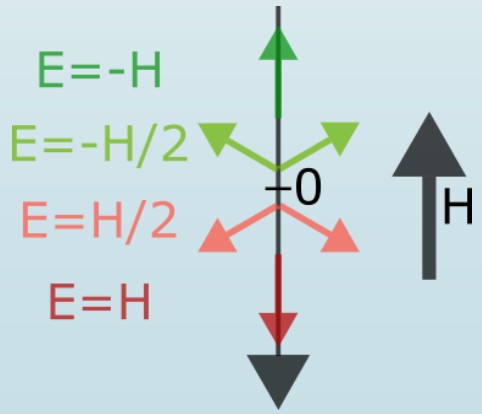


We need to flip a close loop of spins.

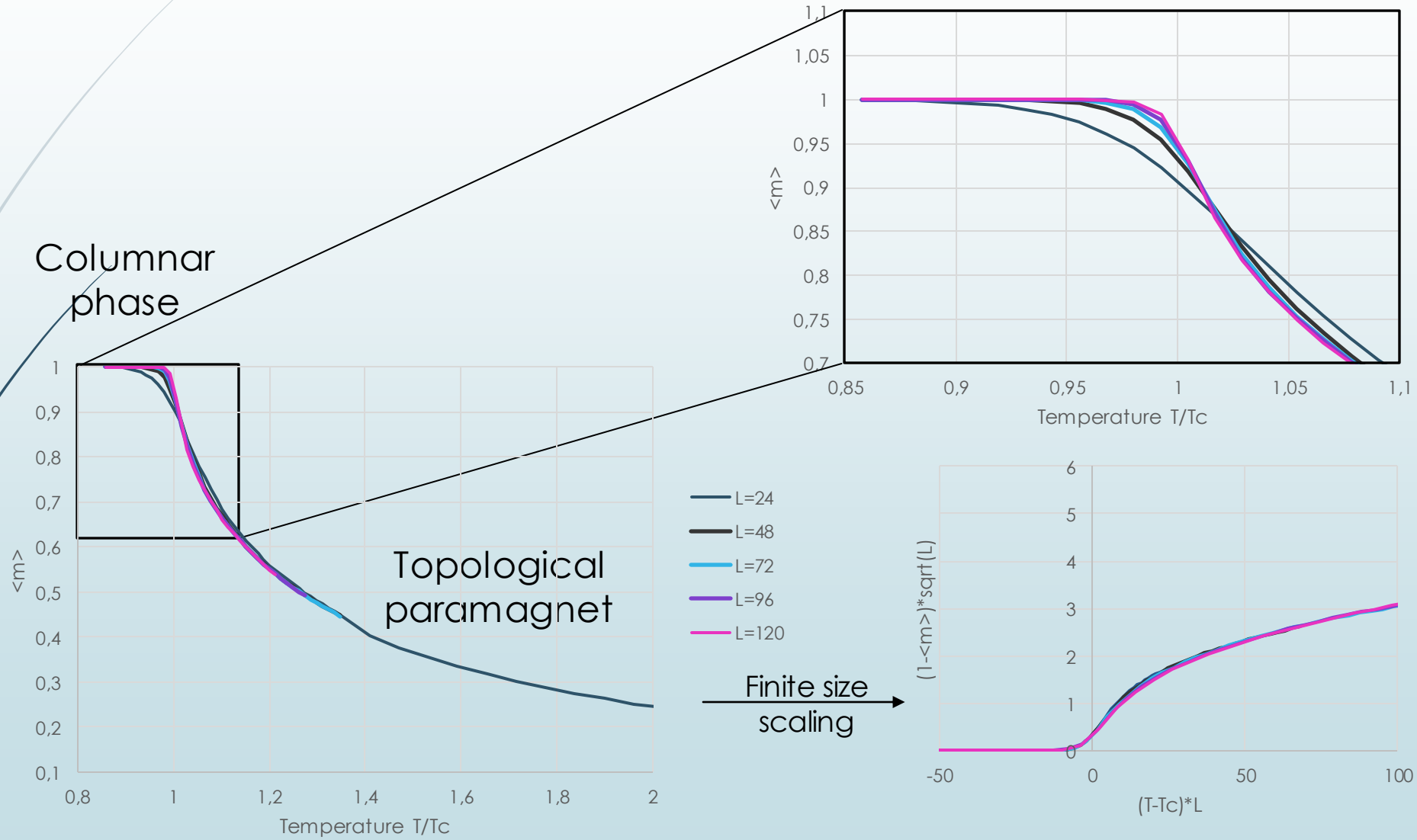


Above the critical temperature defects are unbound.





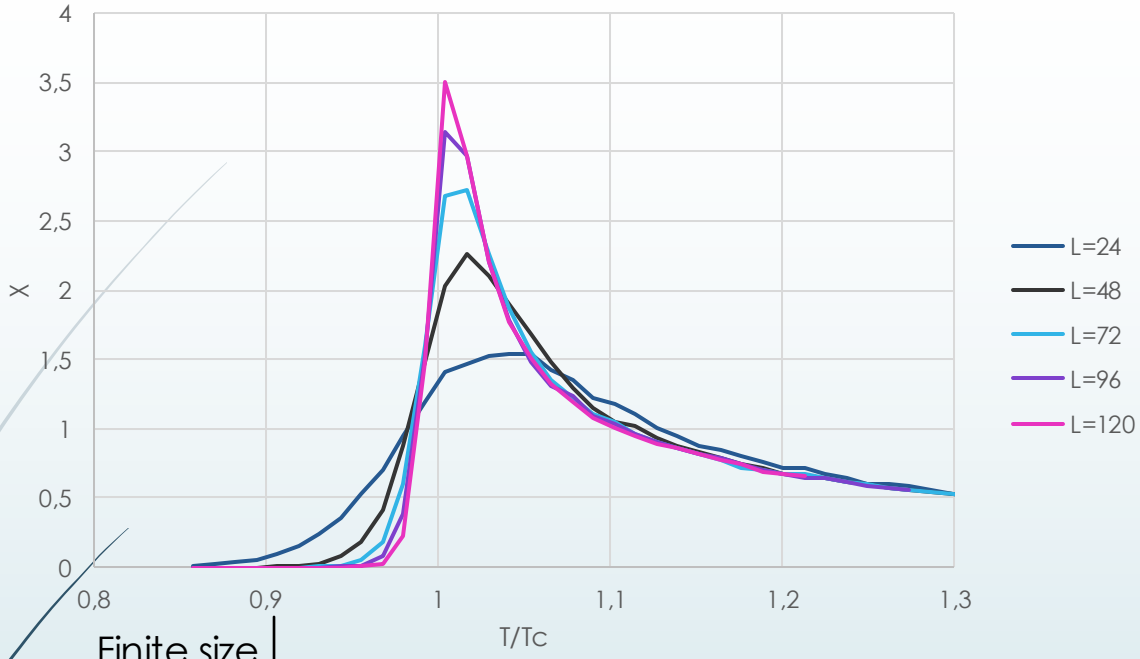
Magnetization against temperature with H=1



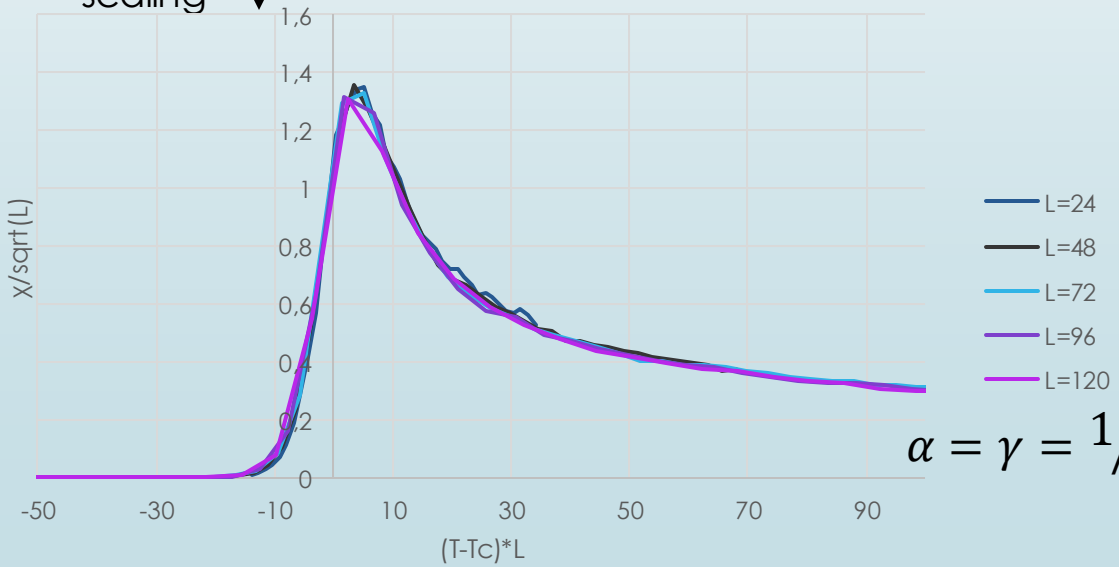
$\nu = 1$

$\beta = {}^{1}/_{2}$

Magnetic susceptibility against temperature.



Finite size scaling

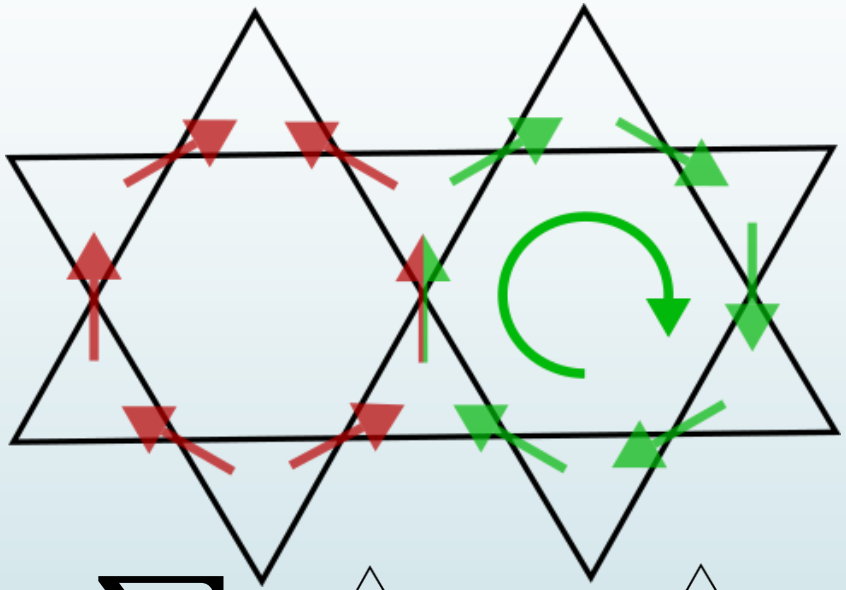


- 2nd order transition
- There is no internal energy in the system.
- No spontaneous symmetry breaking.
- Topological transition.

$$\alpha = \gamma = {}^{1}/_{2}$$

Plaquette energy
BKT transition

Diagonal term of the Hamiltonian use in quantum dimer model[1,2]

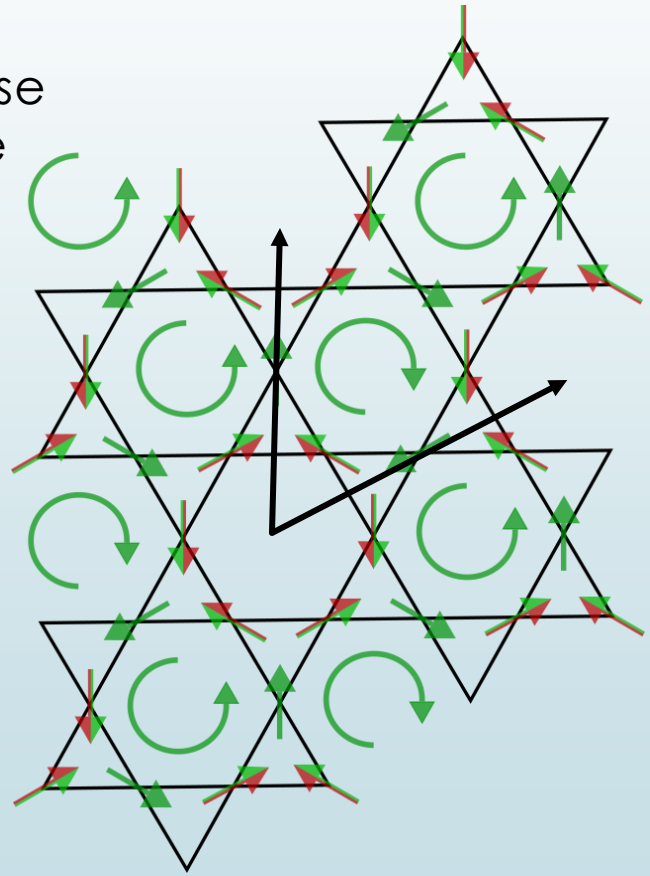


$$H_V = H_0 - V \sum_{\hexagram} |\circlearrowright\rangle\langle\circlearrowright| + |\circlearrowright\rangle\langle\circlearrowright|$$

1 R. Moessner and S. L. Sondhi. "Ising models of quantum frustration". In:Phys. Rev. B 63 (22 May 2001)
2 Thiago M. Schlittler, Rémy Mosseri, and Thomas Barthel. "Phase diagram of the hexagonal lattice quantum dimer model: Order parameters, ground-state energy, and gaps". In: Phys. Rev. B 96 (19 Nov. 2017)

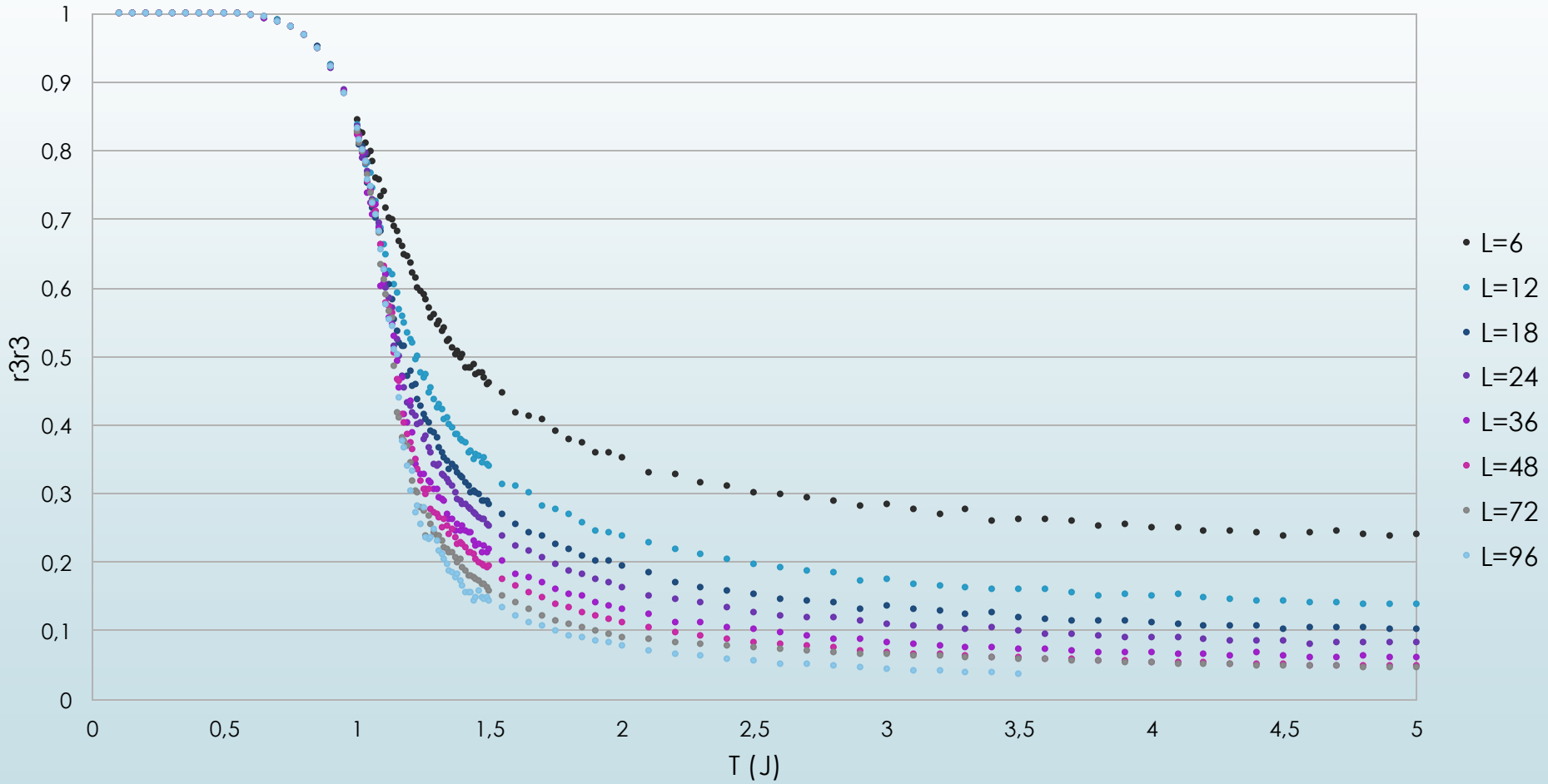
The ground state maximise the number of short loops[1]

$\sqrt{3} * \sqrt{3}$ phase
= star phase

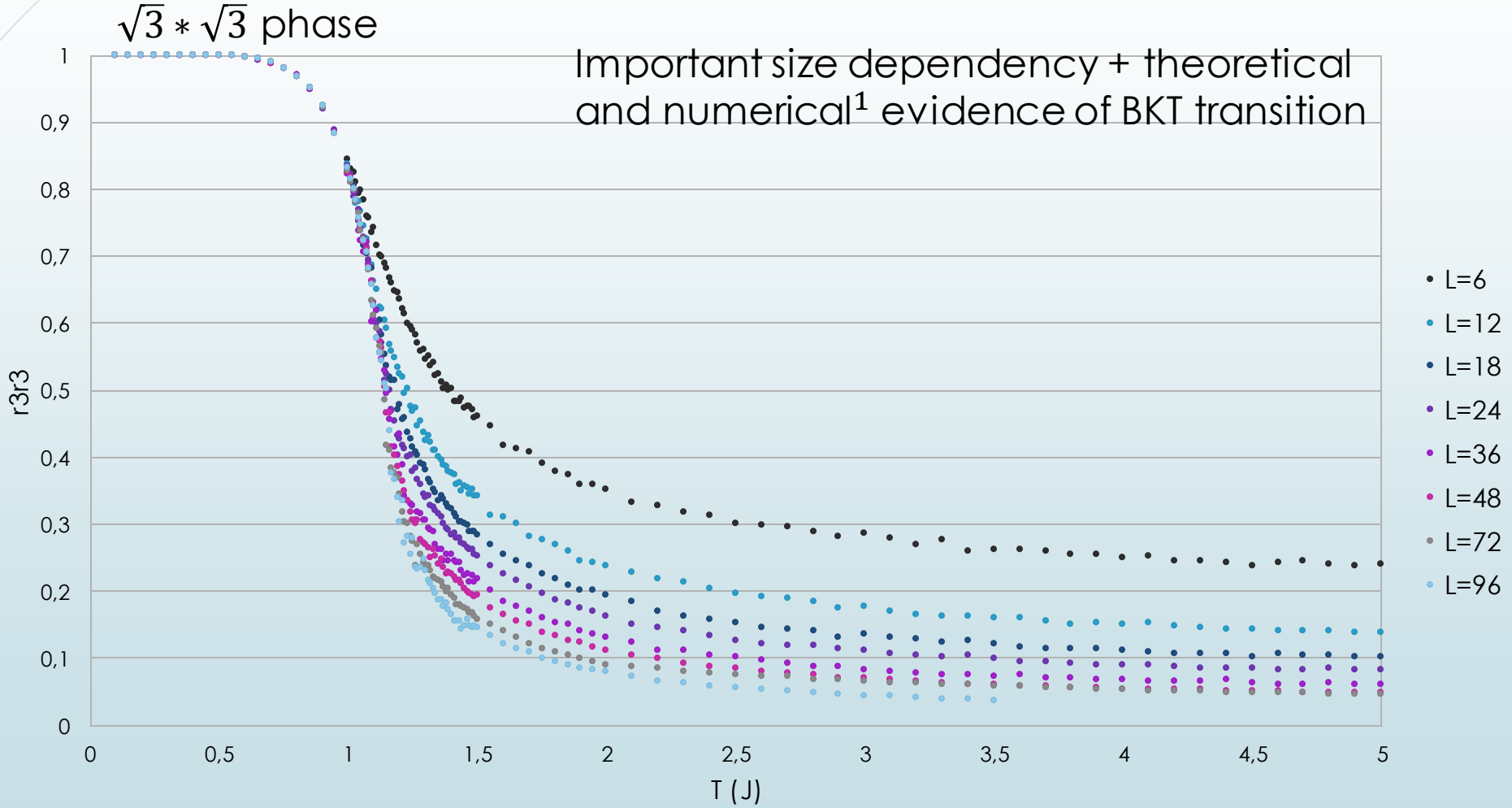


1 Fabien Alet et al. "Classical dimers with aligning interactions on the square lattice". In: Phys. Rev. E 74 (4 Oct. 2006).

Order parameter against temperature with V=1



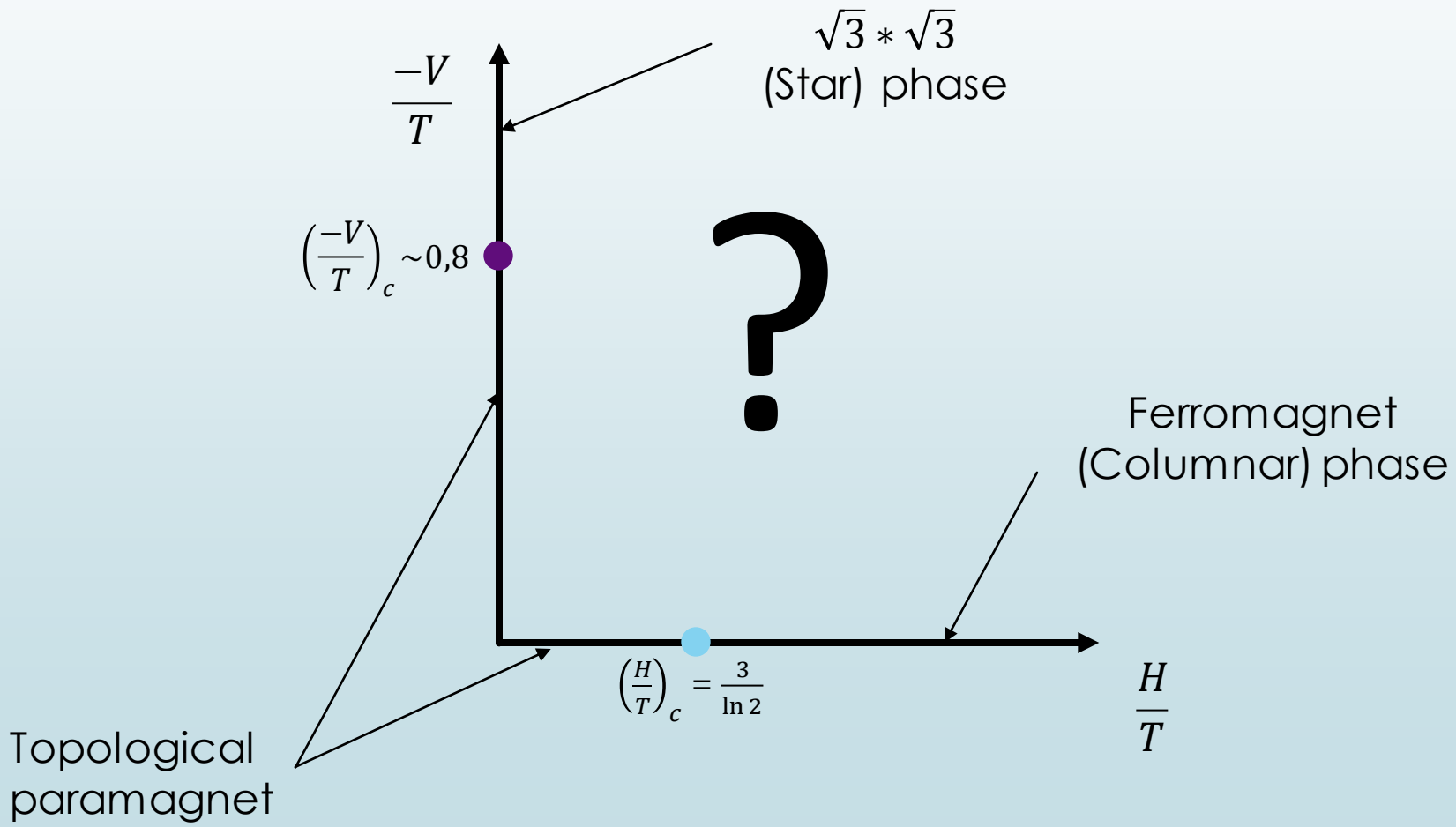
Order parameter against temperature with V=1



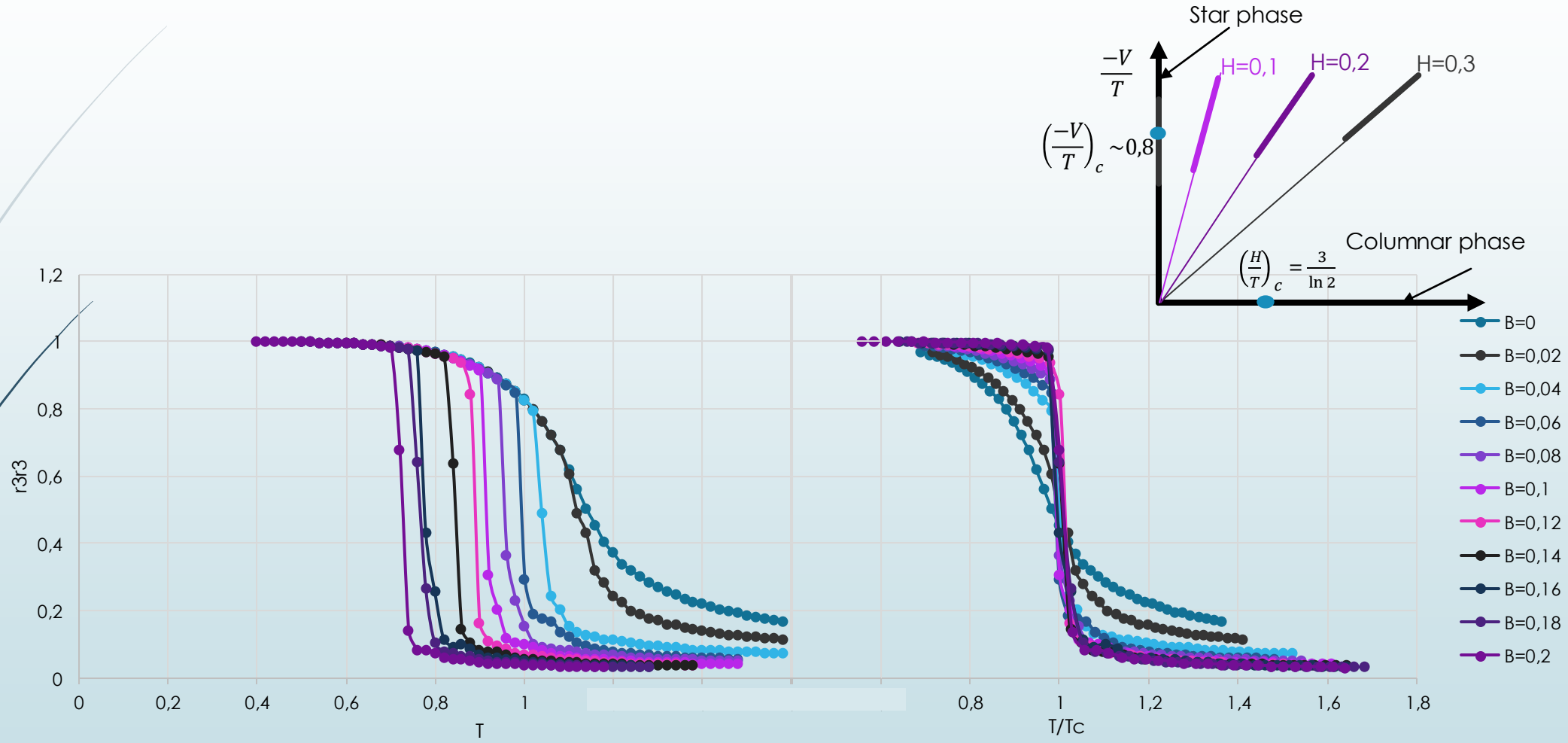
1 Fabien Alet et al. "Classical dimers with aligning interactions on the square lattice". In: Phys. Rev . E 74 (4 Oct. 2006).
2 Gia-Wei Chern, *et al*. "Two-Stage Ordering of Spins in Dipolar Spin Ice on the Kagome Lattice". PRL.106 (20 May 2011).

Full phase diagram

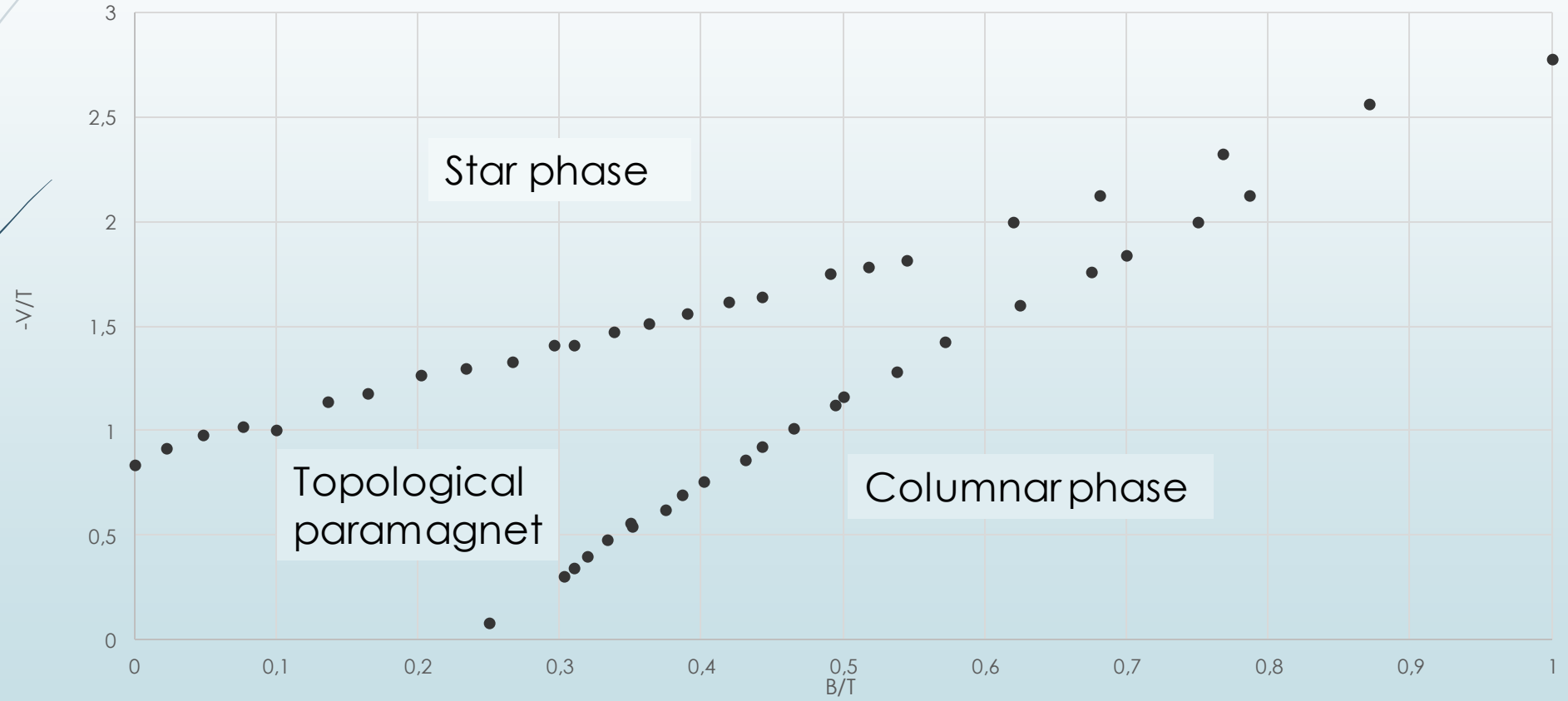
Phase diagram with both H and V?



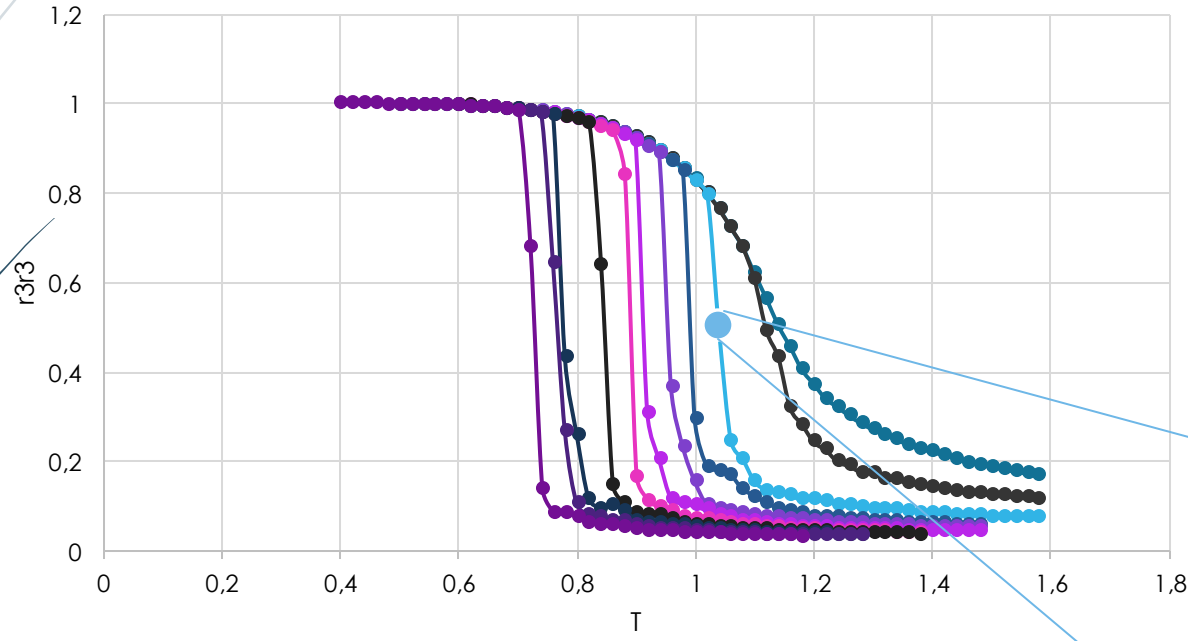
Order parameter against temperature with V=1

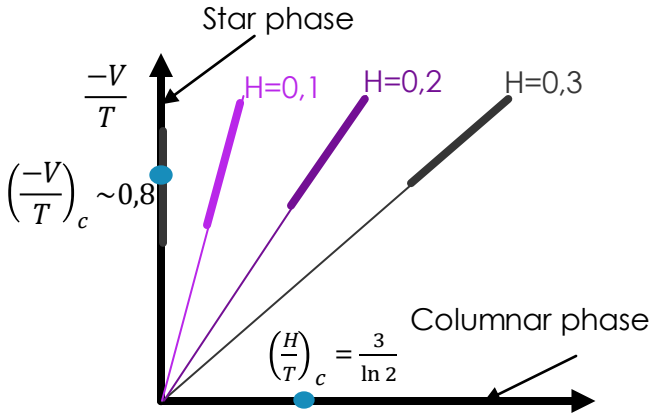


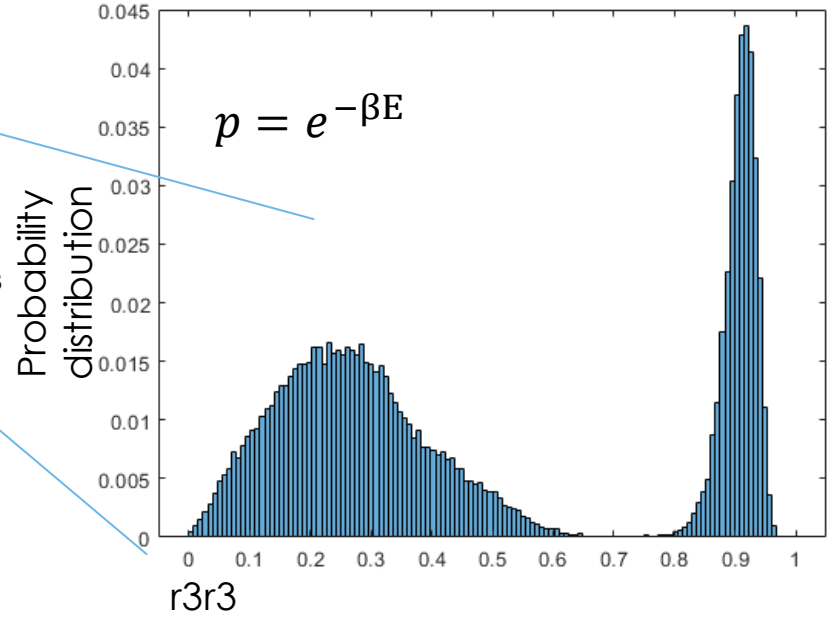
Phase diagram



Change in phase transition







Conclusion

- The H/V phase diagram is rich in non trivial phase transitions. The interface between BKT and 1st order transition remains open.

- Our next work will focus on quantum model with the introduction of off diagonal terms for short loops

Acknowledgement

I would like Fabien Alet, and Flavien Museur for their precious discussions.

Thank you for your attention!