A mechanism for kindred and camouflaged orders in a simple model

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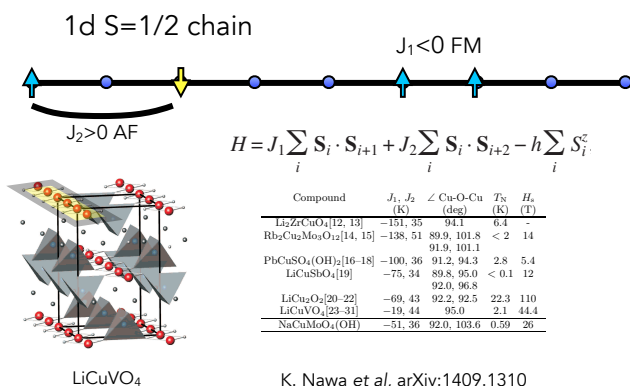
arXiv:1510.07640
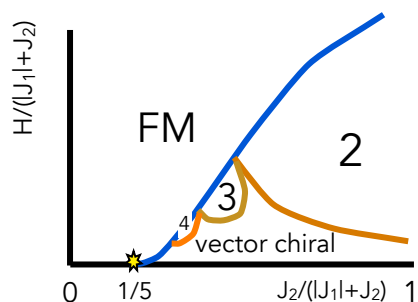
Origins of quantum complexity?

- Frustration and phase competition
- Emergent symmetry
- Quantum criticality
- Bad luck
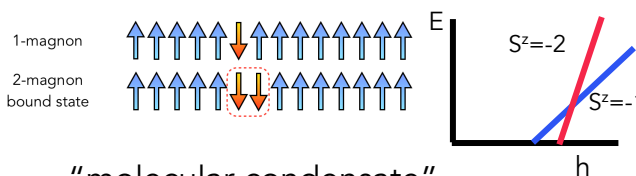- Here: bound states and quantum droplets

Model: Frustrated ferromagnet

1d S=1/2 chain

$J_1 < 0$ FM

$J_2 > 0$ AF

$$H = J_1 \sum_i \mathbf{S}_i \cdot \mathbf{S}_{i+1} + J_2 \sum_i \mathbf{S}_i \cdot \mathbf{S}_{i+2} - h \sum_i S_i^z$$

Compound	J_1, J_2 (K)	$\angle$ Cu-O-Cu (deg)	T_N (K)	H_s (T)
Li$_2$ZrCuO$_4$[12, 13]	$-151, 35$	94.1	6.4	-
Rb$_2$Cu$_2$Mo$_3$O$_{12}$[14, 15]	$-138, 51$	89.9, 101.8	< 2	14
		91.9, 101.1		
PbCuSO$_4$(OH)$_2$[16-18]	$-100, 36$	91.2, 94.3	2.8	5.4
LiCuSbO$_4$[19]	$-75, 34$	89.8, 95.0	< 0.1	12
		92.0, 96.8		
LiCu$_2$O$_2$[20–22]	$-69, 43$	92.2, 92.5	22.3	110
LiCuVO$_4$[23–31]	$-19, 44$	95.0	2.1	44.4
NaCuMoO$_4$(OH)	$-51, 36$	92.0, 103.6	0.59	26

LiCuVO$_4$

K. Nawa et al, arXiv:1409.1310

Phase diagram

H/(|J$_1$|+J$_2$)

FM

2

3

4

vector chiral

0   1/5   J$_2$/(|J$_1$|+J$_2$)   1

Hikara et al, 2008

J. Sudan et al, 2009

Multipolar phases

1-magnon

2-magnon bound state

E

$S^z = -2$

$S^z = -1$

h

"molecular condensate"

$$\Psi_n \sim \langle (S^-)^n \rangle$$

n>1: camouflaged order

{ n } = kindred orders

Lifshitz NLsM

$$S = \int dx d\tau \left\{ i s \mathcal{A}_B[\hat{m}] + \delta |\partial_x \hat{m}|^2 + K |\partial_x^2 \hat{m}|^2 + u |\partial_x \hat{m}|^4 - h \hat{m}_z \right\}$$

WZW/Berry phase term

tunes QCP

two symmetry allowed interactions at O(q^4)

z=4 QCP

$$h = \delta = 0$$

u < 0 from quantum fluctuations

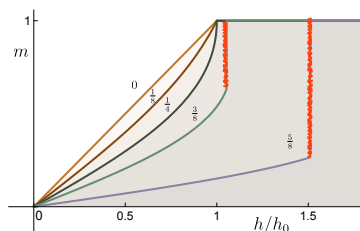## Saddle point

rescaling gives

$$S = \sqrt{\frac{K}{\delta}} \bar{S}\left(\frac{u}{K}, \frac{hK}{\delta^2}\right)$$

➡ semi-classical limit

metamagnetism

$$-1 < \frac{u}{K} < -\frac{1}{4}$$

m

0
1/8
1/4
3/8

5/8
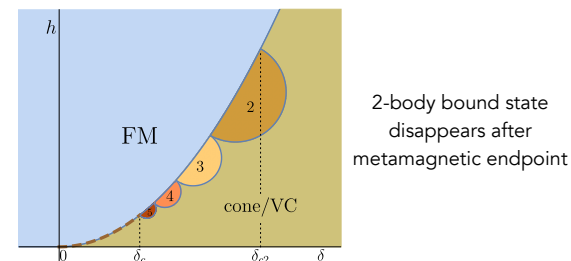
0   0.5   1   1.5 h/h_0

Quantum effects

$$\hat{m} = \sqrt{2 - \frac{\bar{\eta}\eta}{s}} \left[\frac{\bar{\eta} + \eta}{2\sqrt{s}} \hat{e}_1 + i \frac{\bar{\eta} - \eta}{2\sqrt{s}} \hat{e}_2 \right] + (1 - \frac{\bar{\eta}\eta}{s}) \hat{e}_3,$$

η becomes quantum boson field study in expansion in $\varepsilon = -(\frac{u}{K} + \frac{1}{4})$

- Calculate quantum corrections to energy density $\mathcal{E}_{FM} - \mathcal{E}_{cone} \sim \varepsilon^3 \delta^2 - \varepsilon^2 \delta^{5/2}$
- Solve two-body Schrödinger equation

h

FM

2

3

4

cone/VC

0   δ_c δ_{c2} δ

2-body bound state disappears after metamagnetic endpoint

Ramifications

- Quantum first order transitions can have hidden richness
- Finite coexistence domains become *multi-magnon bound states* (classical texture becomes quantum collective excitation)
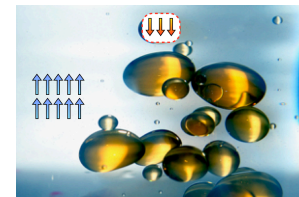
generalizations and applications to d=2,3 forthcoming