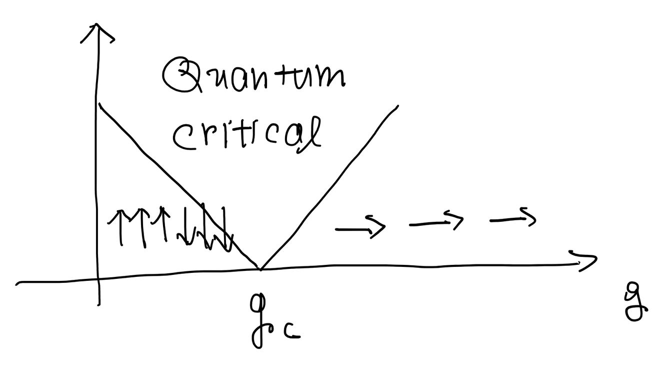
Oshikawa

Thursday, August 29, 2024 14:04



Domain wall Quasiparticles ⟷ Flipped spin Quasiparticles.

$$H = -t \sum_{\langle j,k \rangle} (c_j^{+} c_k + c_k^{+} c_j) + V \sum_{\langle j,k \rangle} n_j n_k$$

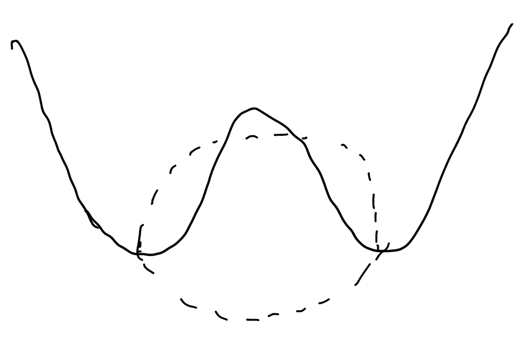
U(1) symmetry: $\begin{cases} c_j \to e^{i\theta} c_j \\ c_j^{+} \to e^{-i\theta} c_j \end{cases}$

Nambu Goldstone theorem ⟶ gapless excitation

There are many gapless systems without SSB.

However, any other mechanism for gaplessness?

Yes, if there is a lattice with translational invariance.



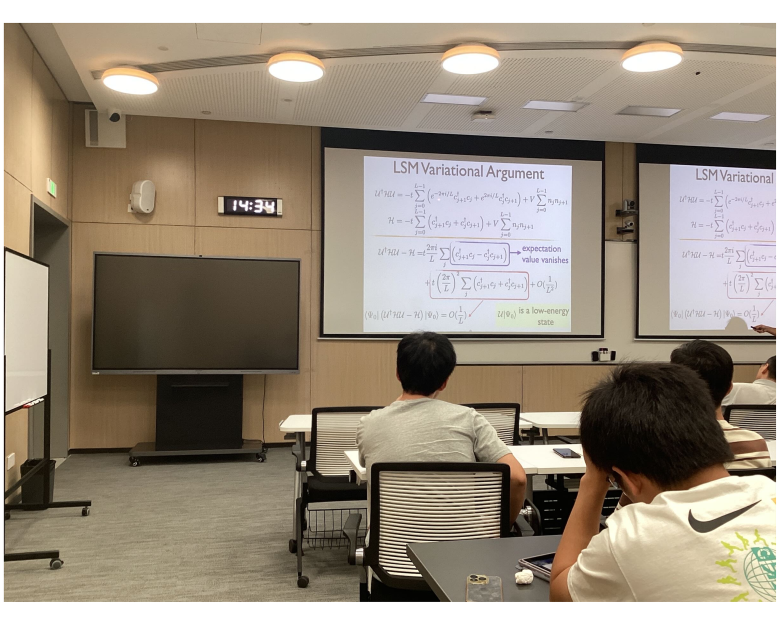
What is the difference between two system. One with gapped excitation spectrum, the other with gapless excitation spectrum. ?

LSM: U(1) + Lattice translational symmetry + spatial inversion or time reversal

U(1) Generator: $e^{i\theta N} = e^{i\theta \sum c_i^{+} c_i}$

$$U^{+} c_j U \to e^{i\theta_j} c_j$$

$$\langle \Psi_0 | U^{+} H U - H | \Psi_0 \rangle = O(\tfrac{1}{L})$$



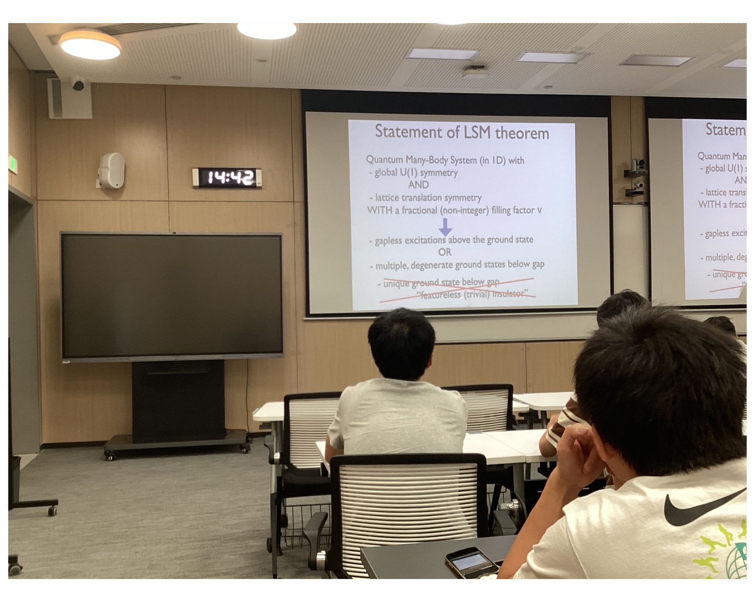
$$U^{+} H U - H = t \frac{2\pi i}{L} \sum_j (c_{j+1}^{+} c_j - c_j^{+} c_{j+1}) + t \left(\frac{2\pi}{L}\right)^2 \sum_j (c_{j+1}^{+} c_j + c_j^{+} c_{j+1}) + O(\tfrac{1}{L^2})$$

$U|\Psi_0\rangle$ could be identical to Ψ_0

$$T|\Psi_0\rangle = e^{iP_0} |\Psi\rangle$$

$$T U \Psi_0 = T U T^{+} T |\Psi_0\rangle = e^{iP_0 + i\nu n}$$

$\nu \neq$ integer

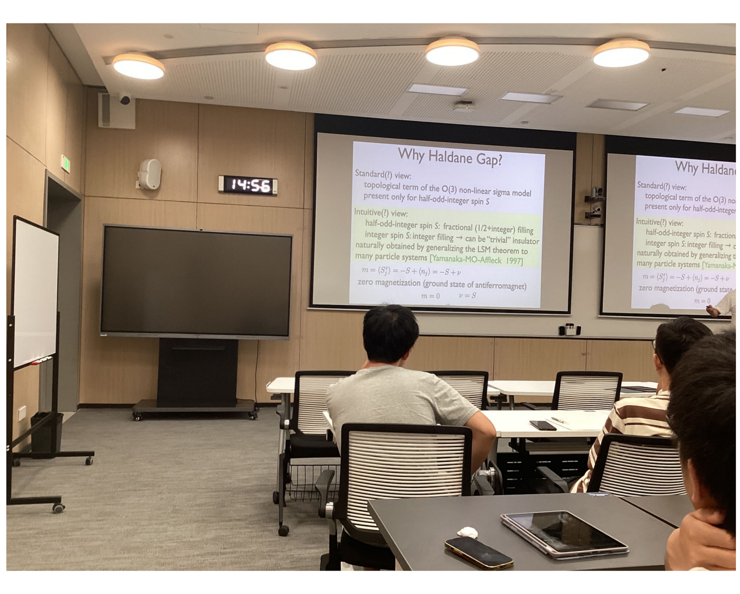


Gapped phase needs the particles to be locked, the density of particles need to be commensurate with lattice.

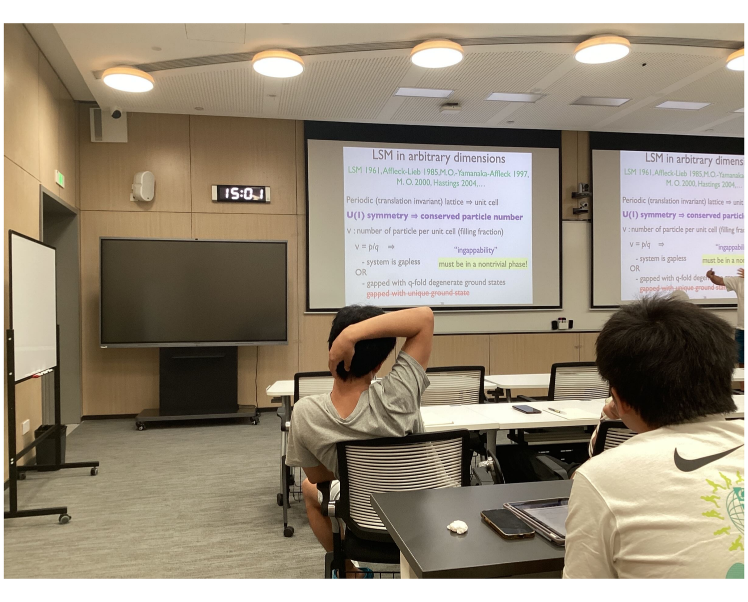
Lieb and mathins (1961)

S: half-odd integer ⟶ gapless

Yamanaka - MO - Affleck (1997)



把 SU(4) spin chain 中 LSM 搞一遍



Hooft anomaly.