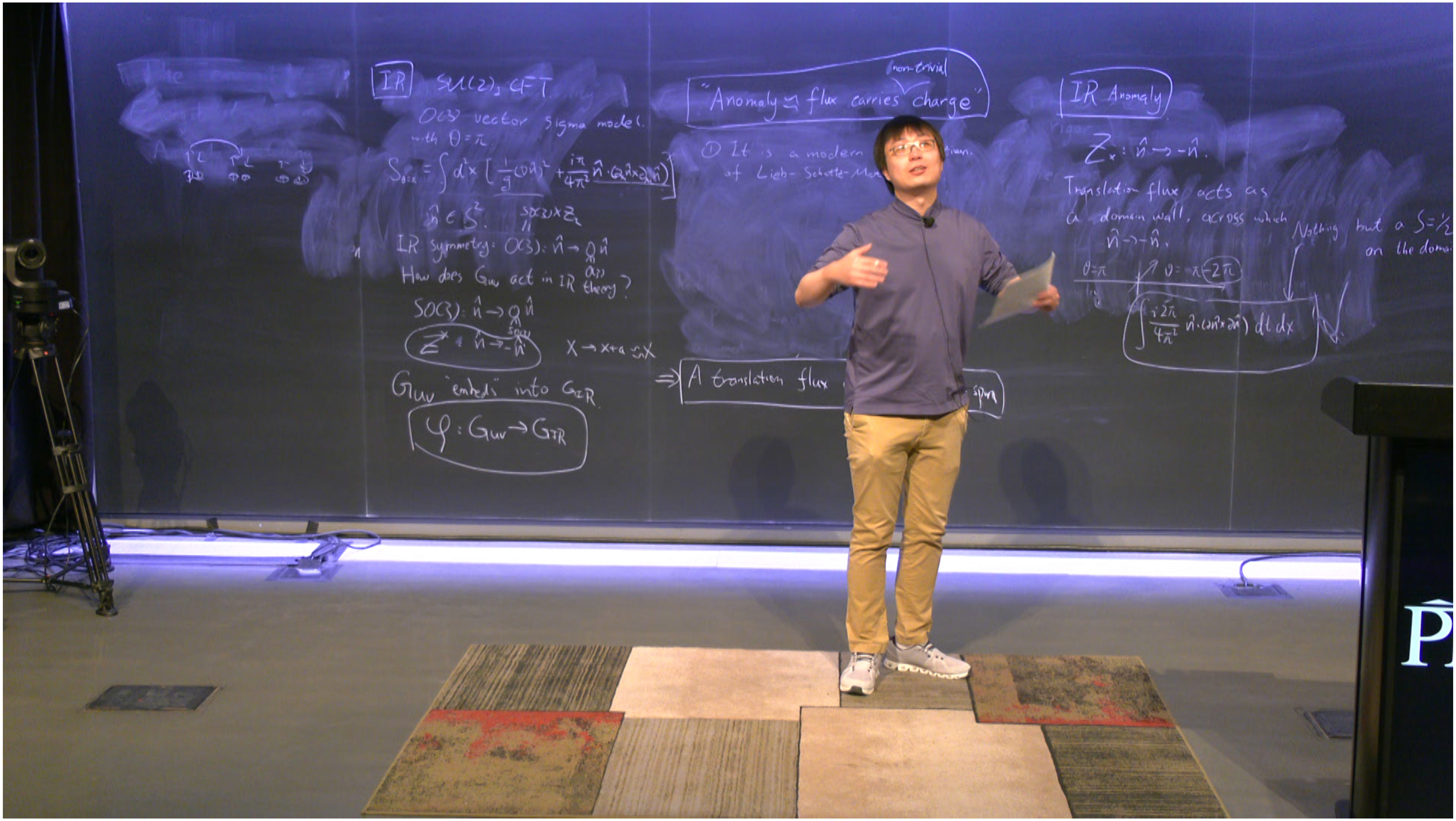
Title: Emergibility: from lattice spins to critical gauge theories and beyond - Talk 2

Speakers: Chong Wang

Collection: Quantum Criticality: Gauge Fields and Matter

Date: May 19, 2022 - 10:15 AM

URL: https://pirsa.org/22050044


IR SU(2)1 CFT
O(3) vector sigma model.
with θ = π
IR symmetry: O(3): n̂ → O n̂
How does GUV act in IR theory?
SO(3): n̂ → O n̂
X → x+a
GUV "embeds" into GIR
φ : GUV → GIR
"Anomaly ≃ flux carries non-trivial charge"
① It is a modern
A translation flux
IR Anomaly
Zx : n̂ → -n̂.
Translation flux acts as a domain wall, across which n̂ → -n̂.
Nothing but a S=1/2

igma model.

$$+\frac{i\pi}{4\pi^2}\hat{n}\cdot(\partial_{x_1}\hat{n}\times\partial_{x_2}\hat{n})$$

$\times \mathbb{Z}_2$

$\hat{n} \to O\,\hat{n}$, $O \in O(3)$

IR theory?

$X \to X + a \cdot \hat{n}_1 X$

Anomaly $\rightsquigarrow$ flux carries charge

① It is a modern manifestation of Lieb-Schultz-Mattis Thm.

$\Rightarrow$ A translation flux carries half-integer spin

...gma model.

$$+\frac{i\pi}{4\pi^2}\hat{n}\cdot(\partial_x\hat{n}\times\partial_\tau\hat{n})$$

$\times \mathbb{Z}_2$

$\hat{n} \to O\hat{n}$, $O \in O(3)$

IR theory?

$X \to X + a$

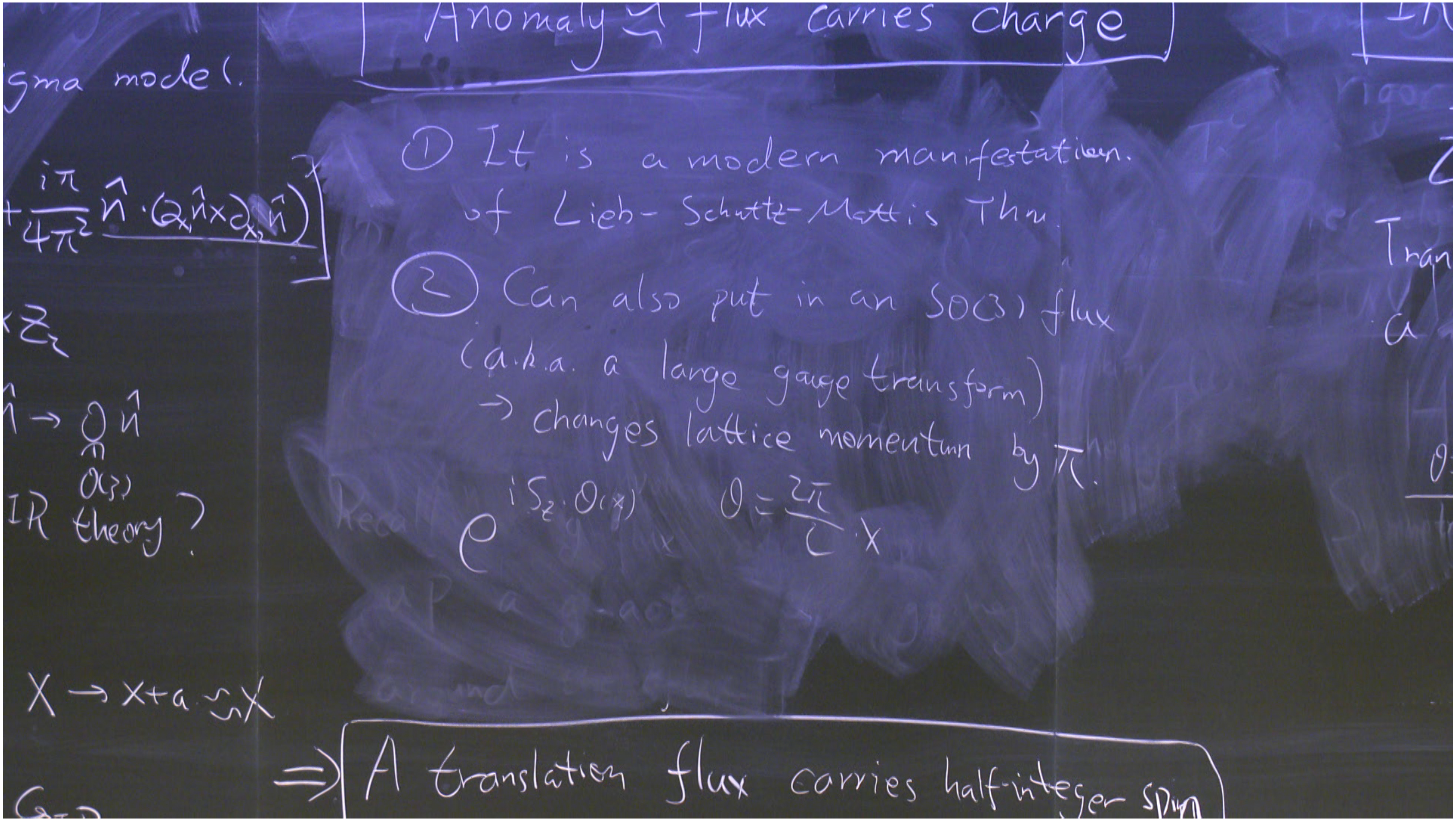
$$\boxed{\text{Anomaly} \Leftrightarrow \text{flux carries charge}}$$

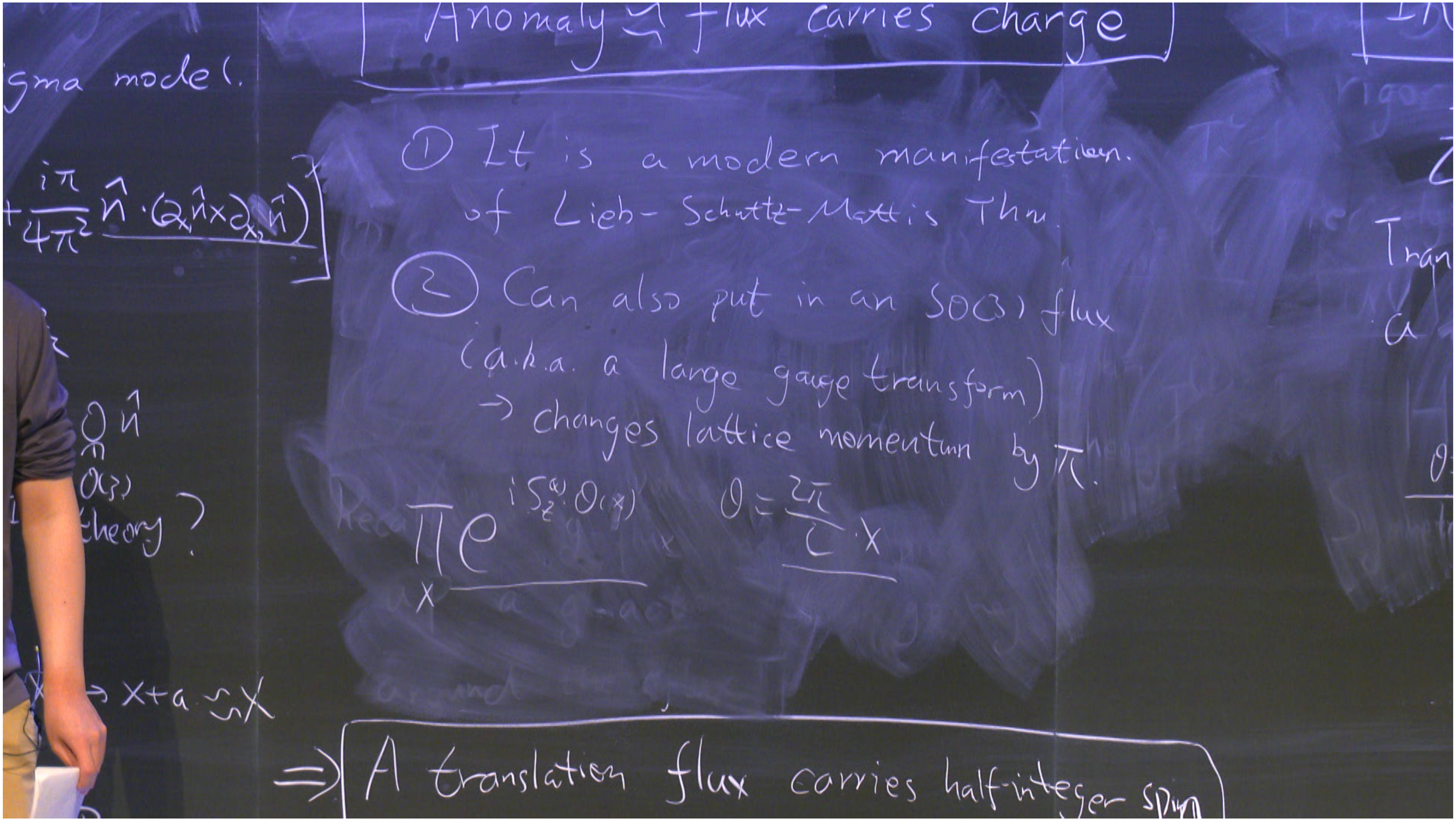
① It is a modern manifestation of Lieb-Schultz-Mattis Thm.

② Can also put in an SO(3) flux (a.k.a. a large gauge transform)

→ changes lattice momentum by π!

$\Rightarrow$ $\boxed{\text{A translation flux carries half-integer spin}}$


Anomaly ⇝ flux carries charge
① It is a modern manifestation of Lieb-Schultz-Mattis Thm.
② Can also put in an SO(3) flux
(a.k.a. a large gauge transform)
→ changes lattice momentum by π.
$e^{iS_z \cdot \theta(x)}$
$\theta = \frac{2\pi}{L} \cdot x$
$\Rightarrow$ A translation flux carries half-integer spin
gma model.
$+\frac{i\pi}{4\pi^2}\hat{n}\cdot(\partial_x\hat{n}\times\partial_{x_2}\hat{n})$
$\times \mathbb{Z}_2$
$\hat{n} \to O\hat{n}$
$O(3)$
IR theory?
$X \to X + a \cdot \hat{n}_x$
Tran


Anomaly ≃ flux carries charge
① It is a modern manifestation of Lieb-Schultz-Mattis Thm.
② Can also put in an SO(3) flux (a.k.a. a large gauge transform)
→ changes lattice momentum by π.
$\prod_x e^{iS_z^{(x)} \theta(x)}$ $\theta = \frac{2\pi}{L} x$
⇒ A translation flux carries half-integer spin
igma model.
$+\frac{i\pi}{4\pi^2} \hat{n} \cdot (\partial_x \hat{n} \times \partial_x \hat{n})$
theory ?
$x \to x + a$

$\boxed{\text{Anomaly} \Leftrightarrow \text{flux carries charge}}$

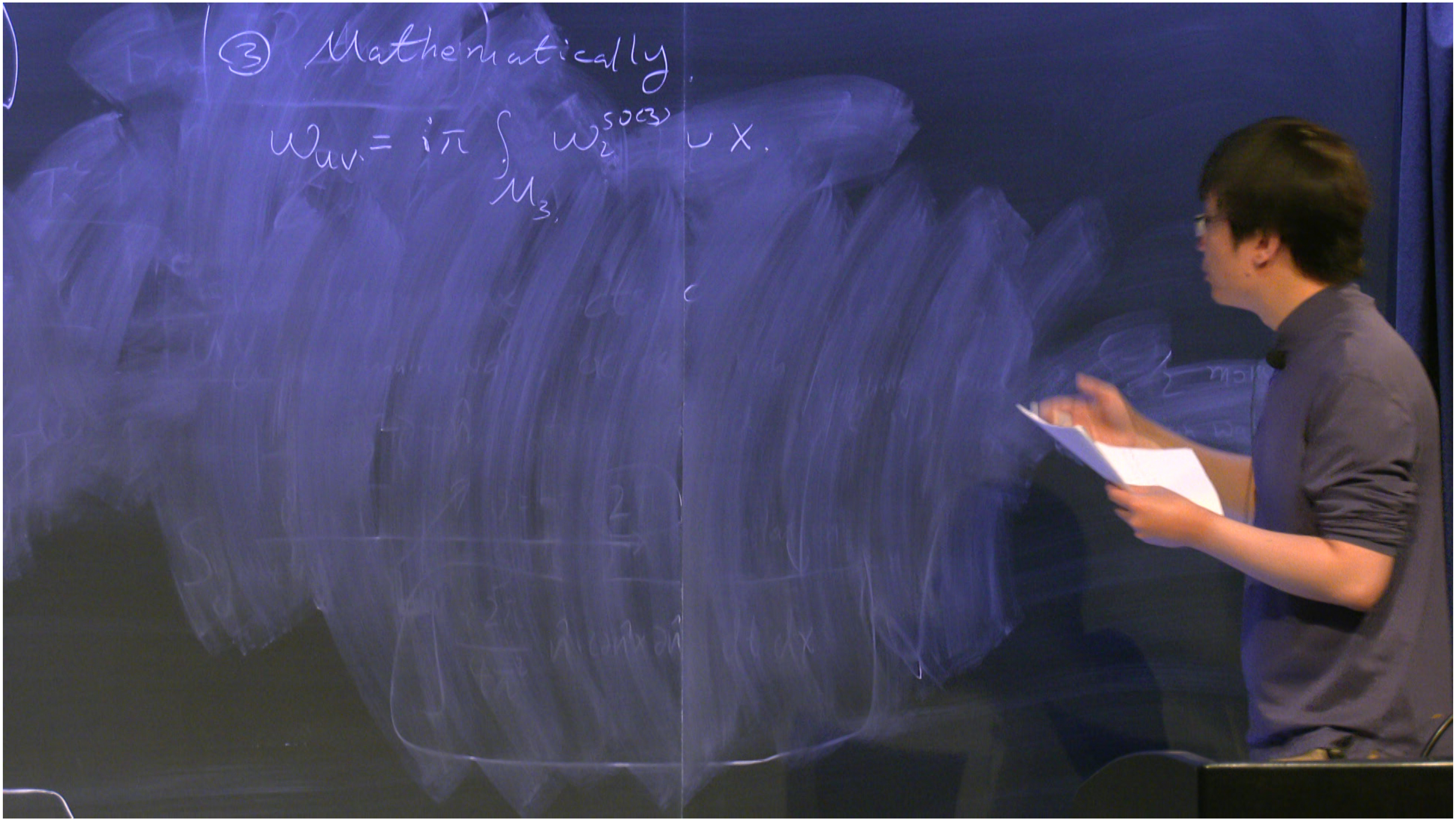
① It is a modern manifestation of Lieb-Schultz-Mattis Thm.

② Can also put in an $SO(3)$ flux (a.k.a. a large gauge transform)

$\rightarrow$ changes lattice momentum by π.

$$\prod_x e^{i\frac{\sigma_z(x)}{2}\cdot\theta(x)} \qquad \theta = \frac{2\pi}{L}\cdot x$$

$\Rightarrow$ $\boxed{\text{A translation flux carries half-integer spin}}$


③ Mathematically.
$\omega_{UV} = i\pi \int_{M_3} w_2^{SO(3)} \cup x.$

③ Mathematically.

$$\omega_{UV} = i\pi \int_{M_3} w_2^{SO(3)} \cup x, \quad \omega_{IR} = i\pi \int_{M_3} w_3^{O(3)}.$$

③ Mathematically.

$$\omega_{UV} = i\pi \int_{M_3} w_2^{SO(3)} \cup X. \quad , \quad \omega_{IR} = i\pi \int_{M_3} w_3^{O(3)}.$$

Symmetry embedding $\varphi : G_{UV} \to G_{IR}$.

Anomaly matching means $\varphi^*(\omega_{IR}) = \omega_{UV}$.

③ Mathematically.

$$\omega_{UV} = i\pi \int_{M_3} w_2^{SO(3)} \cup x \,, \quad \omega_{IR} = i\pi \int_{M_3} w_3^{O(3)}.$$

Symmetry embedding $\varphi : G_{UV} \to G_{IR}$.

Anomaly matching means $\varphi^*(\omega_{IR}) = \omega_{UV}$. (*)

For given ω_{UV} and ω_{IR}, (*) becomes an algebraic equation on φ.

③ Mathematically.

$$\omega_{UV} = i\pi \int_{M_3} w_2^{SO(3)} \cup x \,, \quad \omega_{IR} = i\pi \int_{M_3} w_3^{O(3)}.$$

Symmetry embedding $\varphi : G_{UV} \to G_{IR}$.

Anomaly matching means $\varphi^*(\omega_{IR}) = \omega_{UV}$. (*)

For given ω_{UV} and ω_{IR}, (*) becomes an algebraic equation on φ, i.e. on possible realizations of UV symmetry in IR.

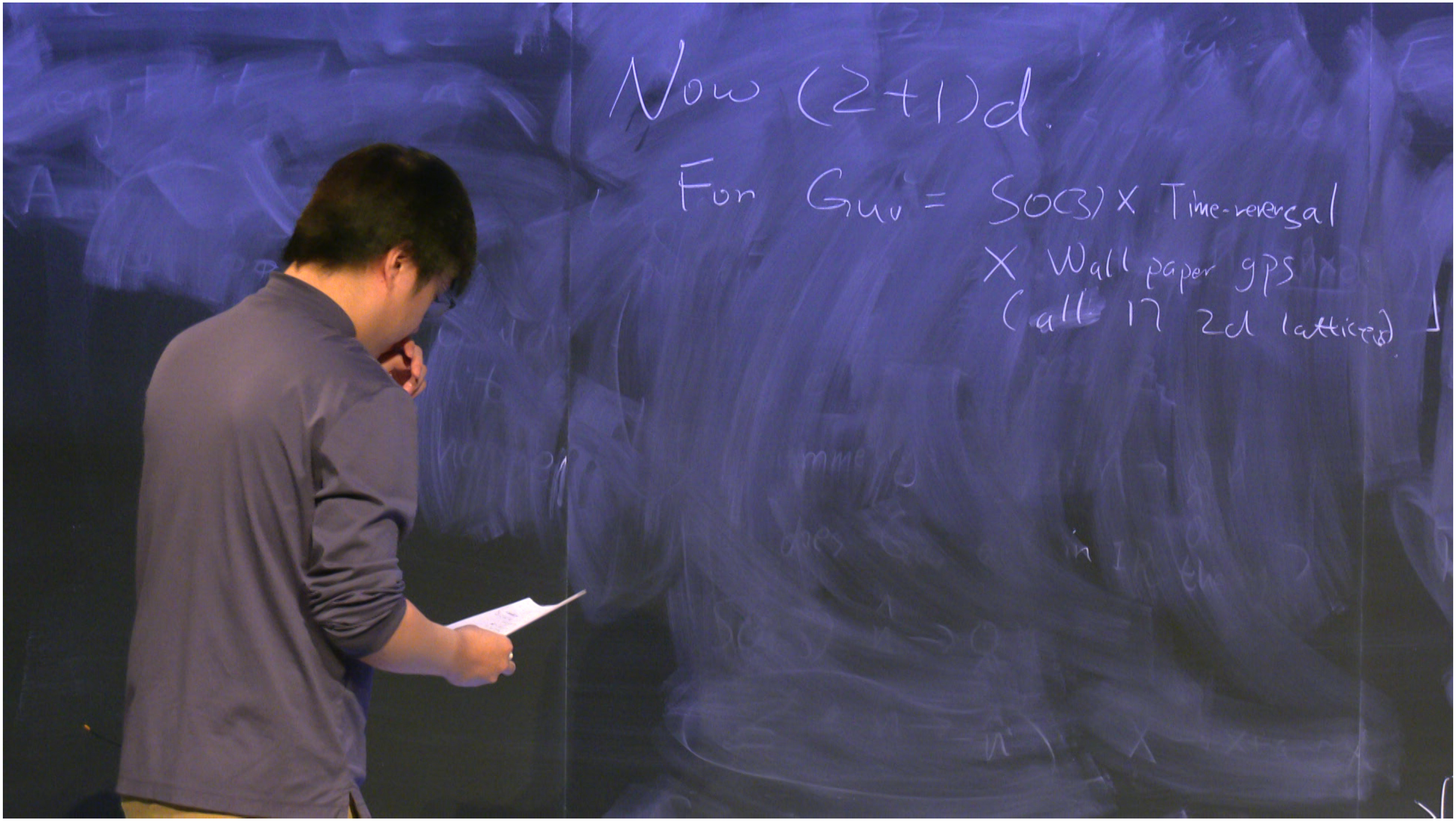
③ Mathematically.

$$\omega_{UV} = i\pi \int_{M_3} w_2^{SO(3)} \cup x \,, \quad \omega_{IR} = i\pi \int_{M_3} w_3^{O(3)}.$$

Symmetry embedding $\varphi : G_{UV} \to G_{IR}$.

Anomaly matching means $\boxed{\varphi^*(\omega_{IR}) = \omega_{UV} \quad (*)}$

For given ω_{UV} and ω_{IR}, $(*)$ becomes an algebraic equation on φ, i.e. on possible realizations of UV symmetry in IR.


Now (2+1)d.
For G_UV = SO(3) × Time-reversal
× Wall paper gps
(all 17 2d lattices)

Now (2+1)d.

For $G_{UV} = SO(3) \times$ Time-reversal

$\times$ Wall paper gps

(all 17 2d lattices)

W_{UV} listed in 2111.12097

Now (2+1)d.

For G_{uv} = SO(3) × Time-reversal
× Wall paper gps
(all 17 2d lattices)

W_{uv} listed in 2111.12097

Some results:

- The "standard" DQCP (square & honeycomb) and U(1) Dirac Spin liquids (triangular & Kagome)
($N_f = 4$ QED_3)

Anomaly $\Leftrightarrow$ flux carries charge

(1) A "non-parton" U(1) Dirac spin liquid

$$\mathcal{L} = \sum_{i=1}^{4} \bar{\psi}_i \, i \not{D}_a \psi_i + \frac{1}{4e^2} f_{\mu\nu}^2$$

al

ttices)

honeycomb)

2 Kagome)

ates

(3) Mathem

$\omega_{UV} = i\pi$

Symme

Anomaly

For given U

on φ_1 :

Anomaly ⇔ flux carries charge

(1) A "non-parton" $U(1)$ Dirac spin liquid.

$$\mathcal{L} = \sum_{i=1}^{4} \bar{\psi}_i \, i \not{D}_a \psi_i + \frac{1}{4e^2} f_{\mu\nu}^2$$

ψ_i form a spin-$3/2$ rep of $SO(3)$

Anomaly calculation ⇒ Emergible on any inter-spin lattice

(3) ...

$\omega_{UV} = i\pi$

Symme...

Anomaly

For given ...

on ψ_i ...

$\boxed{\text{Anomaly} \Leftrightarrow \text{flux carries charge}}$

(1) A "non-parton" $U(1)$ Dirac spin liquid.

$$\mathcal{L} = \sum_{i=1}^{4} \bar{\psi}_i \, i \not{D}_a \psi_i + \frac{1}{4e^2} f_{\mu\nu}^2$$

ψ_i form a spin-$3/2$ rep of $SO(3)$

Anomaly calculation $\Rightarrow$ Emergible on any inter-spin lattice ($S = \frac{1}{2}$ on honeycomb also O.K.)

Anomaly ⇒ flux carries charge

① A "non-parton" $U(1)$ Dirac spin liquid.

$$\mathcal{L} = \sum_{i=1}^{4} \bar{\psi}_i \, i \not{D}_a \psi_i + \frac{1}{4e^2} f_{\mu\nu}^2$$

ψ_i form a spin-$3/2$ rep of $SO(3)$

Anomaly calculation ⇒ Emergible on any inter-spin lattice ($S=\frac{1}{2}$ on honeycomb also o.k.)

The most relevant spin excitations carry spin-2.

$W_{u.v.} = i\pi$

Symme

Anomaly

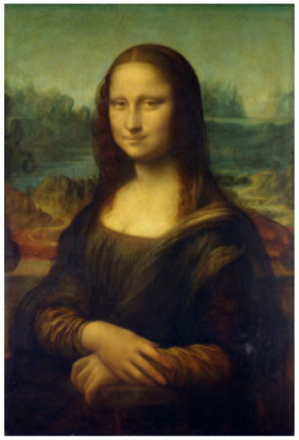
For given

on φ_1

The meaning of "constructing" a phase on lattice

- Classic:

$$J\sum \mathbf{S}_i \cdot \mathbf{S}_j \to J\sum \langle \mathbf{S}_i \rangle \cdot \mathbf{S}_j$$



- Modern:

$$\mathbf{S} = \frac{1}{2} f_\alpha^\dagger \sigma_{\alpha\beta} f_\beta$$

$$H_{MF} = \sum_{ij} t_{ij} f_i^\dagger f_j$$

- Postmodern?

$$\varphi : G_{UV} \to G_{IR}$$

$$w[G_{UV}] = \varphi^* w[G_{IR}]$$