Title: Entanglement Entropy in nonAbelian Gauge Theories

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Abstract:

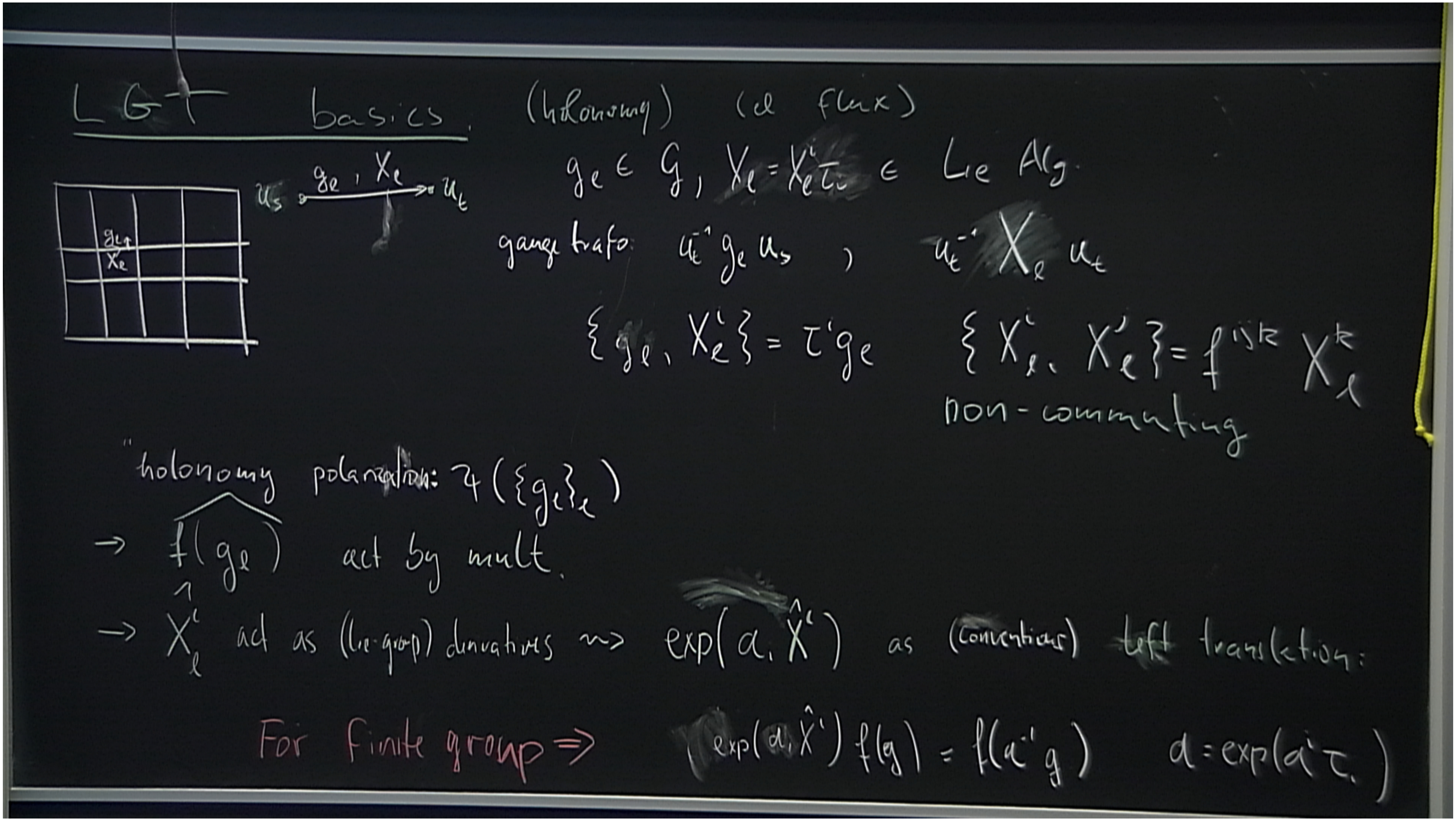
Basis of gauge-invariant states in LGT ?

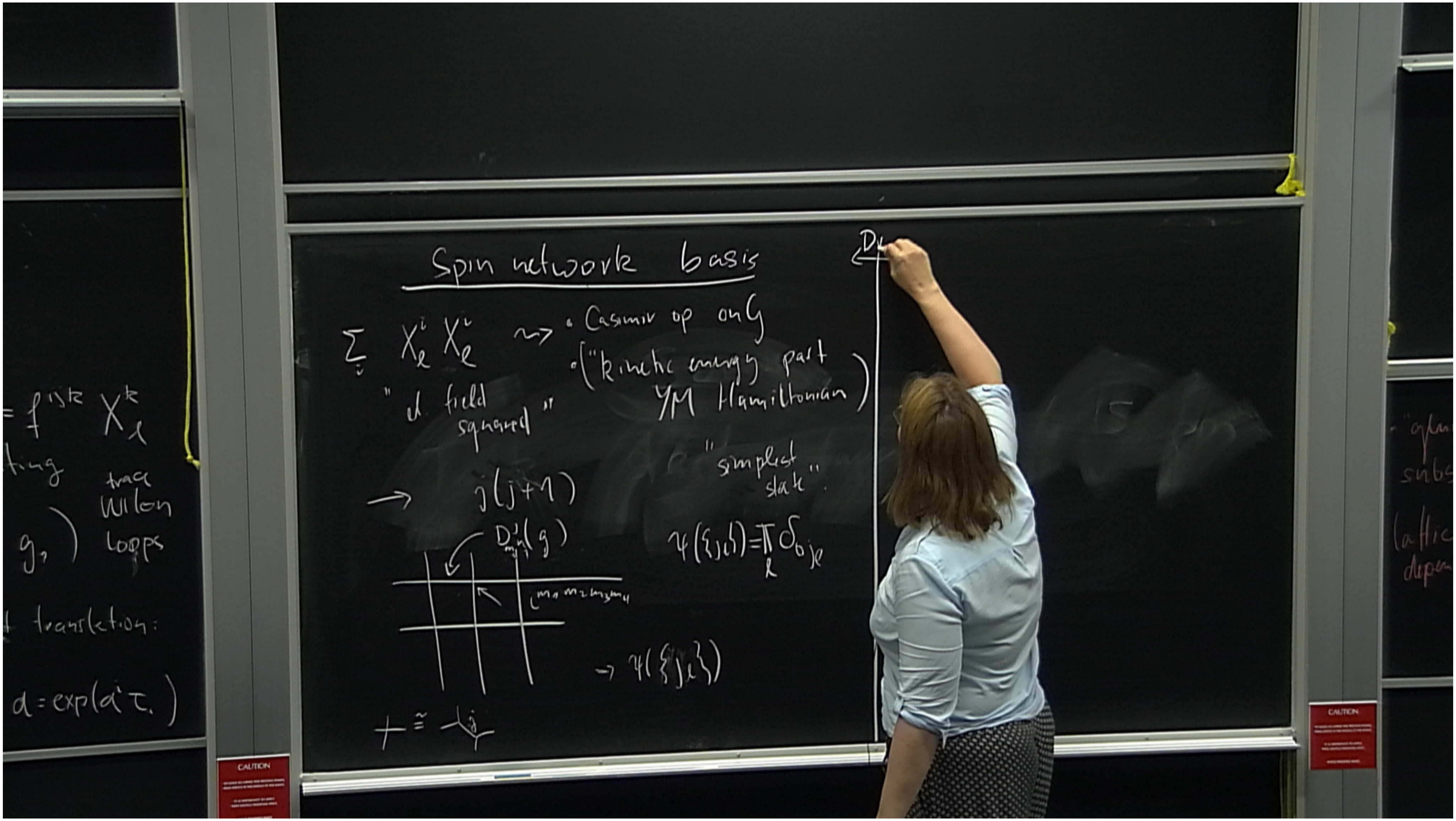
Spin network basis
simplest state / vacuum
(Donnelly) notion of entanglement entropy
(Donnelly & Freidel) notion of subsystem (gluing)
(Casini et al) "electric centre"

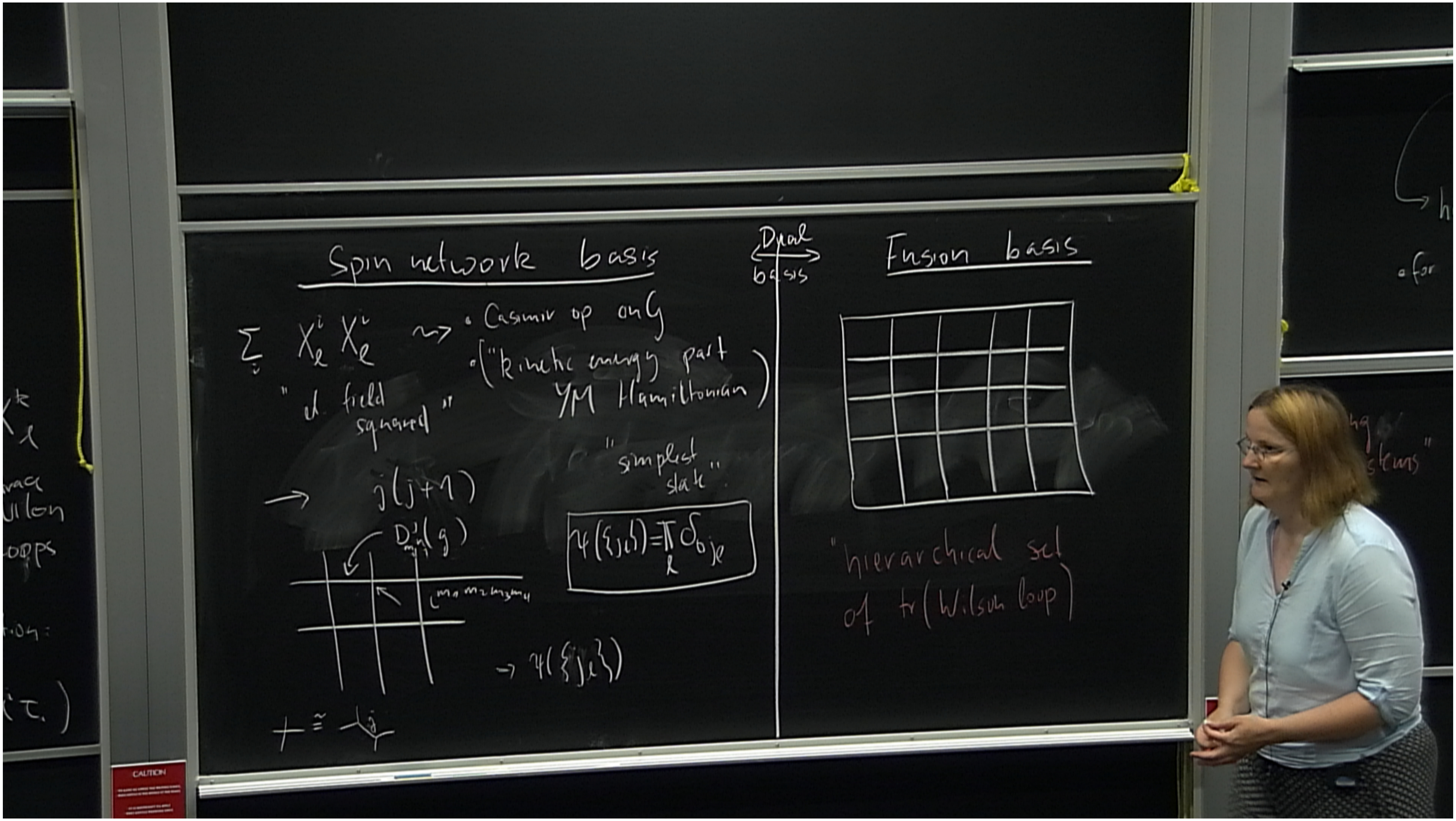
* inconvenient for coarse graining

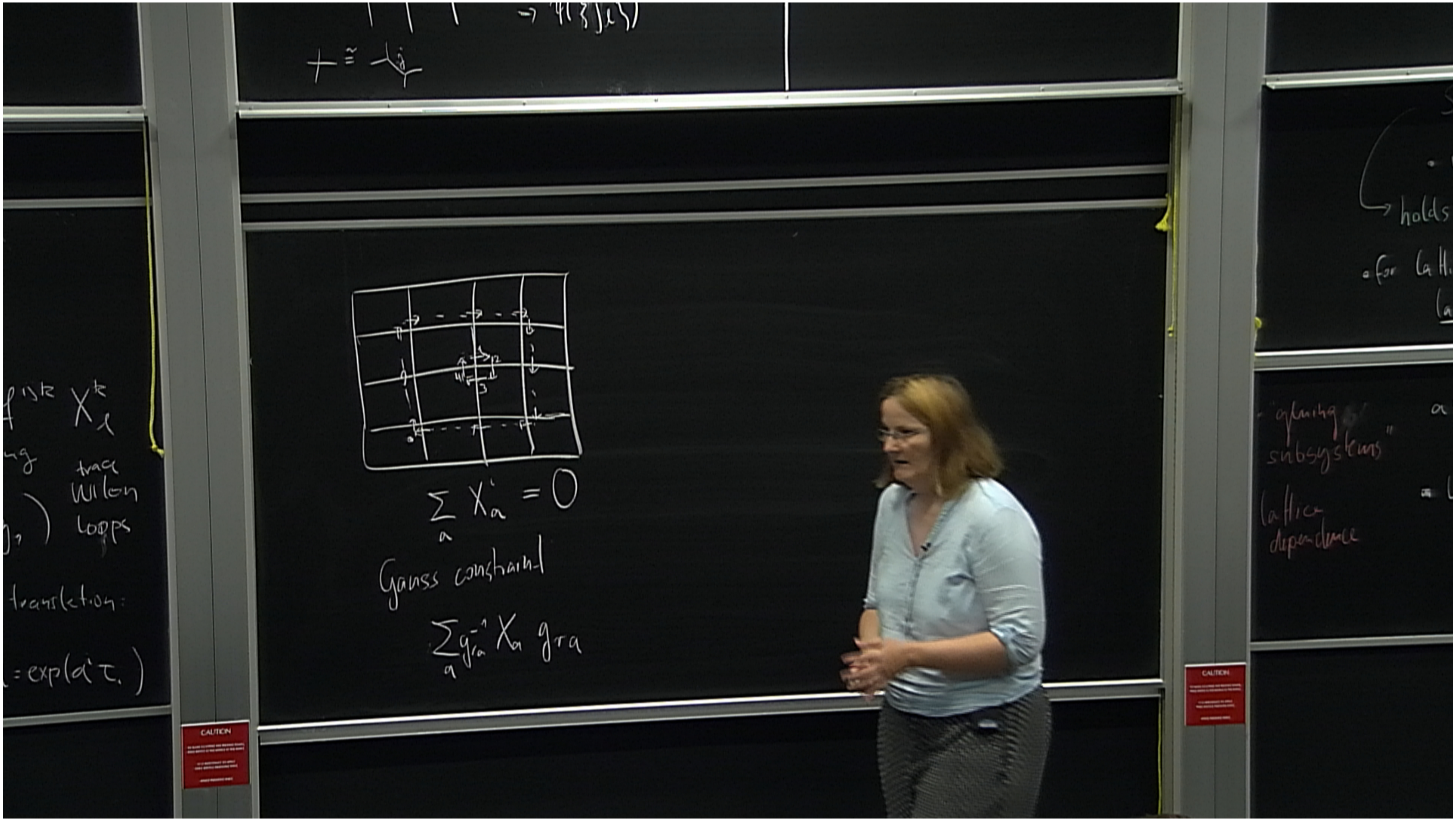
Fusion basis : multi-scale
simplest state (TQFT vacuum)
another notion of entanglement entropy
another notion of subsystem (gluing)
generalization of "magnetic centre"
(Need an "electric part")

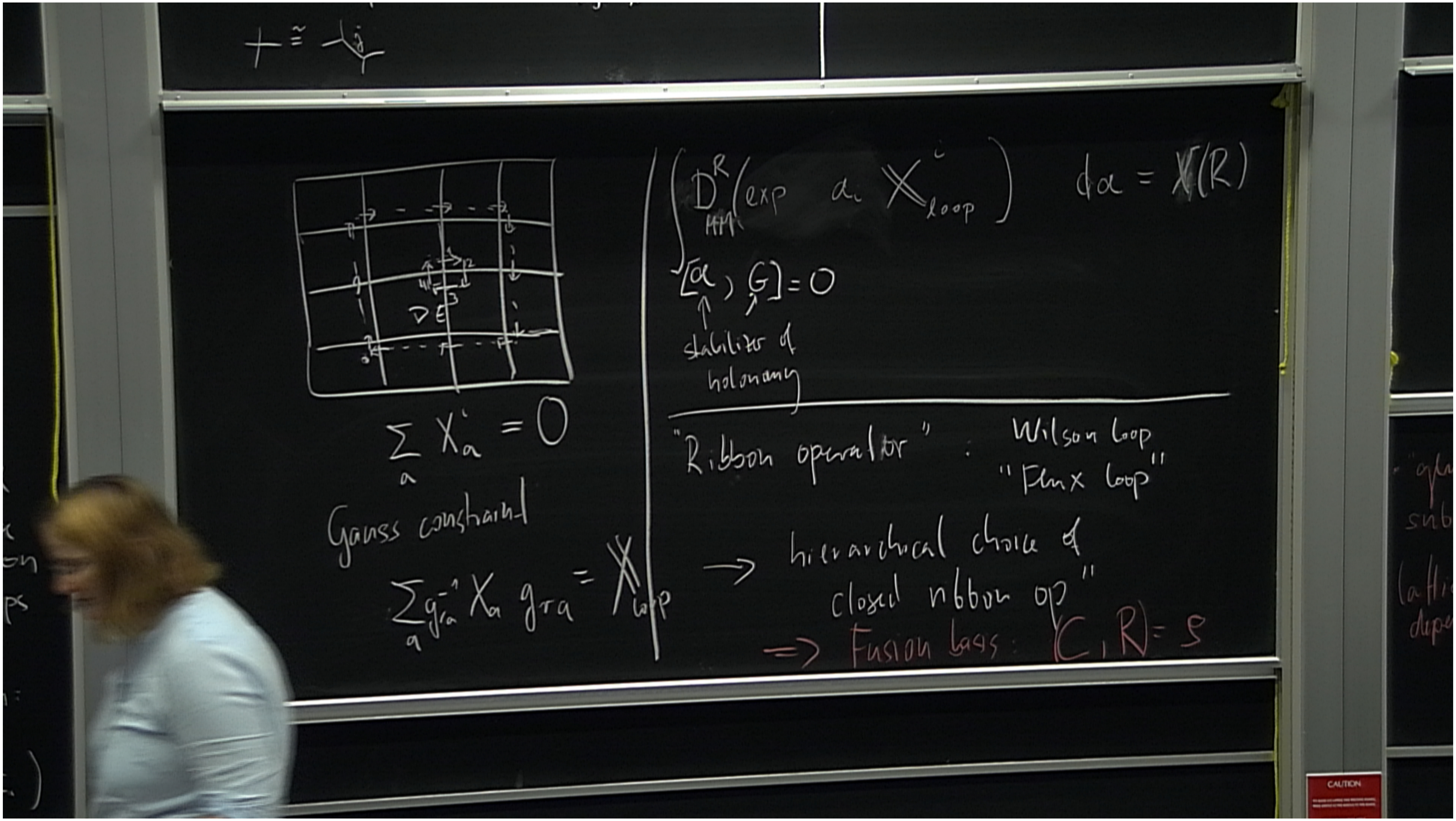
Fusion basis in Non Ab. Lattice gauge theory

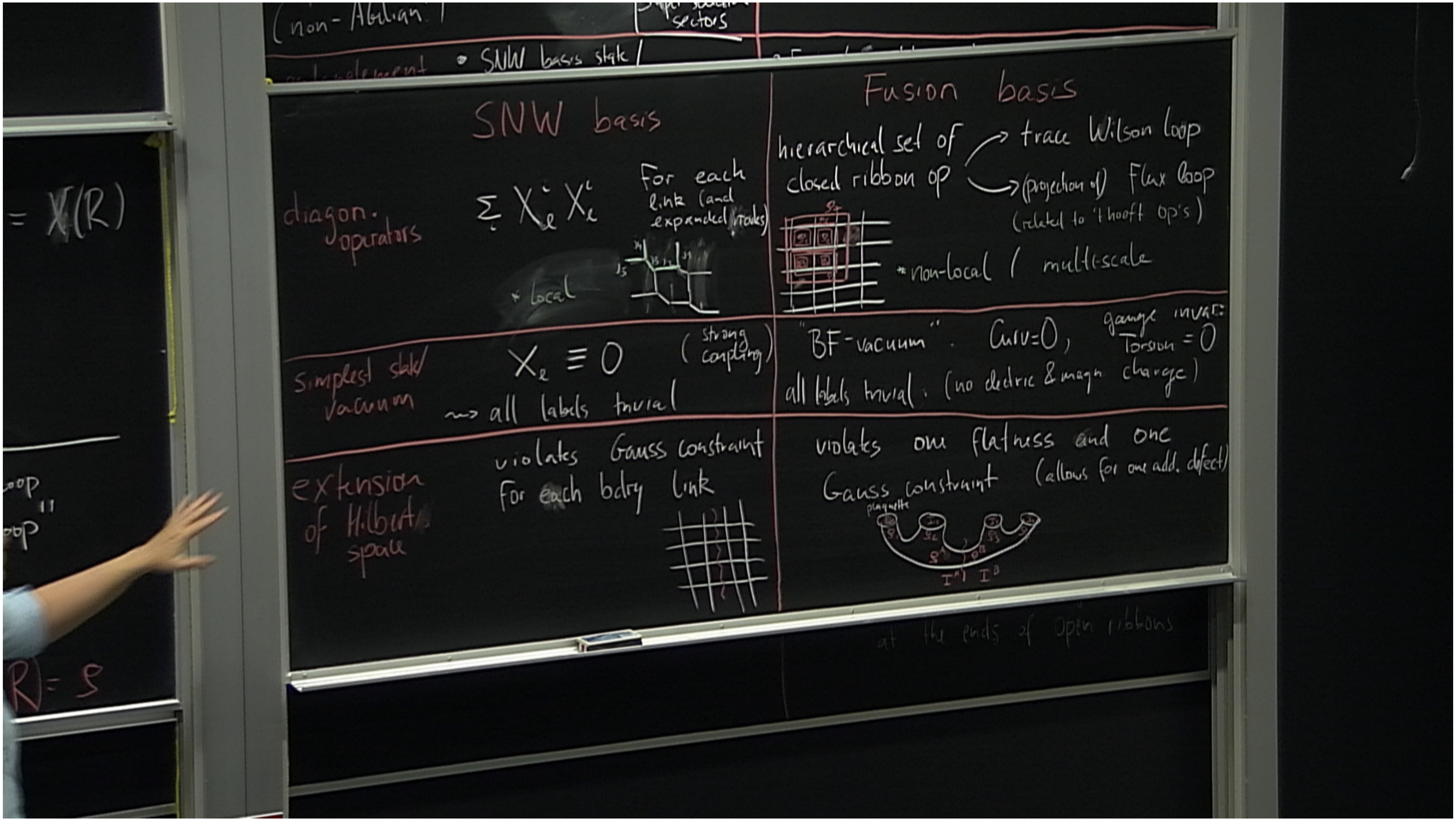

LGT basics
(holonomy) (el flux)
$g_e \in G$, $X_e = X_e^i \tau_i \in$ Lie Alg
u_s g_e, X_e u_t
g_e X_e
gauge trafo: $u_t^{-1} g_e u_s$, $u_t^{-1} X_e u_t$
$\{g_e, X_e^i\} = \tau^i g_e$
$\{X_e^i, X_e^j\} = f^{ijk} X_e^k$
non-commuting
"holonomy polarization: $\psi(\{g_e\}_e)$
$\rightarrow$ $\widehat{f(g_e)}$ act by mult.
$\rightarrow$ $\hat{X}_e^i$ act as (Lie group) derivatives $\rightsquigarrow$ $\exp(\alpha_i \hat{X}^i)$ as (conventions) left translation:
For finite group $\Rightarrow$
$\exp(\alpha_i \hat{X}^i) f(g) = f(a^{-1} g)$
$a = \exp(\alpha^i \tau_i)$

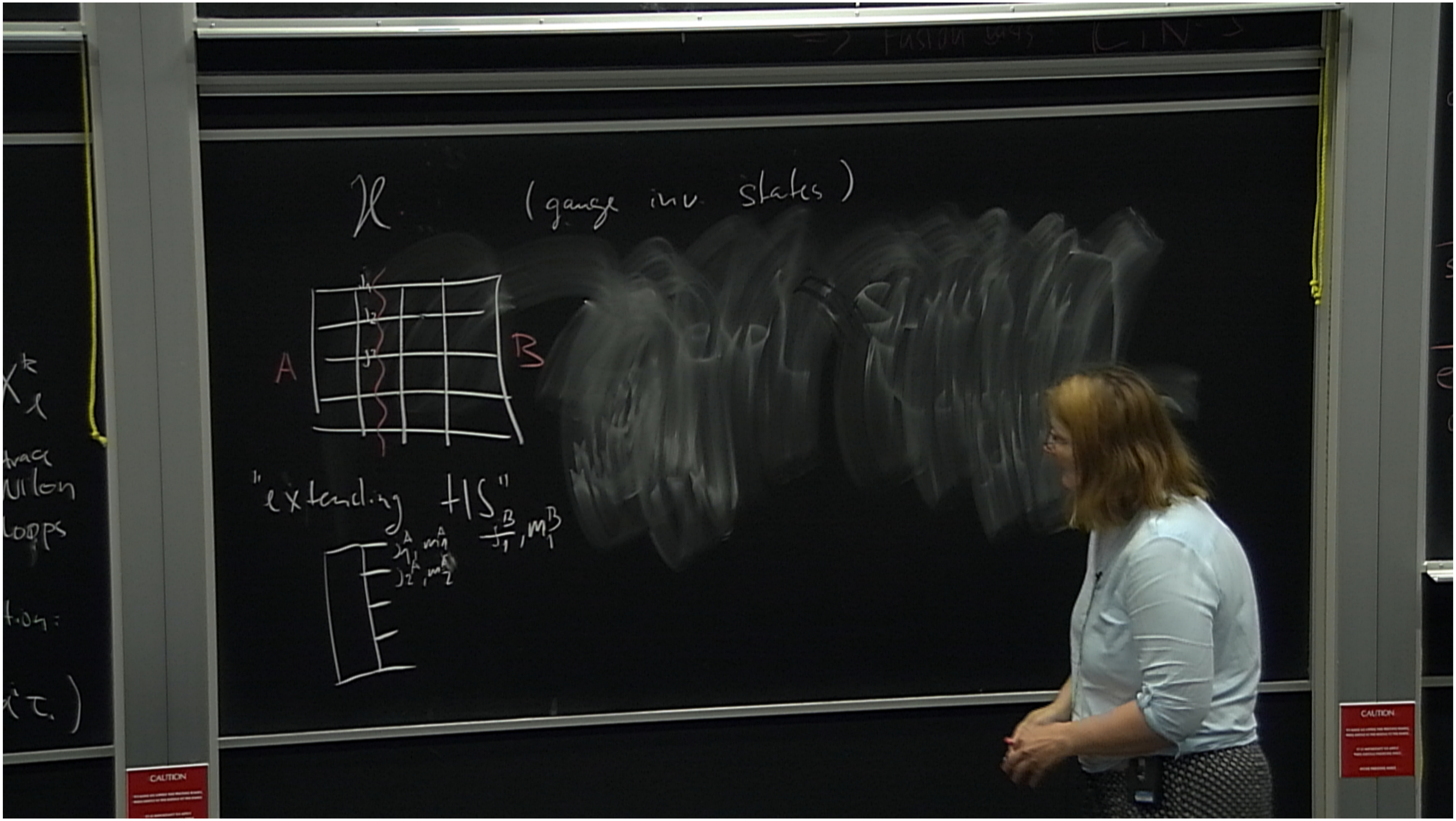

Spin network basis
Casimir op on G
"kinetic energy part YM Hamiltonian"
"simplest state"
trace Wilson loops
translation:

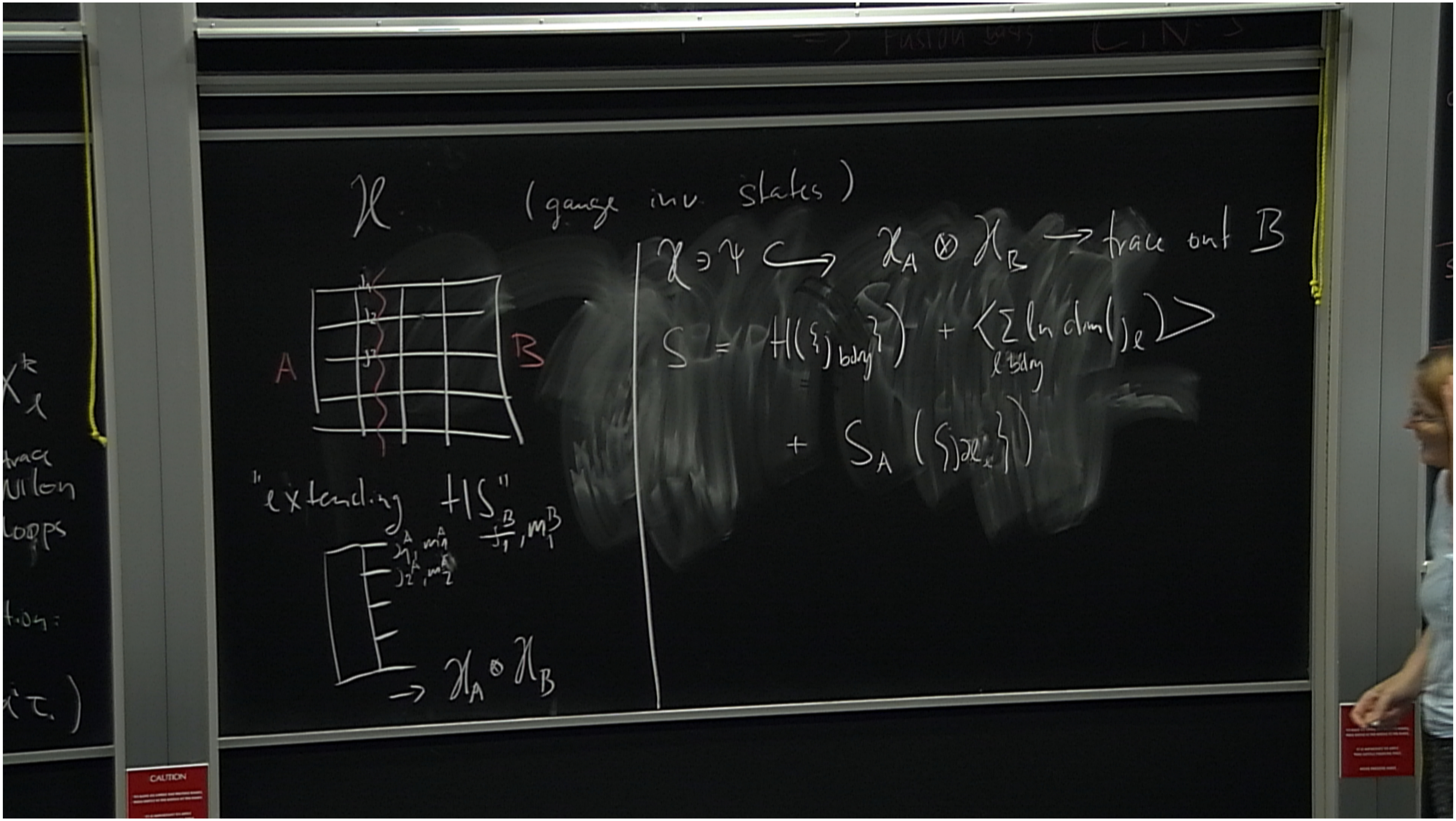

Spin network basis
Dual basis
Fusion basis
Casimir op on G
"kinetic energy part YM Hamiltonian"
"el. field squared"
"simplest state"
j(j+1)
"hierarchical set of tr(Wilson loop)"


Gauss constraint
Wilson loops
lattice dependence

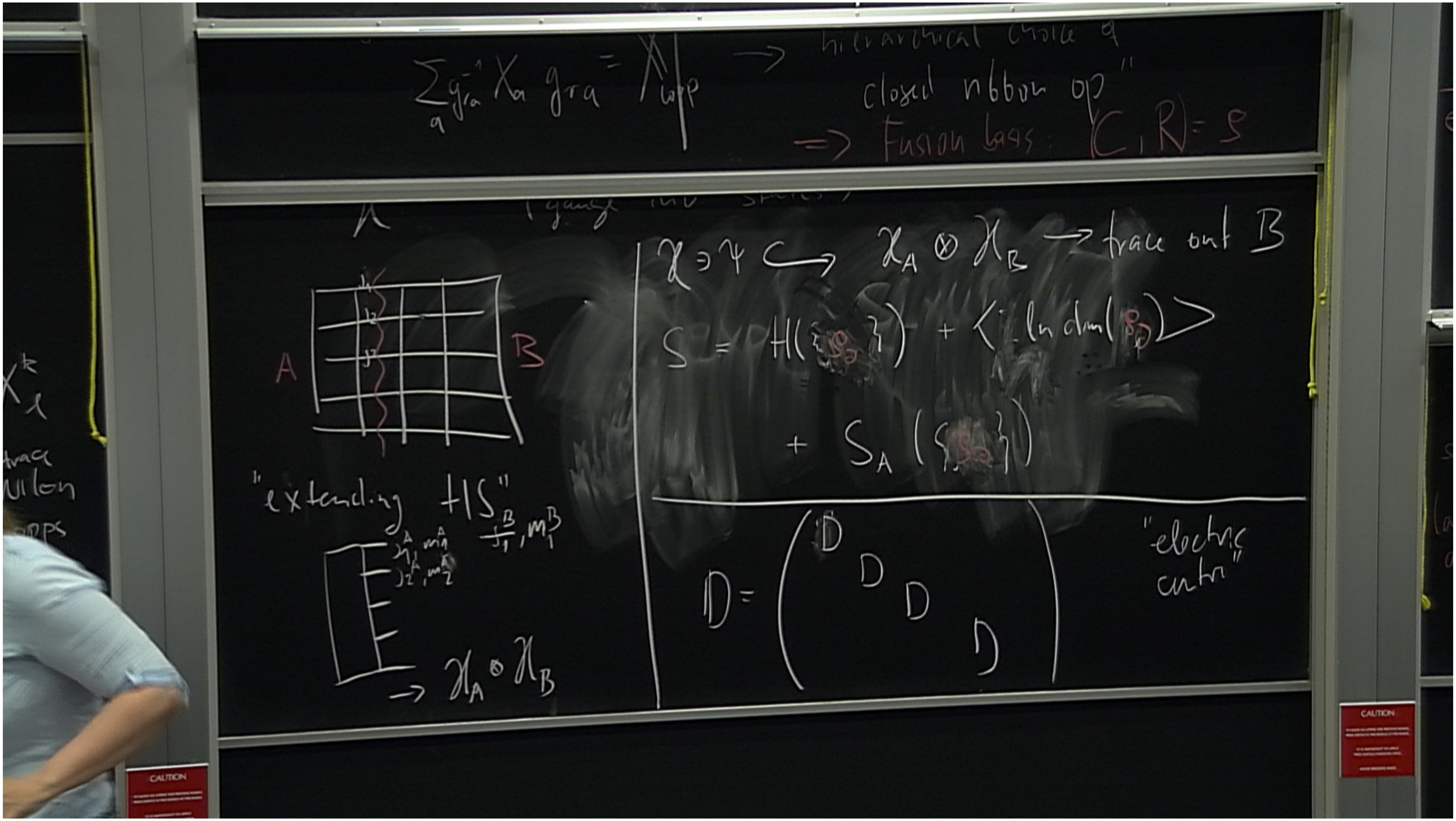

Gauss constraint
stabilizer of holonomy
"Ribbon operator"
Wilson loop
"Flux loop"
hierarchical choice of
closed ribbon op"
Fusion laws
CAUTION

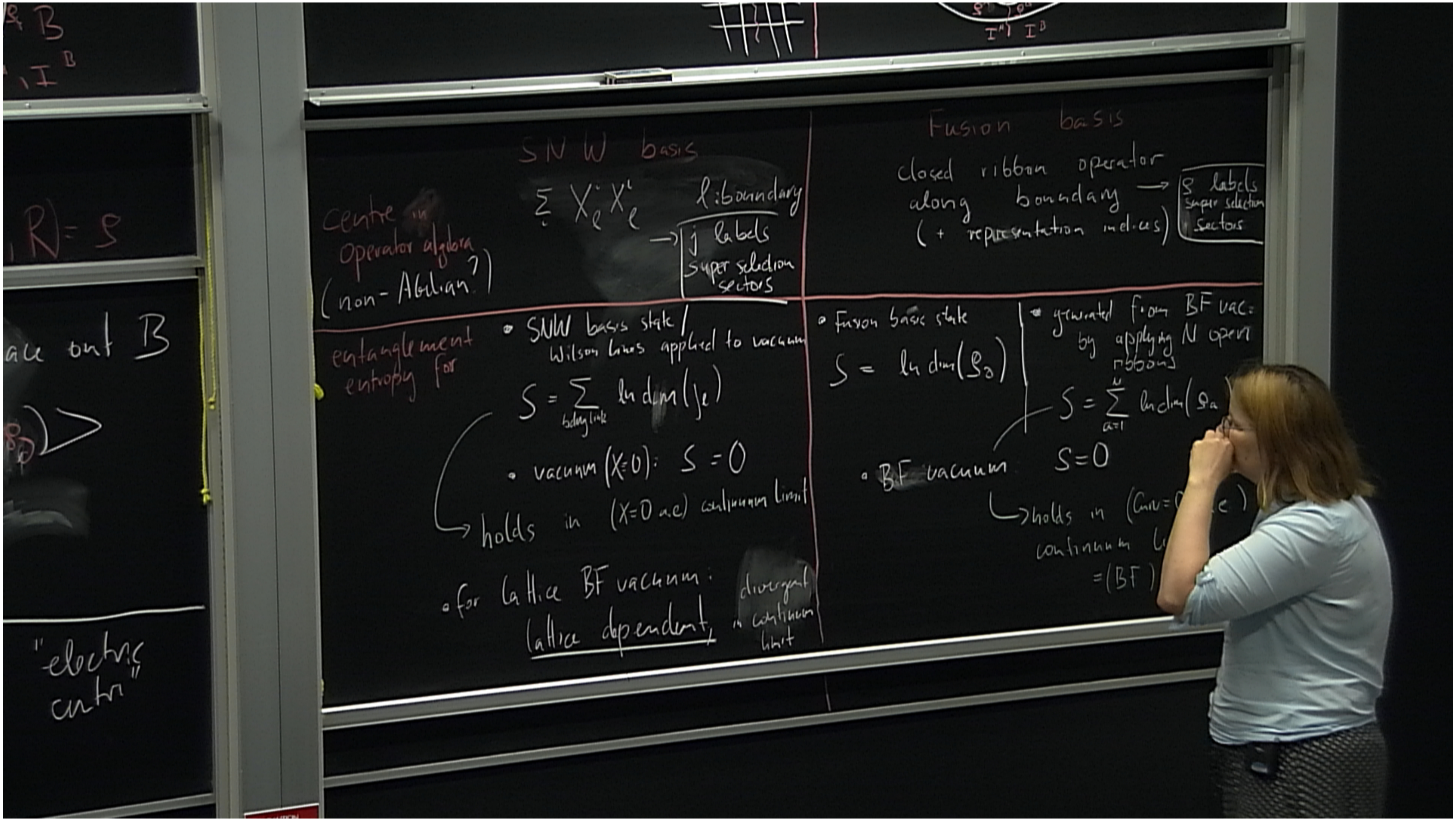

SNW basis
Fusion basis
diagon. operators
For each link (and expanded nodes)
* local
hierarchical set of closed ribbon op
trace Wilson loop
(projection of) Flux loop
(related to 't hooft op's)
* non-local / multi-scale
simplest state/ vacuum
(strong coupling)
~> all labels trivial
"BF-vacuum". Curv=0, gauge invar: Torsion = 0
all labels trivial. (no electric & magn charge)
extension of Hilbert space
violates Gauss constraint For each bdry link
violates one flatness and one Gauss constraint
(allows for one add. defect)
plaquette
at the ends of open ribbons


(gauge inv. states)
A
B
"extending H S"

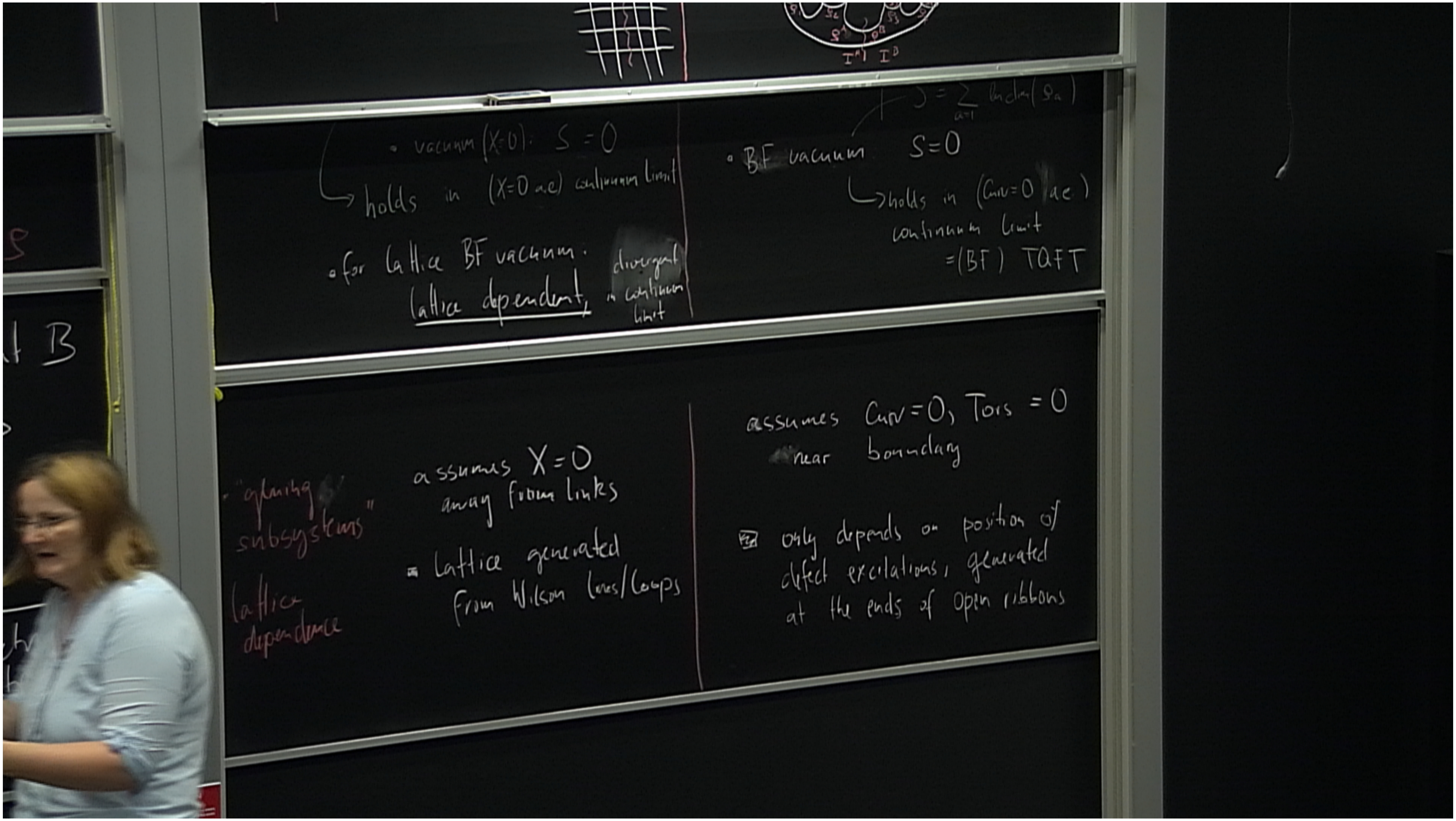


H (gauge inv. states)
H ∋ ψ ↪ H_A ⊗ H_B → trace out B
S = H({j}_bdry) + ⟨Σ_{ℓ bdry} ln dim( )_ℓ⟩
+ S_A ({j_∂x})
A
B
"extending HS"
→ H_A ⊗ H_B
trace
Wilson
loops


closed ribbon op"
Fusion laws
trace out B
A
B
"extending HS"
"electric center"



SNW basis
Fusion basis
l: boundary
j labels
super selection
sectors
closed ribbon operator
along boundary
(+ representation indices)
ρ labels
super selection
sectors
centre in
operator algebra
(non-Abelian?)
entanglement
entropy for
• SNW basis state /
Wilson lines applied to vacuum
• Fusion basis state
S = ln dim(ρ)
• generated from BF vac.
by applying N open
ribbons
• vacuum (X=0): S = 0
holds in (X=0 a.e) continuum limit
• BF vacuum
S=0
• for lattice BF vacuum:
lattice dependent,
divergent
in continuum
limit
"electric
centr"


vacuum (X=0). S = 0
holds in (X=0 a.e) continuum limit
for lattice BF vacuum.
lattice dependent, divergent in continuum limit
BF vacuum S=0
holds in (Curv=0 a.e.)
continuum limit
=(BF) TQFT
assumes Curv = 0, Tors = 0
near boundary
"gluing subsystems"
lattice dependence
assumes X = 0
away from links
lattice generated
from Wilson lines/loops
only depends on position of
defect excitations, generated
at the ends of open ribbons