Title: Quantum Matter Lecture (230414)

Speakers: Ganapathy Baskaran

Collection: Quantum Matter (2022/2023)

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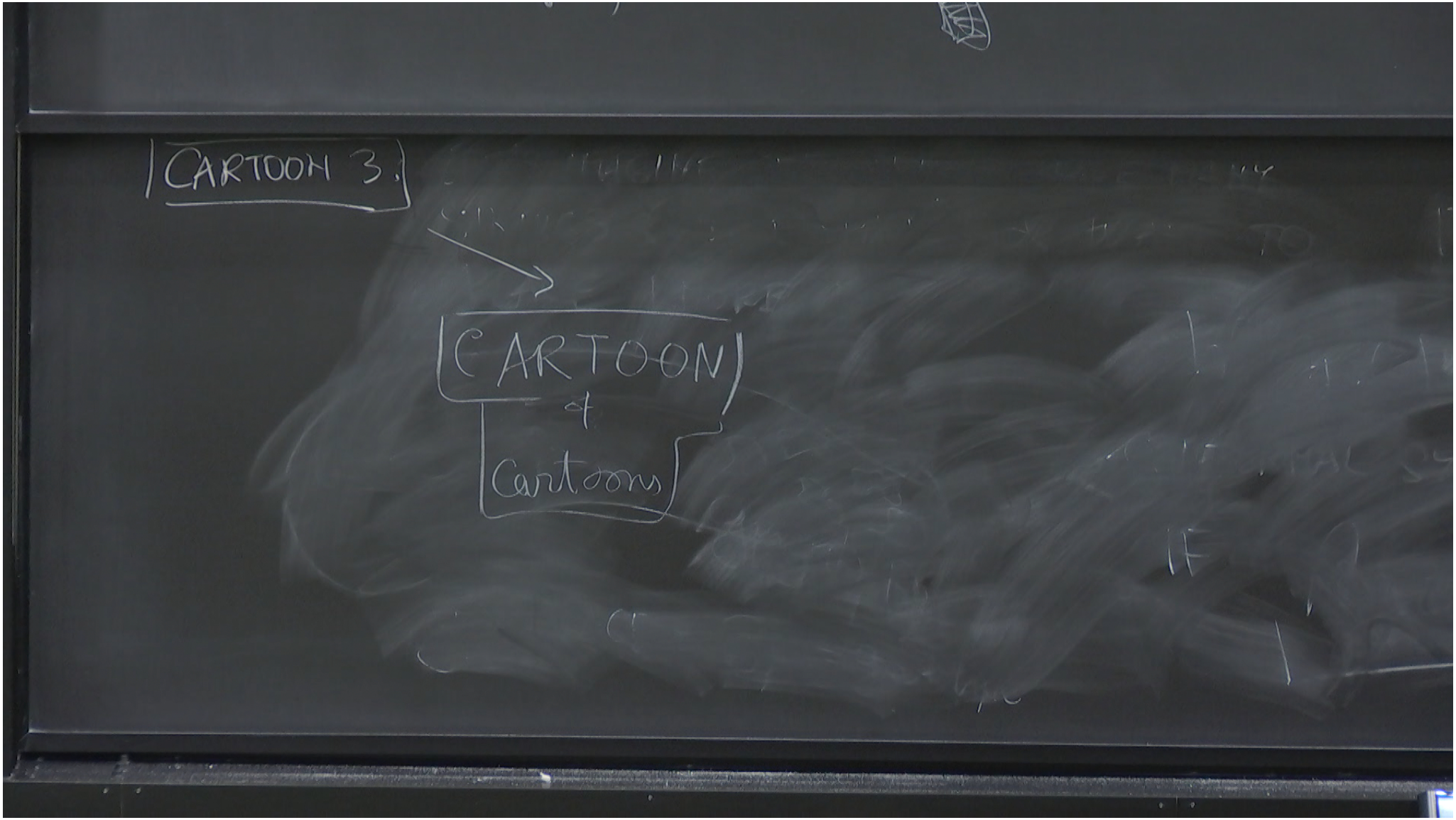
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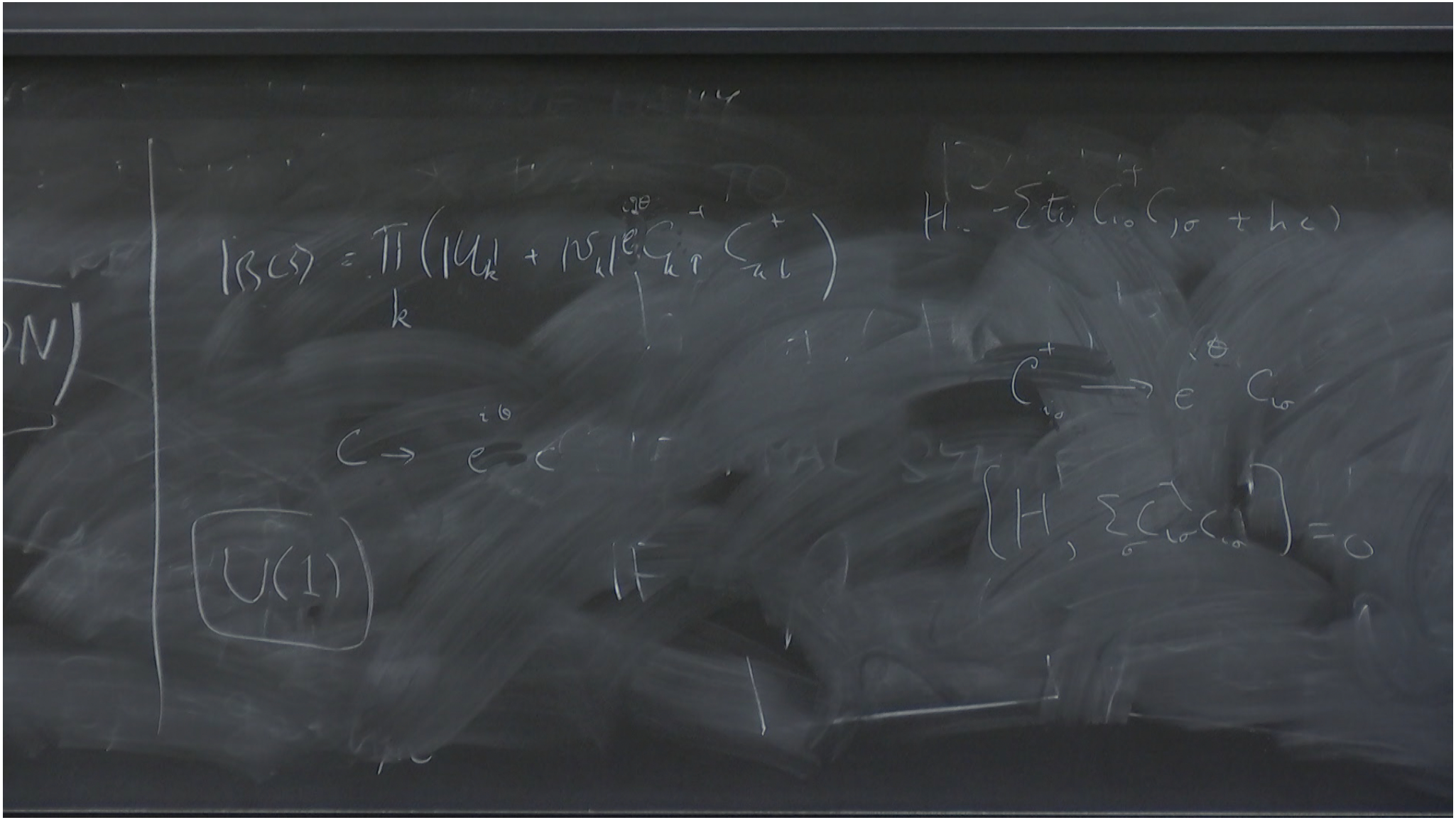
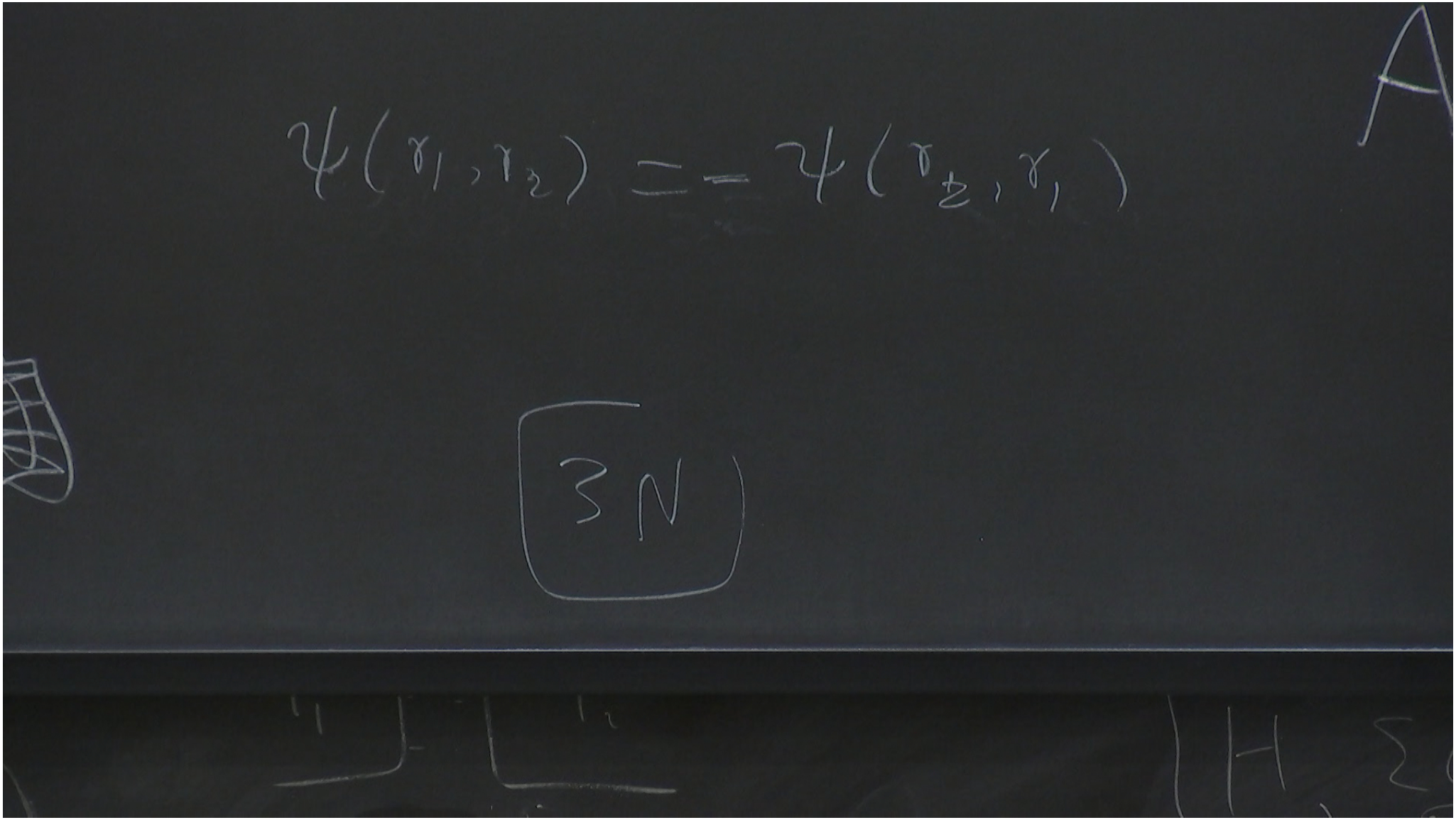
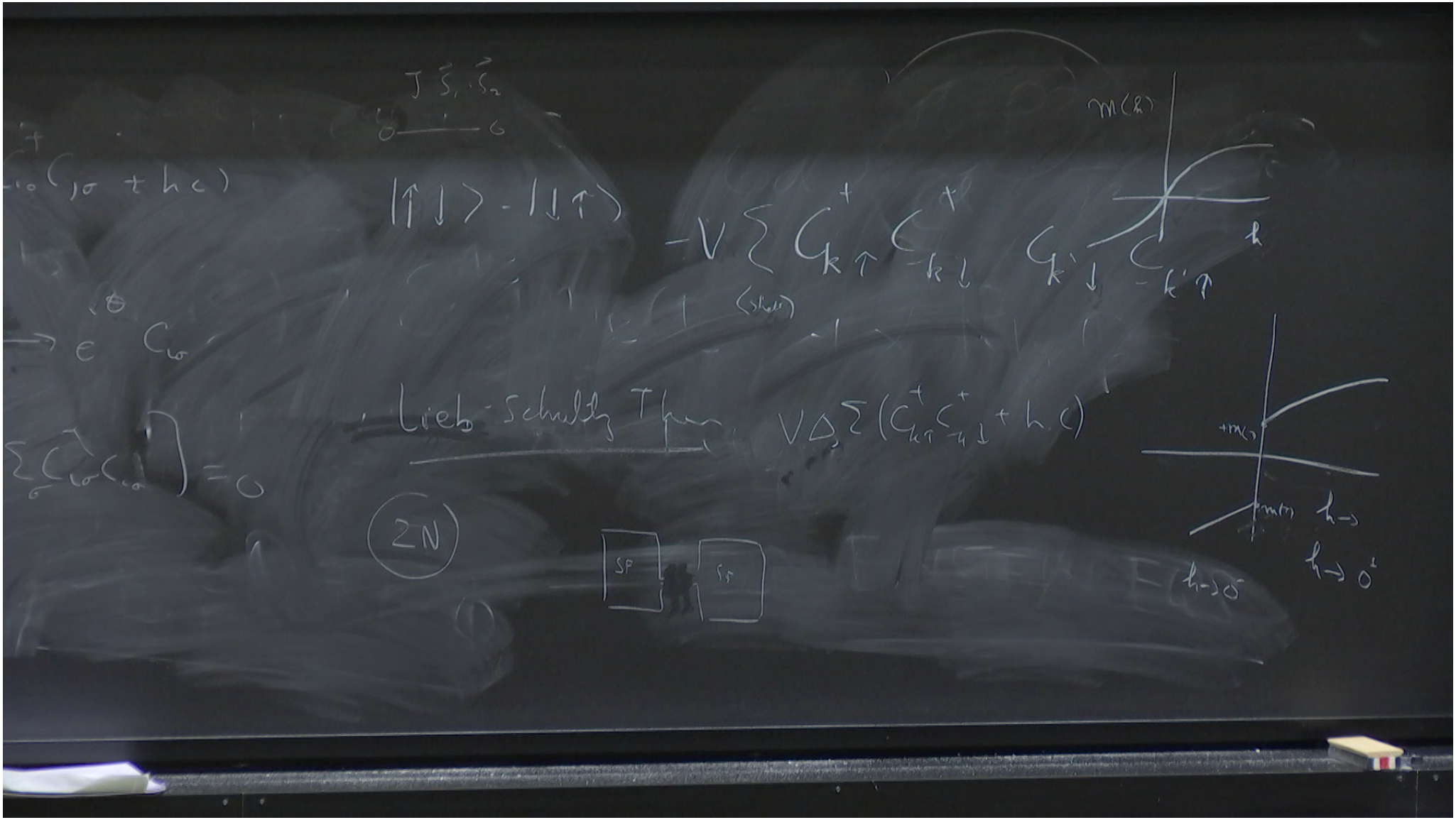

$|BCS\rangle = \prod_k \left(|U_k| + |V_k| e^{i\theta} C_{k\uparrow}^\dagger C_{k\downarrow}^\dagger \right)$
$H = -\sum t_{ij} C_{i\sigma}^\dagger C_{j\sigma} + h.c.$
$C \to e^{i\theta} C$
$C_{i\sigma}^\dagger \to e^{i\theta} C_{i\sigma}$
U(1)
$\left[H, \sum_\sigma C_{i\sigma}^\dagger C_{i\sigma} \right] = 0$

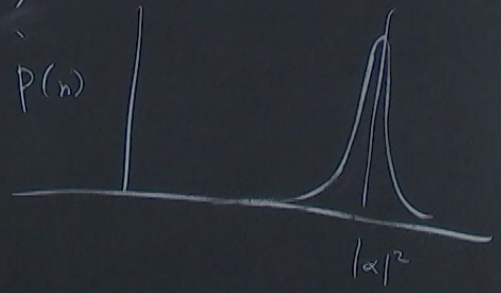

$\psi(r_1, r_2) = -\psi(r_2, r_1)$
A
3N

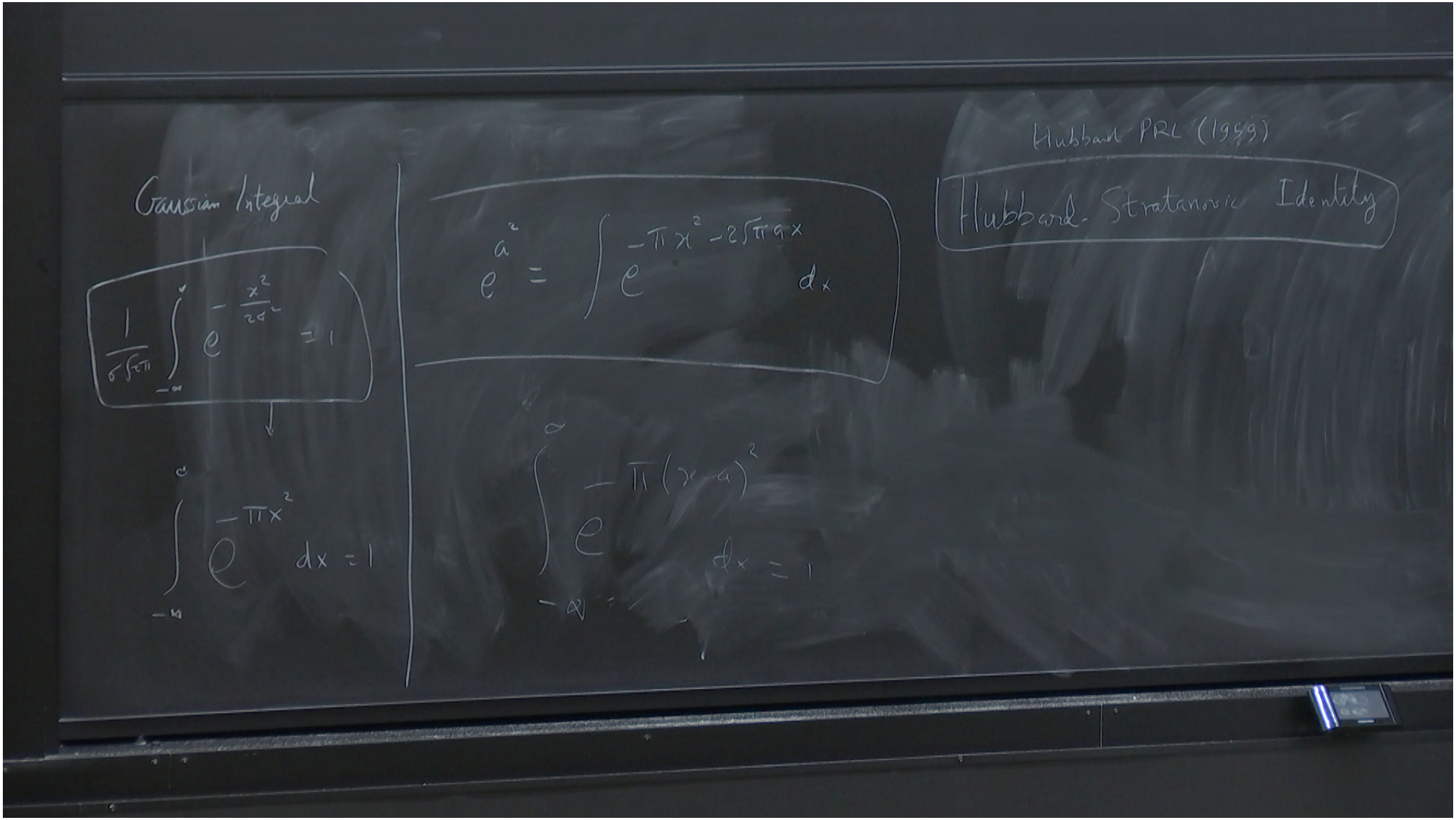

J $\vec{S}_1 \cdot \vec{S}_2$
$|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle$
$-V \sum c^\dagger_{k\uparrow} c^\dagger_{-k\downarrow} c_{k'\downarrow} c_{-k'\uparrow}$
(sum)
Lieb-Schultz Thm
$V\Delta \sum (c^\dagger_{k\uparrow} c^\dagger_{-k\downarrow} + h.c)$
$m(h)$
h
$+m(0)$
$m(h)$
$h \to$
$h \to 0^+$
$h \to 0^-$
2N
SF
SF

$a^\dagger, a$ $\quad |\alpha\rangle = e^{-\alpha a^\dagger} |0\rangle$ $\quad \vdots$

$[a, a^\dagger) = 1$

$|\alpha| \sim N$




Gaussian Integral
$\frac{1}{\sigma\sqrt{2\pi}}\int_{-\infty}^{\infty} e^{-\frac{x^2}{2\sigma^2}} = 1$
$\int_{-\infty}^{\infty} e^{-\pi x^2} dx = 1$
$e^{a^2} = \int e^{-\pi x^2 - 2\sqrt{\pi} q x} dx$
$\int_{-\infty}^{\infty} e^{-\pi (x-q)^2} dx = 1$
Hubbard PRL (1959)
Hubbard-Stratanovic Identity

Hubbard PRL (1959)

Hubbard-Stratanovic Identity

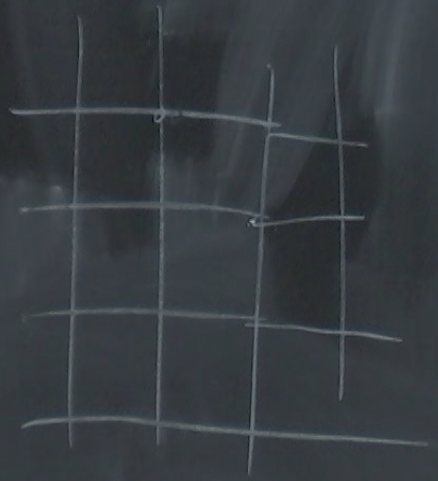
Polyakov

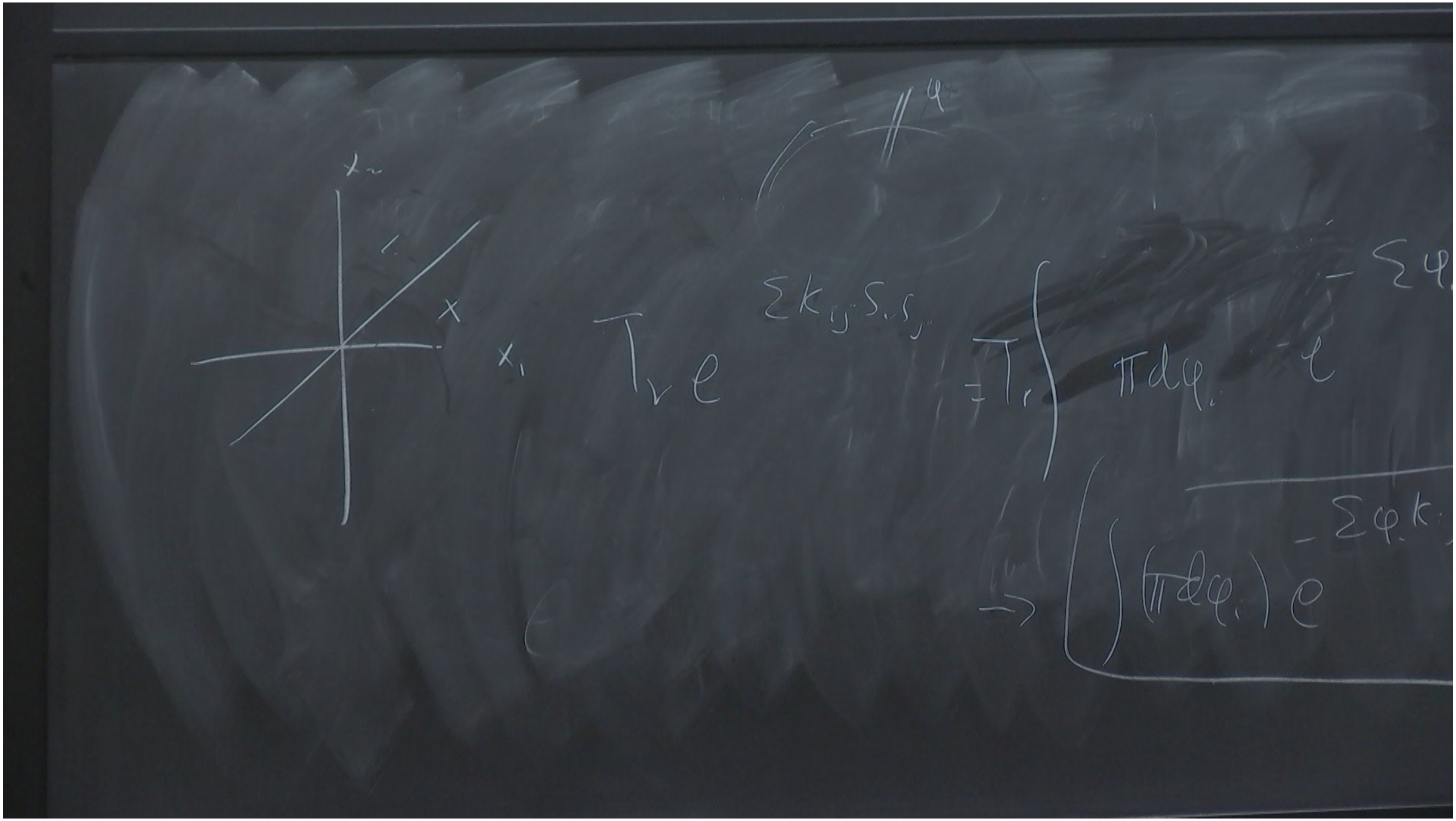
Weiss

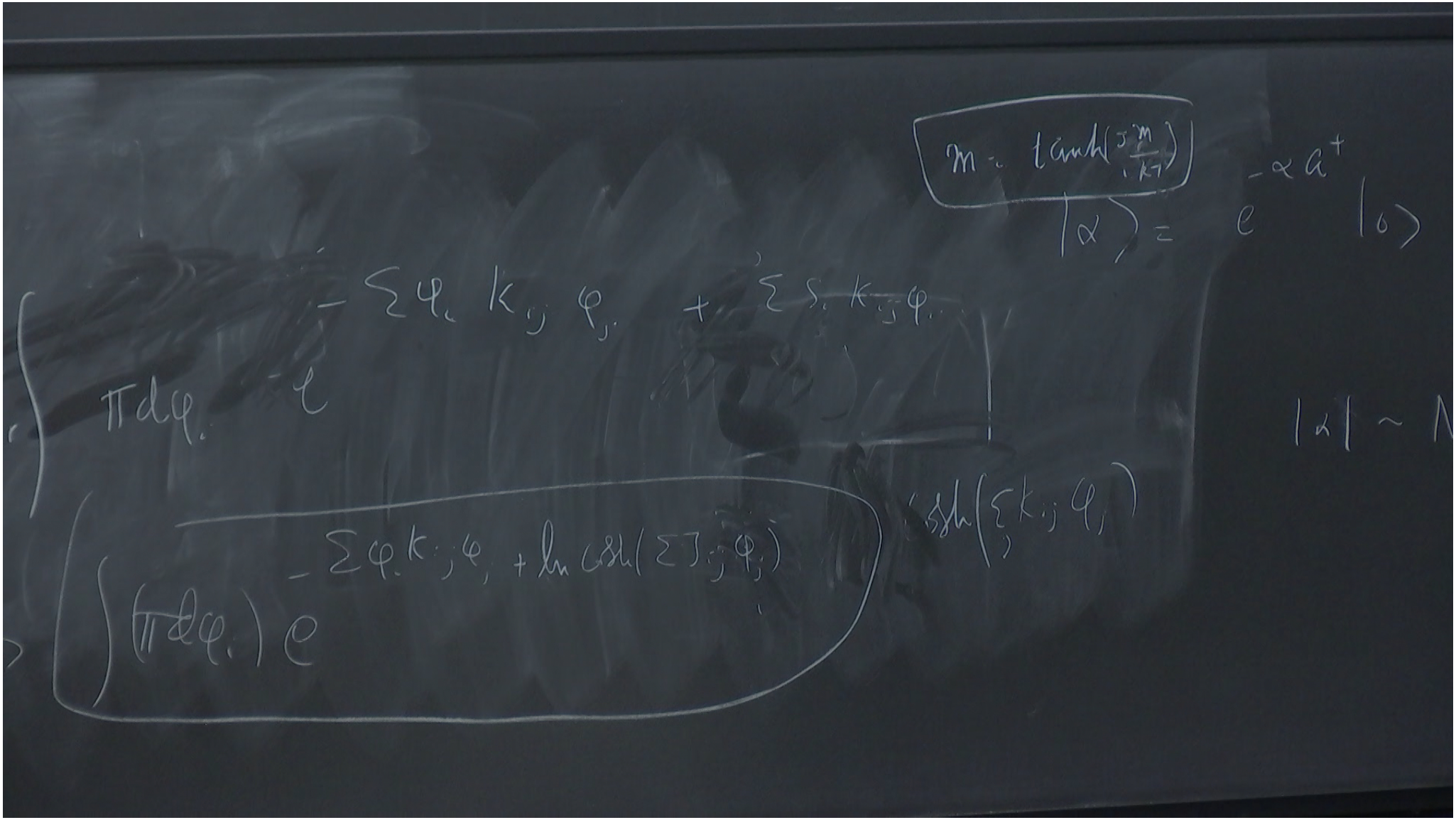
$S_i^z = \pm 1$

$H = -J \sum_{\langle i,j \rangle} S_i^z S_j^z - h \sum_i S_i^z$

$Z(\beta) = \sum_{\{S_i = \pm 1\}} e^{\beta J \sum_{\langle i,j \rangle} S_i^z S_j^z}$






$m = \tanh\left(J \frac{m}{k_B T}\right)$
$|\alpha\rangle = e^{-\alpha a^\dagger} |0\rangle$
$\int \pi d\varphi_i \; e^{-\sum \varphi_i k_{ij} \varphi_j + \sum s_i k_{ij} \varphi_i}$
$\int (\pi d\varphi_i) \, e^{-\sum \varphi_i k_{ij} \varphi_j + \ln \cosh(\sum J_{ij} \varphi_j)}$
$\cosh\left(\sum_j k_{ij} \varphi_j\right)$
$|\alpha| \sim N$