

Title: Spontaneous Broken Symmetry 2B

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URL: <http://pirsa.org/07110063>

Abstract:

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle = M^*$$

$$\frac{\partial}{\partial \lambda}$$

$$C_1 = 1 + \frac{\mu}{z}$$

$$H_{\text{rem}} = H_{\text{int}} - M H_{\text{ext}}$$

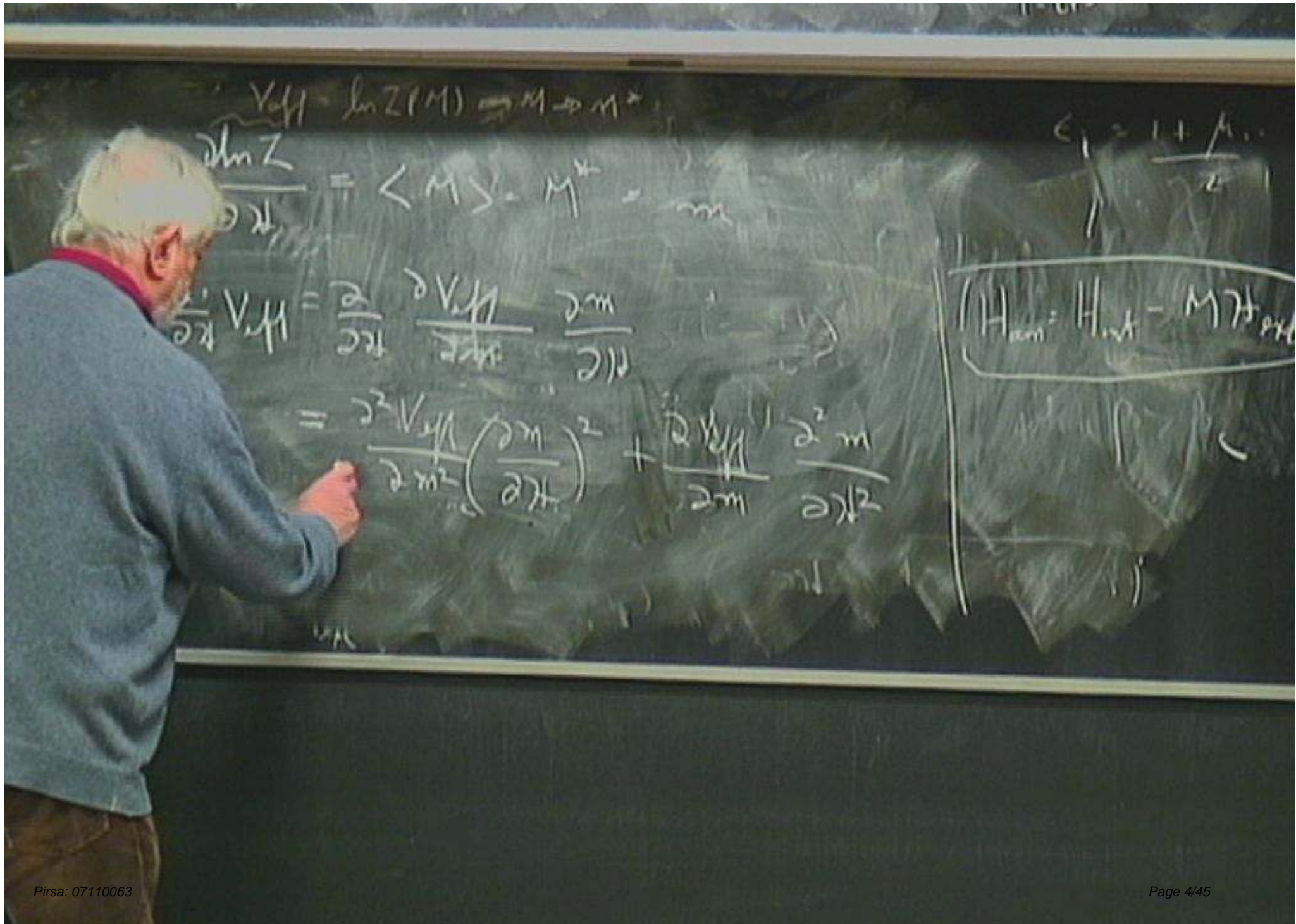
$$Y_{eff} = \ln Z(M) \Rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle = M^*$$

$$\frac{\partial \langle M \rangle}{\partial \lambda} = \frac{\partial^2 \ln Z}{\partial \lambda^2} = \frac{\partial M^*}{\partial \lambda}$$

$$C = \frac{\partial M^*}{\partial \lambda}$$

$$H_{rem} = H_{int} - M H_{ext}$$



$$V_{eff} = \ln Z(M) \Rightarrow M \rightarrow M^*$$

$$\frac{\delta \ln Z}{\delta M} = \langle M \rangle = M^*$$

$$\frac{\delta V_{eff}}{\delta M} = \frac{\delta}{\delta M} \left(\frac{1}{i} \ln \int \mathcal{D}\phi \exp(iS[\phi, M]) \right)$$

$$= \frac{\delta}{\delta M} \left(\frac{1}{i} \ln \int \mathcal{D}\phi \exp(iS[\phi, M]) \right) + \frac{\delta}{\delta M} \left(\frac{1}{i} \ln \int \mathcal{D}\phi \exp(iS[\phi, M]) \right)$$

$$\epsilon = \frac{1 + \mu}{2}$$

$$H_{ren} = H_{int} - M H_{ext}$$

$$Y_{eff} = \ln Z(M) \Rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial k} = \langle M \rangle = M^* = m$$

$$\frac{\partial \ln Z}{\partial k} = \frac{\partial}{\partial k} \left(\frac{1}{m} \frac{\partial \ln Z}{\partial k} \right)$$

$$= \frac{1}{m} \frac{\partial^2 \ln Z}{\partial k^2} + \frac{\partial \ln Z}{\partial k} \frac{\partial}{\partial k} \left(\frac{1}{m} \right)$$

$$C_1 = \frac{1 + \mu}{2}$$

$$H_{ext} = H_{int} - M H_{ext}$$

$$V_{eff} = \ln Z(M) \Rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial \kappa} = \langle M \rangle = M^*$$

$$\frac{\partial V_{eff}}{\partial \kappa} = \frac{\partial}{\partial \kappa} \left(\frac{m c}{\kappa} \right)$$

$$= \frac{\partial}{\partial \kappa} \left(\frac{m c}{\kappa} \right) + \frac{\partial V_{eff}}{\partial \kappa}$$

$$c = \frac{1 + \mu}{2}$$

$$H_{ren} = H_{int} - M H_{ext}$$

$$V_{eff} = \ln Z(M) \rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle = M^*$$

$$V_H = \frac{\partial}{\partial \lambda} \left(\frac{\partial V_{eff}}{\partial \lambda} \right) = \frac{\partial^2 V_{eff}}{\partial \lambda^2}$$

$$= \frac{\partial^2}{\partial \lambda^2} \left(\frac{\partial \ln Z}{\partial \lambda} \right) + \frac{\partial^2 V_{eff}}{\partial \lambda^2}$$

$$c = \frac{1 + \lambda}{2}$$

$$H_{rem} = H_{int} - M H_{ext}$$



$$\psi_{eff} = \ln Z(M) \rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial \beta} = \langle M \rangle - M^*$$

$$\frac{\partial \ln Z}{\partial \beta} = \langle M \rangle - M^* = \frac{\partial}{\partial \beta} \left(\frac{1}{m} \ln Z \right)$$

$$= \frac{1}{m} \left(\frac{\partial \ln Z}{\partial \beta} \right) + \frac{\partial}{\partial \beta} \left(\frac{1}{m} \right)$$

$$\boxed{H_{ann} = H_{int}}$$

$\psi_{eff} = \ln Z(M) \rightarrow M \rightarrow M^*$

$$\frac{\partial \ln Z}{\partial \mu} = \langle M \rangle - M^*$$

$$\frac{\partial}{\partial \mu} \left(\frac{\partial \ln Z}{\partial \mu} \right) = \frac{\partial}{\partial \mu} \langle M \rangle = \frac{\partial}{\partial \mu} \left(\frac{\partial \ln Z}{\partial \mu} \right)$$

$$= \frac{\partial}{\partial \mu} \left(\frac{\partial \ln Z}{\partial \mu} \right) + \frac{\partial}{\partial \mu} \left(\frac{\partial \ln Z}{\partial \mu} \right)$$

$$\left(H_{ann} = H_{int} \right)$$

$$Y_{eff} = \ln Z(M) \rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial M} = \langle M \rangle - M^*$$

$$\frac{\partial}{\partial M} \left(\frac{\partial \ln Z}{\partial M} \right) = \frac{\partial}{\partial M} \langle M \rangle = \frac{\partial}{\partial M} \left(\frac{\partial \ln Z}{\partial M} \right)$$

$$= \frac{\partial}{\partial M} \left(\frac{\partial}{\partial M} \left(\frac{\partial \ln Z}{\partial M} \right) \right) = \frac{\partial}{\partial M} \left(\frac{\partial}{\partial M} \left(\frac{\partial \ln Z}{\partial M} \right) \right)$$

$$= \frac{\partial}{\partial M} \left(\frac{\partial}{\partial M} \left(\frac{\partial \ln Z}{\partial M} \right) \right) = \frac{\partial}{\partial M} \left(\frac{\partial}{\partial M} \left(\frac{\partial \ln Z}{\partial M} \right) \right)$$

$$\left(H_{ext} = H_{int} \right)$$



$$V_{eff} = \ln Z(M) \Rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle - M^*$$

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle - M^* = 0$$

$$= \frac{\partial^2 V_{eff}}{\partial \lambda^2} \left(\frac{\partial M}{\partial \lambda} \right)^2 + \frac{\partial^2 V_{eff}}{\partial \lambda^2} \frac{\partial M}{\partial \lambda}$$

$$\frac{\partial^2 V_{eff}}{\partial \lambda^2} \frac{\partial M}{\partial \lambda}$$

$$\left(H_{int} - H_{ext} \right)$$

$$Y_{eff} = \ln Z(M) \rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle - M^* = m$$

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle - M^* = m$$

$$= \frac{1}{2m} \left(\frac{\partial \ln Z}{\partial \lambda} \right)^2 + \dots$$

$$\frac{\partial \ln Z}{\partial \lambda} = X$$

$$H_{ann} = H_{int} - \dots$$

$$\text{Yaff} = \ln Z(M) \Rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle - M^*$$

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle - M^* \quad \left| \quad \frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle - M^* \right.$$

$$\frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle - M^* + \frac{\partial \ln Z}{\partial \lambda} = \langle M \rangle - M^* = 0$$

$$H_{\text{ann}} = H_{\text{int}}$$

$$\frac{\partial \ln Z}{\partial \ln \lambda}$$

$$\frac{\partial \ln Z}{\partial \ln \lambda}$$

$$\langle \ln \lambda \rangle$$

>

$\ln \lambda$



$$\ln \lambda = 0$$

$$T > T_c$$

Modified only they

$$\frac{\partial \ln Z}{\partial \ln \lambda}$$

$$\frac{\partial \ln Z}{\partial \ln \lambda}$$

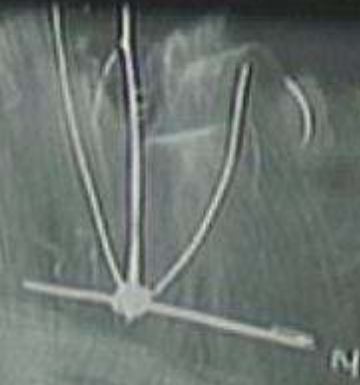
$$\frac{\partial \ln Z}{\partial h_i} = \langle \mu_i \rangle$$

$$\frac{\partial \langle \mu_i \rangle}{\partial h_i} = \frac{\partial^2 \ln Z}{\partial h_i^2}$$

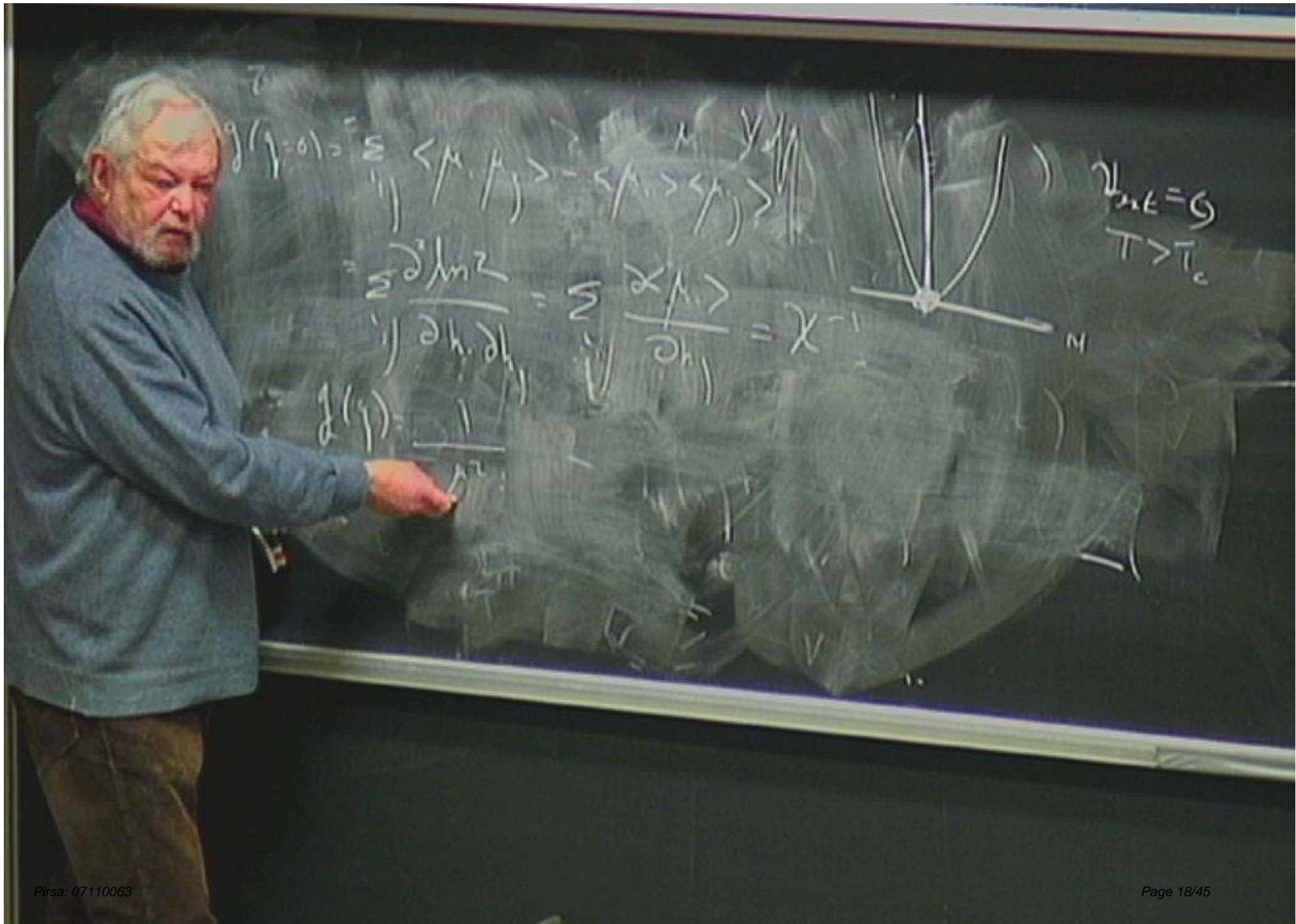
Modified only they

$$\frac{\partial \langle \mu_i \rangle}{\partial h_i} = \frac{\partial^2 \ln Z}{\partial h_i^2}$$

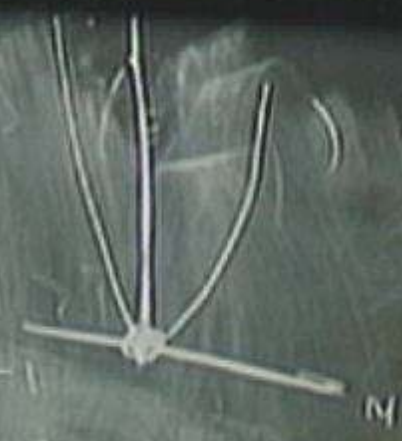
$$\frac{\partial \langle \mu_i \rangle}{\partial h_i}$$



$$\mu_i E = G$$
$$T > T_c$$



$$\begin{aligned}
 g(\eta=0) &= \sum_{\mu, \nu} \langle \mu, \nu \rangle - \langle \mu, \nu \rangle \langle \mu, \nu \rangle \\
 &= \sum_{\mu, \nu} \frac{\partial^2 \ln Z}{\partial h_{\mu} \partial h_{\nu}} = \sum_{\mu, \nu} \frac{\chi_{\mu, \nu}}{\partial h_{\mu} \partial h_{\nu}} = \chi^{-1} \\
 g(\eta) &= \frac{1}{\chi^2}
 \end{aligned}$$



$\chi_{\mu, \nu} = \chi$
 $T > T_c$

$$V_H = \ln Z(M) \rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial M} = \langle M \rangle = M^*$$

$$\frac{\partial \ln Z}{\partial M} = \langle M \rangle = M^*$$

$$= \frac{1}{2} \left(\frac{\partial \ln Z}{\partial M} \right)^2 + \frac{1}{2} \left(\frac{\partial^2 \ln Z}{\partial M^2} \right)$$

$$\frac{\partial^2 \ln Z}{\partial M^2} = \chi$$

$$H_{min} = H_{int}$$

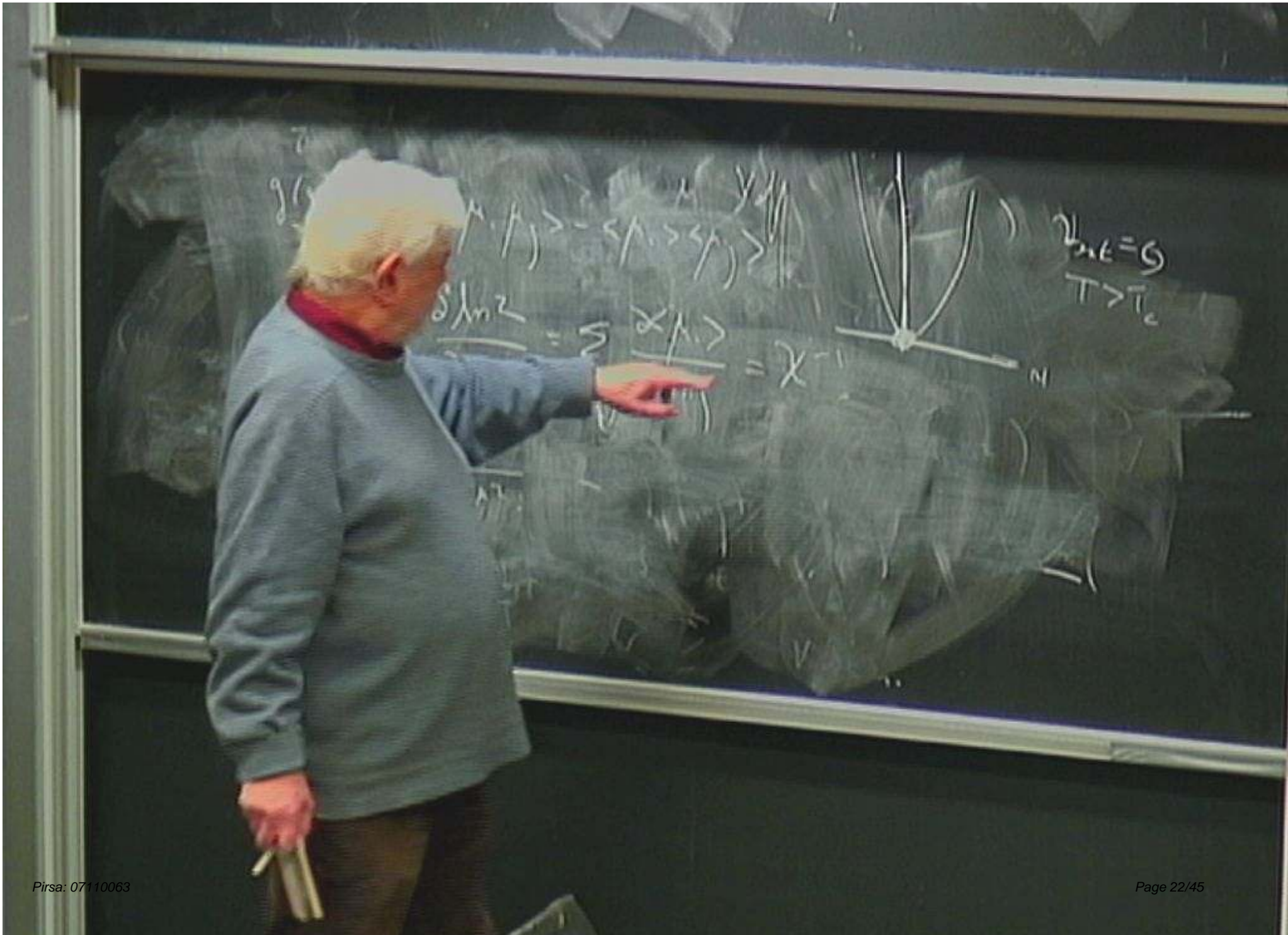
$$Y = \ln Z(M) \rightarrow M \rightarrow M^*$$

$$\frac{\partial \ln Z}{\partial M} = \langle M \rangle = M^* = m$$

$$\frac{\partial \ln Z}{\partial M} = \langle M \rangle = m$$

$$\frac{\partial^2 \ln Z}{\partial M^2} = -\frac{1}{M^2} = -\frac{1}{m^2}$$

$$H_{ann} = H_{int}$$



$$\ln Z(M^*(\lambda)) = \underbrace{\ln \tilde{Z}}_{\text{Others}} + M^* \lambda_{\text{ext}} \quad ; \quad M^* = \langle M \rangle$$

gibbs: $\mathcal{G} = \ln \tilde{Z}$

$$\ln Z = M^* \lambda - \mathcal{G}(M)$$

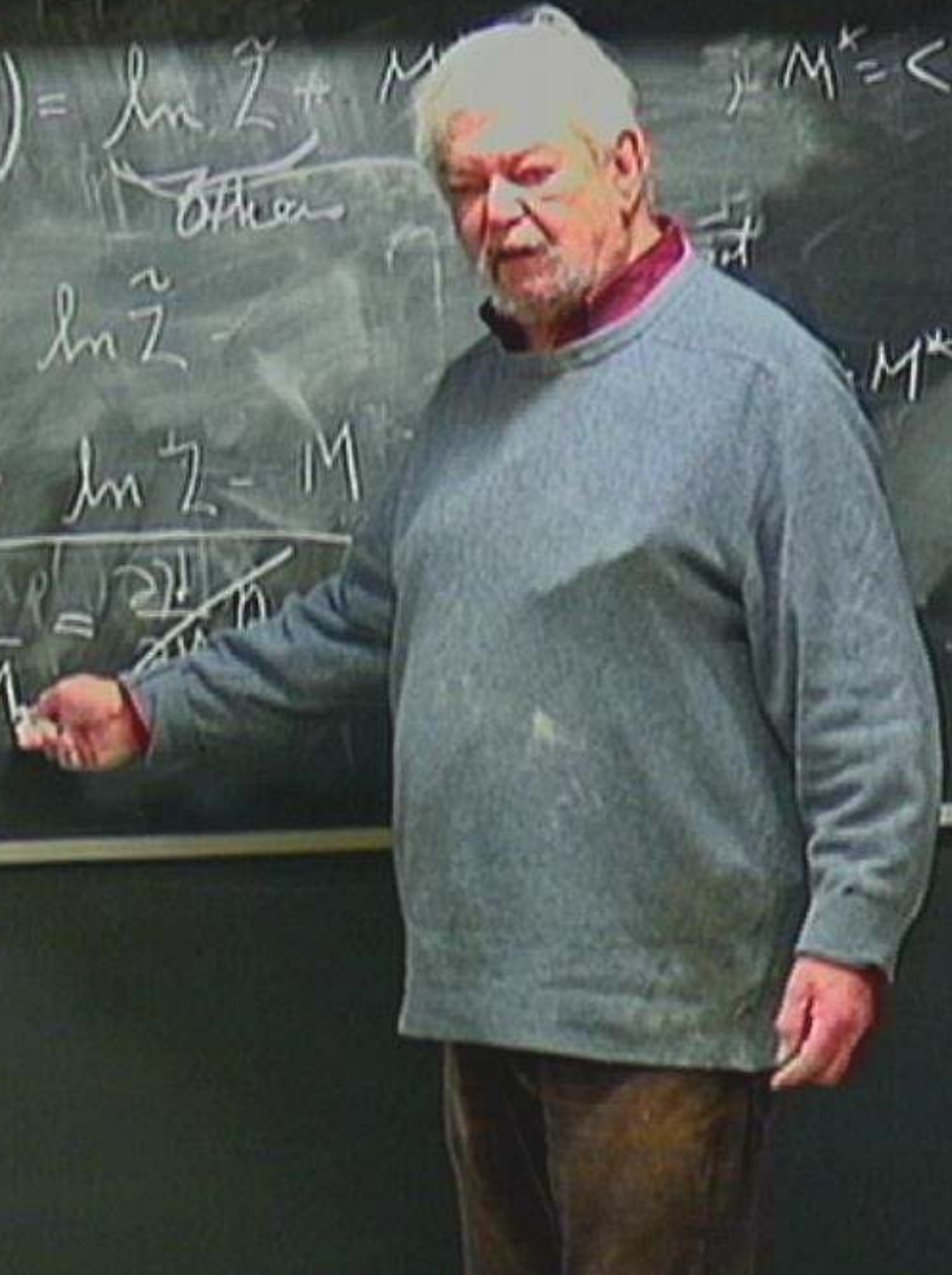
$$= \ln \tilde{Z} - M \lambda_{\text{ext}}$$

$$\ln Z(M^*(\lambda)) = \ln \tilde{Z} + M^* \quad \text{with } M^* = \langle M \rangle$$

gibbi: $Q = \ln \tilde{Z}$
 $= \ln Z - M$

$$M^* \neq G(M)$$

$\frac{\partial G}{\partial M} = \frac{\partial \ln Z}{\partial M}$



$$\ln Z(M^*(\lambda)) = \underbrace{\ln \tilde{Z}}_{\text{Others}} + M^* \lambda_{\text{int}} \quad M^* = \langle M \rangle$$

gibbs: $Q = \ln \tilde{Z}$

$$= \ln \tilde{Z} - M \lambda_{\text{int}}$$

$$\left| \frac{\partial Q}{\partial M} = \frac{\partial}{\partial M} \ln \tilde{Z} - \lambda_{\text{int}} \right.$$

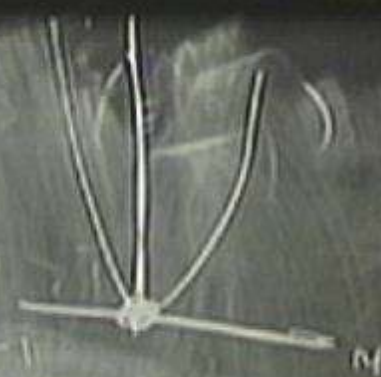
$G(M)$



$$g(\eta=0) = \sum_j \langle \mu_j \mu_j \rangle - \langle \mu_j \rangle \langle \mu_j \rangle$$

$$= \sum_j \frac{\partial^2 \ln Z}{\partial h_j \partial h_j} = \sum_j \frac{\partial \langle \mu_j \rangle}{\partial h_j} = \chi^{-1}$$

$$g(\eta) = \frac{1}{\chi}$$



$T > T_c$

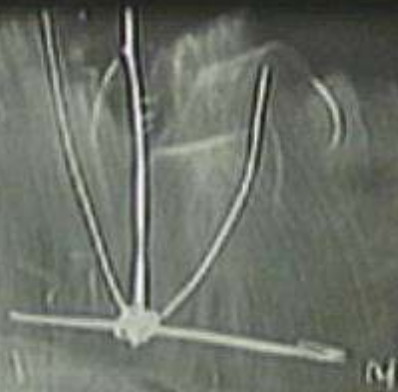


$T < T_c$

$$g(\rho=0) = \sum_{j=1}^M \langle \mu_j \rangle - \langle \mu \rangle \langle \mu_j \rangle$$

$$= \sum_{j=1}^M \frac{\partial \ln Z}{\partial h_j} = \sum_{j=1}^M \frac{\partial \ln Z}{\partial h_j} = \chi^{-1}$$

$$g(\rho) = \frac{1}{\mu^2}$$



$\chi_{\mu E} = 0$
 $T > T_c$



Helm

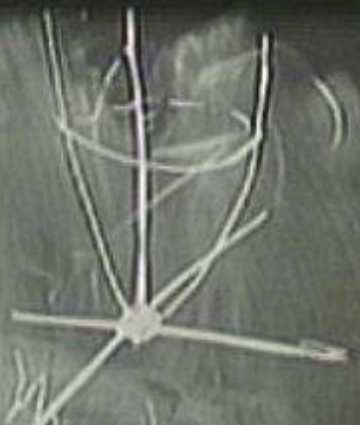
$\chi_{\mu E} > 0$

III

$$g(\rho=0) = \sum_{ij} \langle \mu_i \mu_j \rangle - \langle \mu_i \rangle \langle \mu_j \rangle$$

$$= \sum_{ij} \frac{\partial^2 \ln Z}{\partial h_i \partial h_j} = \sum_{ij} \frac{\partial \langle \mu_i \rangle}{\partial h_j} = \chi^{-1}$$

$$g(\rho) = \frac{1}{\chi^2}$$

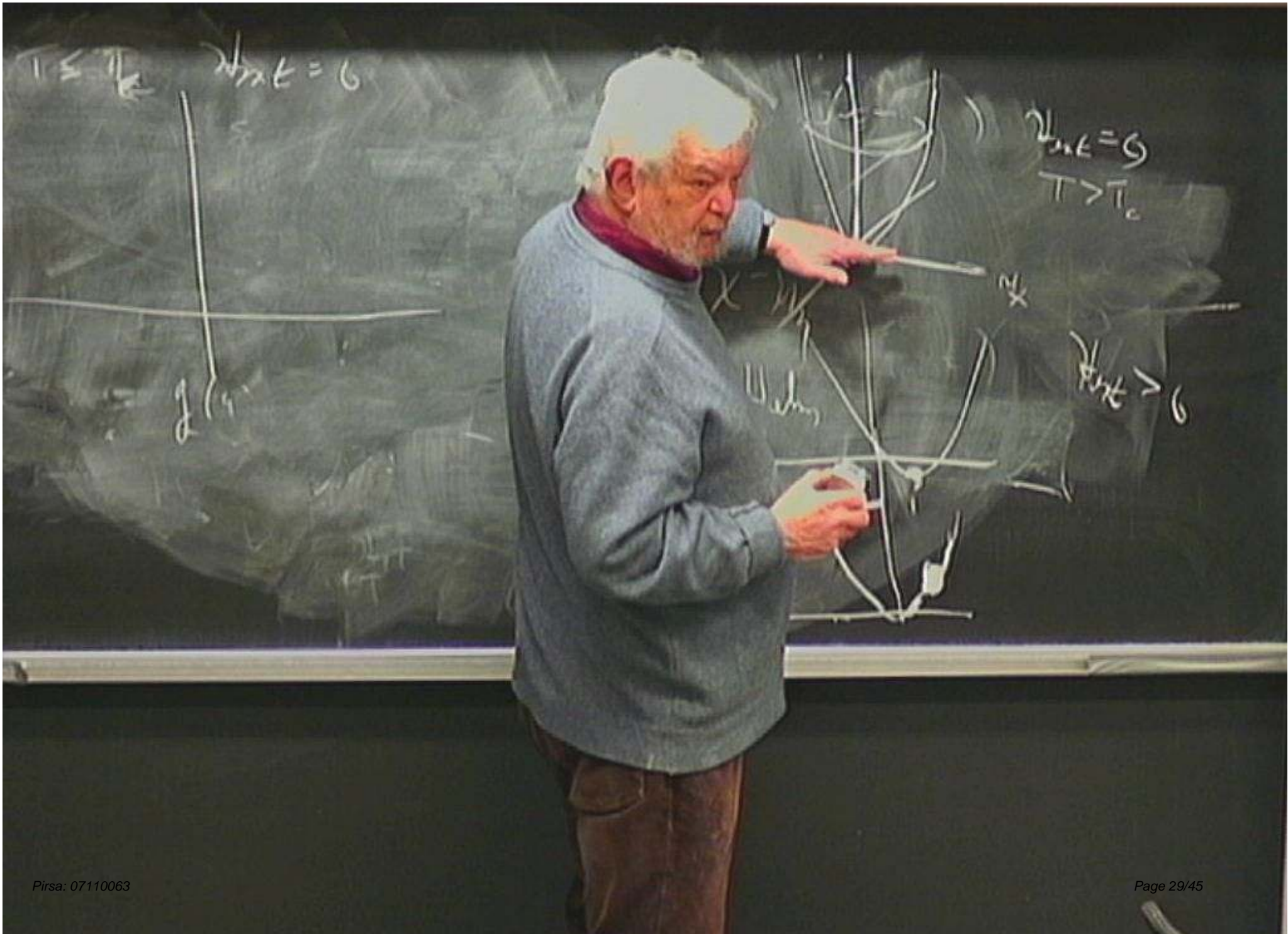


$T < T_c$

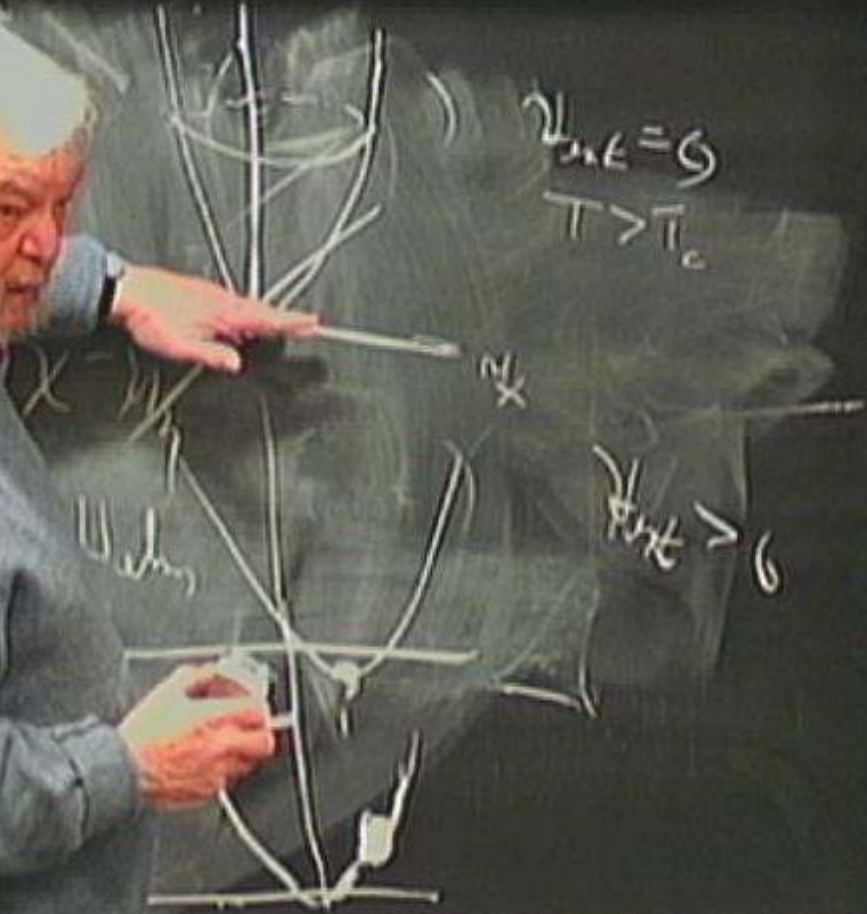


$T > T_c$





$$T \leq T_c \quad \Delta_{\text{max}} = 0$$

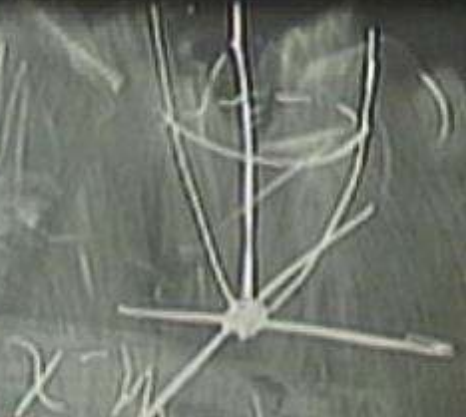
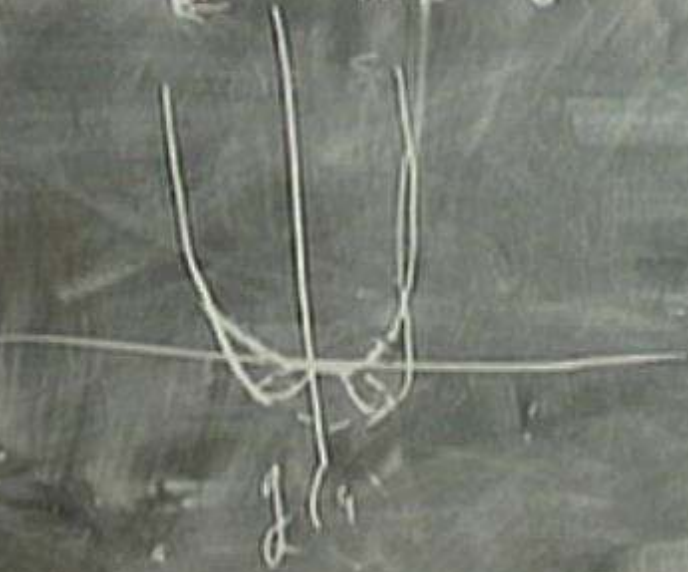


$$\Delta_{\text{max}} = 0 \quad T > T_c$$

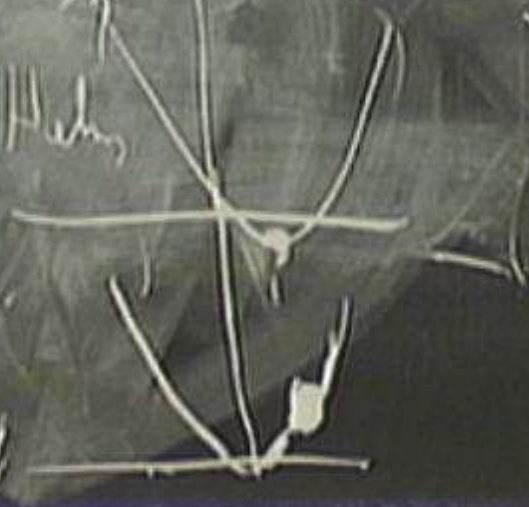
$$\Delta_{\text{max}} > 0$$

$$T \leq T_c$$

$$\mu_{HE} = 0$$

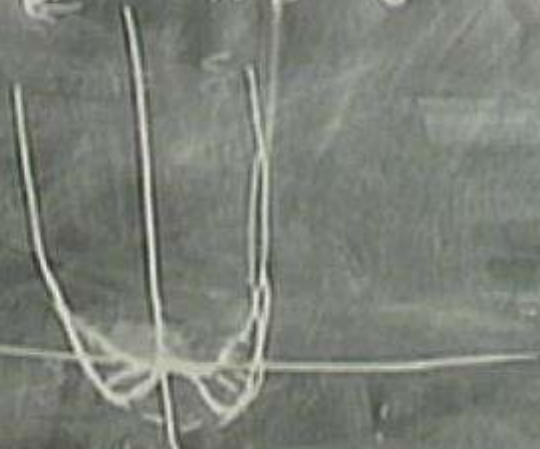


$$\mu_{HE} = 0$$
$$T > T_c$$

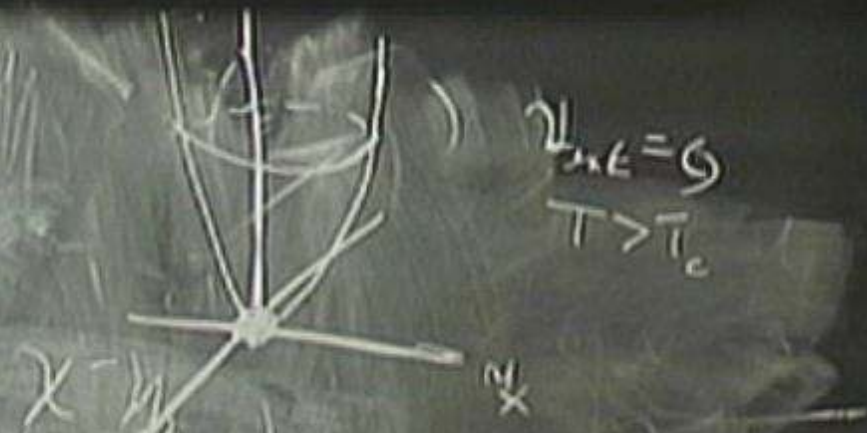
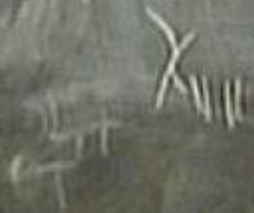


$$\mu_{HE} > 0$$

$T \leq T_c$ $\Delta_{HE} = 0$



Mixed state χ_{HT}



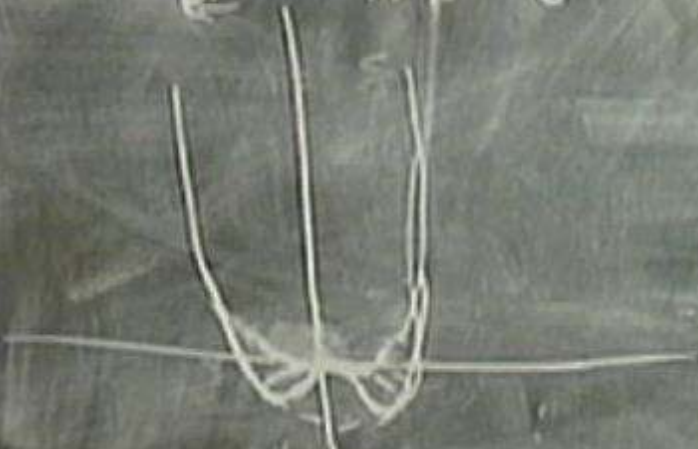
$\Delta_{HE} = 0$
 $T > T_c$



$\Delta_{HE} > 0$



$T \leq T_c$ $\Delta_{HL} = 0$



Magnet diamagnet χ_{II}

χ_{III}



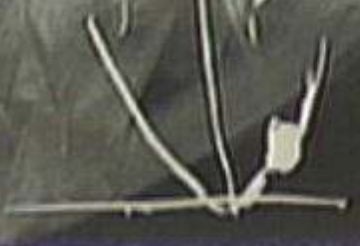
$\Delta_{HL} = 0$
 $T > T_c$

χ_{II} χ_{III}



Helm

$\Delta_{HL} > 0$

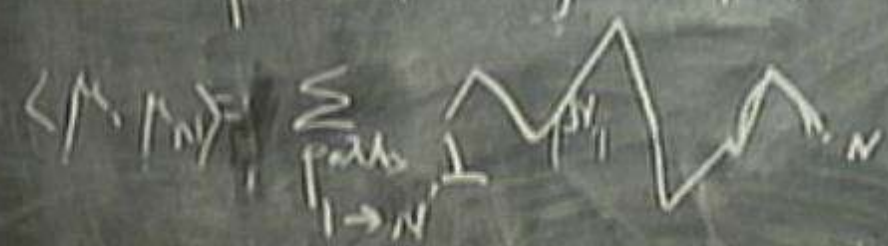


$$H_{\text{eff}} = 0 \quad (\langle M \rangle = 0 \quad T > T_c)$$

$$\langle g_i \rangle = S_i + \dots$$

$$g(\eta) = \frac{1}{1 - \rho(\eta)} \dots \left(1 - \rho(\eta)\right)^2$$

$$\ln g(\eta) = \sum_{j=1}^N \ln \mu_j \sim \frac{1}{N} \sum_{j=1}^N \ln \mu_j$$



$$X = \frac{v_H}{c} \frac{1}{\rho}$$

k bit protocol
 share $k+1$ vector λ_i
 send $\text{sum}(\hat{a} \cdot \lambda_i)$
 $\lambda_1 \cdot \lambda_1 = 0$
 $n = 4$

$\beta \in V, \mu, \nu$
 $\int \in \{ \phi \}$
 $(1 - \rho \nu \lambda_i)^2$
 ν^2
 (ν)
 $1 - \rho \nu^2$

k bit protokol
 share $k+1$ verter λ_k
 send som $(\hat{a} \cdot \lambda_i)$
 $\lambda_1 \cdot \lambda_2 = 0$
 $n = 4$

$$Z = \frac{1}{2} \left(\sum_{i=1}^n s_i v_i + h(s) \right)$$

$$= \int_{-\infty}^{\infty} s \left(\sum_{i=1}^n \Phi_i v_i^{-1} \Phi_i \right)$$

$$\Phi = \Phi_1 \dots \Phi_n$$

$$\lambda = \lambda_1 \dots \lambda_n$$

$(1 - \rho^2)^2$
 $\frac{1}{v^2}$
 (s)



$$Z = \int \mathcal{D}\phi \mathcal{D}\psi \mathcal{D}\bar{\psi} \exp\left(-\int d^4x \mathcal{L}(\phi, \psi, \bar{\psi})\right)$$

$$= \int \mathcal{D}\phi \left\{ \int \mathcal{D}\psi \mathcal{D}\bar{\psi} \exp\left(-\int d^4x \mathcal{L}(\phi, \psi, \bar{\psi})\right)\right\}$$

$$\int \mathcal{D}\psi \mathcal{D}\bar{\psi} \exp\left(-\int d^4x \mathcal{L}(\phi, \psi, \bar{\psi})\right) = \int \mathcal{D}\psi \mathcal{D}\bar{\psi} \exp\left(-\int d^4x \left[\bar{\psi} \not{\partial} \psi - \bar{\psi} \not{A} \psi + \bar{\psi} \not{B} \psi\right]\right)$$

$$Z = \int \mathcal{D}\phi \exp(-\int d^4x \mathcal{L}(\phi, \partial\phi))$$

$$\int \mathcal{D}\phi \exp(-\int d^4x \mathcal{L}(\phi, \partial\phi)) = \int \mathcal{D}\phi_1 \mathcal{D}\phi_2 \dots \mathcal{D}\phi_N \exp(-\int d^4x \mathcal{L}(\phi_1, \partial\phi_1) - \dots - \int d^4x \mathcal{L}(\phi_N, \partial\phi_N))$$

$$\int \mathcal{D}\phi = \int \mathcal{D}\phi_1 \mathcal{D}\phi_2 \dots \mathcal{D}\phi_N$$

$$\int \mathcal{D}\phi = \int \mathcal{D}\phi_1 \mathcal{D}\phi_2 \dots \mathcal{D}\phi_N$$

$$Z = \int \mathcal{D}\phi \exp(-\int d^4x \mathcal{L}(\phi, \partial\phi))$$

$$= \int \mathcal{D}\phi \exp(-\int d^4x \left[\frac{1}{2} \partial_\mu \phi \partial^\mu \phi + V(\phi) \right])$$

$$\mathcal{L}(\phi) = \frac{1}{2} \partial_\mu \phi \partial^\mu \phi - V(\phi)$$

$$\Rightarrow \mathcal{L}(\phi) = \frac{1}{2} \dot{\phi}^2 - \frac{1}{2} (\nabla \phi)^2 - V(\phi)$$

$$Z = \frac{1}{h} \left(\sum_{\nu} \sum_{i} v_{i\nu} \right) / \left(\prod_{\nu} \nu \right)$$

$$= \int \delta(\phi) \left(\frac{1}{h} \sum_{\nu} \int \delta(\nu) \right)$$

$$Z = \frac{1}{h} \left(\frac{\beta}{2\pi} \sum v_i \right) \dots$$

$$\dots \sum \phi_i \dots \prod \coth \phi_i$$

$1 - cr^3$

$$Z = \int \prod_i d\phi_i \exp \left[-\beta \sum_i \left(\frac{1}{2} \phi_i V \phi_i + \mu \phi_i \right) \right]$$

$$= \int \mathcal{D}\{\phi\} \exp \left[-\beta \left(\frac{1}{2} \Phi V \Phi^{-1} \Phi + \sum_i \ln \cos \phi_i \right) \right]$$

$$Z = \frac{1}{h} \int \sum_i \exp(-\beta \epsilon_i) \Omega(\epsilon_i) d\epsilon_i$$

$$= \int \Omega(\epsilon) \exp(-\beta \epsilon) \Omega(\epsilon) d\epsilon$$

$$Z = \int \mathcal{D}\phi \exp\left(-\frac{i}{\hbar} \int d^4x \mathcal{L}(\phi, \partial\phi)\right)$$

$$= \int \mathcal{D}\phi \exp\left(-\frac{i}{\hbar} \int d^4x \left[\frac{1}{2} \partial_\mu \phi \partial^\mu \phi - V(\phi) \right]\right)$$

$$Z = \frac{1}{h} \int \prod_i \exp(-\beta \sum_i v_i) \prod_i \exp(-\beta \sum_i \ln \cos \phi_i)$$

$$= \int \prod_i \{ \phi_i \} \exp \left[-\frac{\beta}{2} \sum_i \Phi_i \mathbf{M}^{-1} \Phi_i \right] \exp \sum_i \ln \cos \phi_i$$

1-cr3