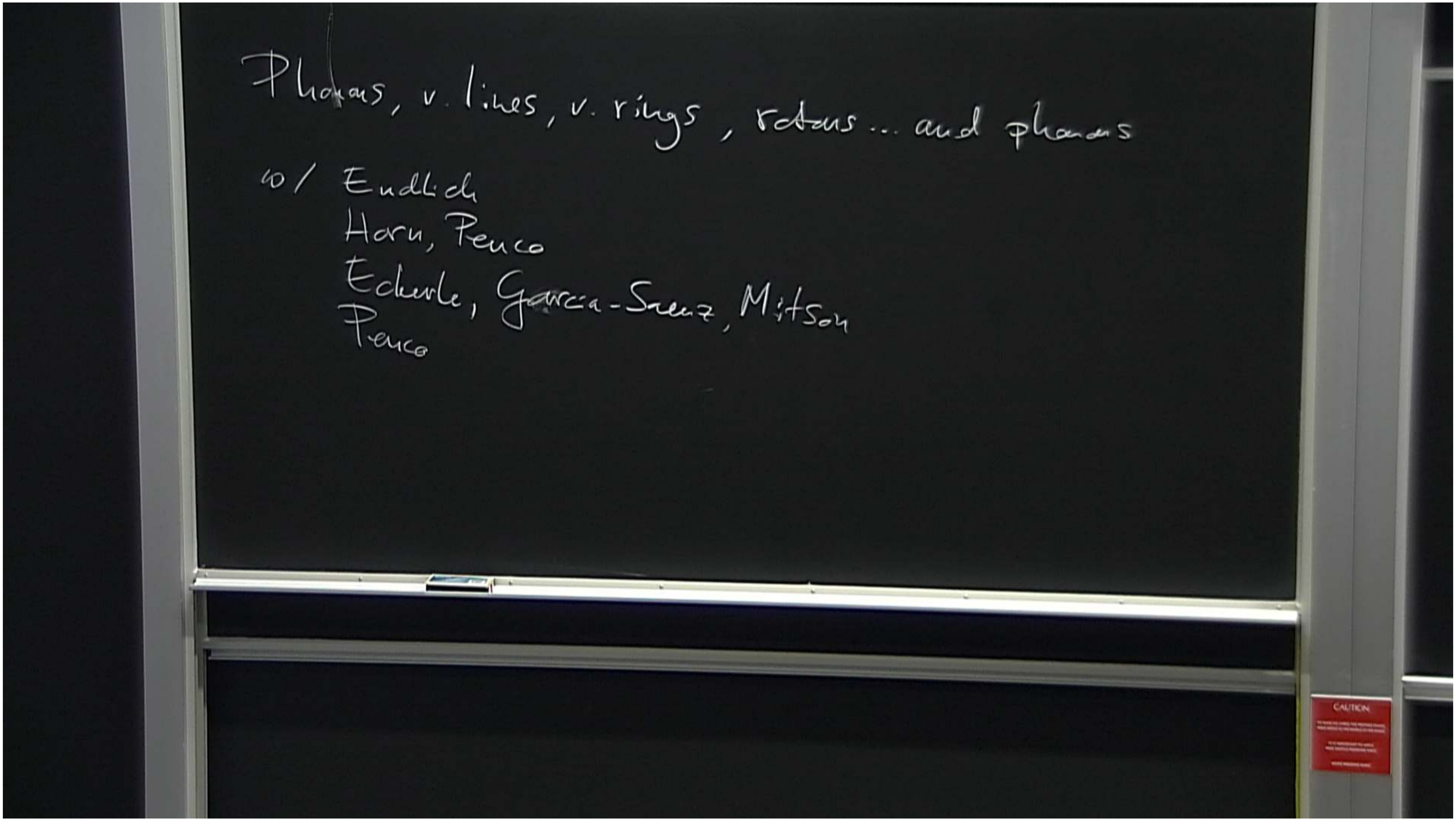
Title: TBA

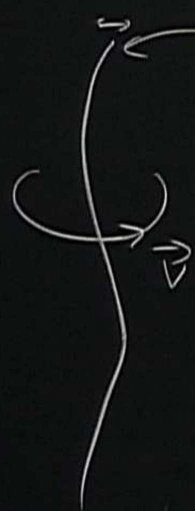
Date: Aug 22, 2016 09:30 AM

URL: http://pirsa.org/16080033

Abstract:


Phonons, v. lines, v. rings, rotons ... and phonons
w/ Endlich
Horn, Penco
Eckerle, Garcia-Saenz, Mitsou
Penco

◦ superfluid vs fluid



$\vec\nabla \times \vec v \neq 0$

$\langle J^\mu \rangle \propto \delta^\mu_0$

Superfluid = $\underset{\text{SSB (BEC)}}{\cancel{\emptyset}}$ + $(\langle Q \rangle \neq 0)$

◦ Goldstones: (phonons)

$\underline{\phi(x)} = \underline{\mu} t + \pi(x)$

↑ Lorentz scalar

$\phi(x) \to \phi(x) + a$

s. fluid

$\neq 0$

$$\text{Superfluid} = \underbrace{\cancel{Q}}_{\text{SSB}} + (\langle Q \rangle \neq 0)$$

(BEC)

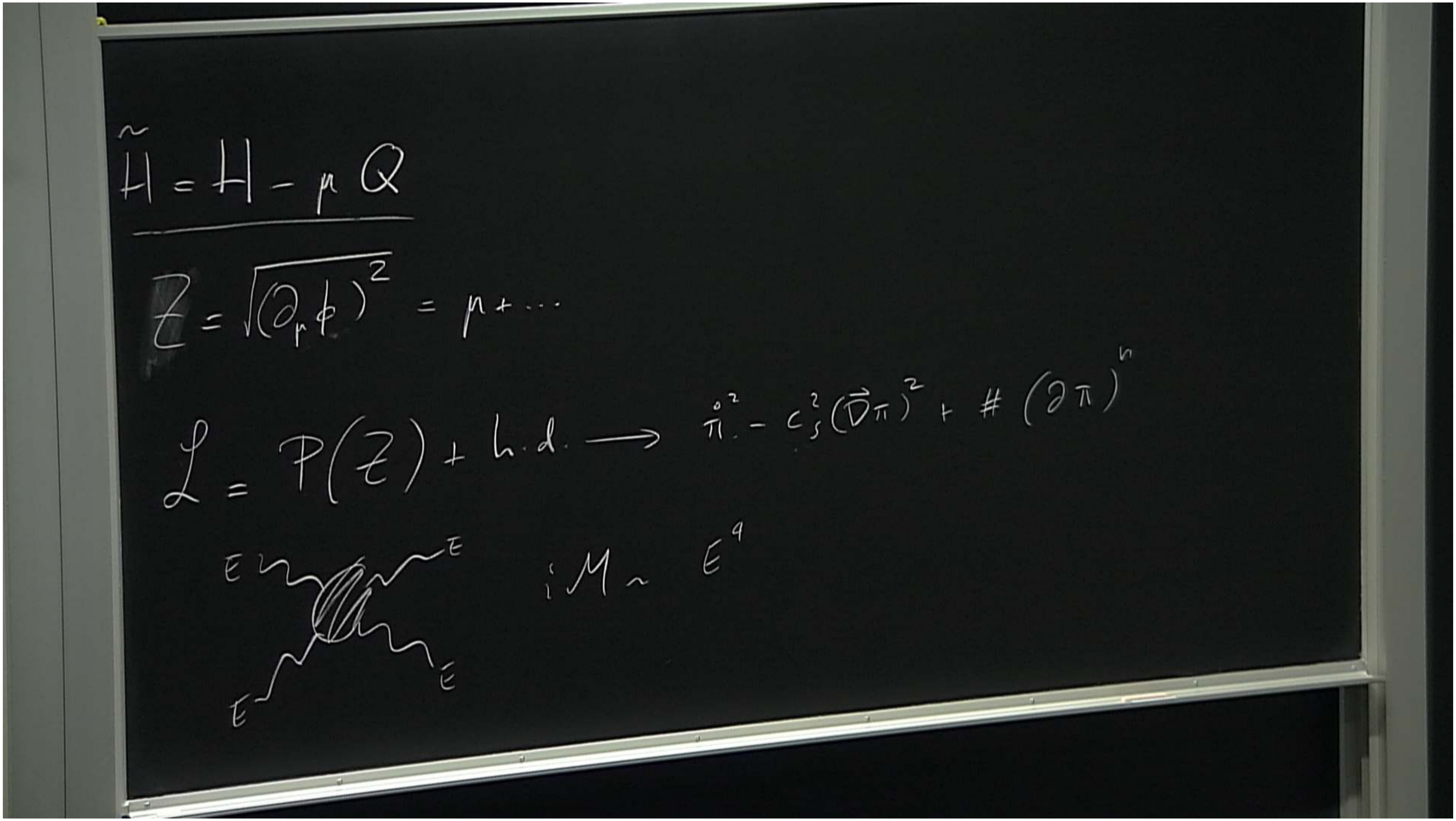
$$\Phi(x) = \rho(x) e^{i\phi}$$

- Goldstones: (phonons)

$$\phi(x) = \mu t + \pi(x)$$

Lorentz scalar

- $\phi(x) \to \phi(x) + a$
- Poincaré

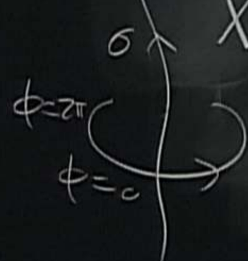

$\tilde{H} = H - \mu Q$
$Z = \sqrt{(\partial_\mu \phi)^2} = \mu + \dots$
$\mathcal{L} = P(Z) + h.d. \longrightarrow \dot{\pi}^2 - c_s^2 (\vec{\nabla}\pi)^2 + \# (\partial\pi)^n$
E
E
E
E
$i\mathcal{M} \sim E^4$

• Vortex lines $\quad A_{(2)\mu\nu} \to A_{(2)\mu\nu} + \partial_\mu \xi_\nu - \partial_\nu \xi_\mu$

$X^\mu(\tau,\sigma)$

$\phi \longleftrightarrow A_{(2)\mu\nu}$ (magnetic dual)

$X^3 = \sigma$



$$\left(\int A_\mu \, dq^\mu\right)$$

$$S_{KR} = \lambda \int A^{(2)}_{\mu\nu}\, \partial_\tau X^\mu \partial_\sigma X^\nu \cancel{\left(\partial_\sigma X^\alpha \partial^\sigma X_\alpha\right)}\, d\tau\, d\sigma$$

$$f((\partial\phi)^2)\,\partial_\mu\phi \longleftrightarrow \epsilon_{\mu\nu\rho\sigma}\,\partial^\nu \mathcal{A}_{(2)}^{\rho\sigma}\; g((d\mathcal{A}_{(2)})^2)$$

$\nabla^2\vec{A}$ = source

$$\mathcal{A}^{00}_{(2)} = 0$$

$$\phi(x) = \underline{\mu}\, t + \pi(x) \longleftrightarrow \quad \mathcal{A}^{0i}_{(2)} = n\cdot A^i(x)$$

$$\mathcal{A}^{ij}_{(2)} = n\cdot\epsilon^{ijk}\left(x^k + B^k(x)\right)$$

$$\mu \longleftrightarrow n$$

choice of gauge $\begin{cases} \vec{\nabla}\cdot\vec{A} = 0 \\ \vec{\nabla}\times\vec{B} = 0 \end{cases}$

$$\langle A\, A \rangle = \text{transverse} \times \frac{i}{\vec{k}^2}$$

$$\langle B\, B \rangle = \text{longitudinal} \times \frac{i}{\omega^2 - c_s^2 \vec{k}^2 + i\varepsilon}$$

$$\int P(Z) \longleftrightarrow \int \rho(Y)$$

$$Y = \sqrt{(dA_{(2)})^2} = n + \dots$$

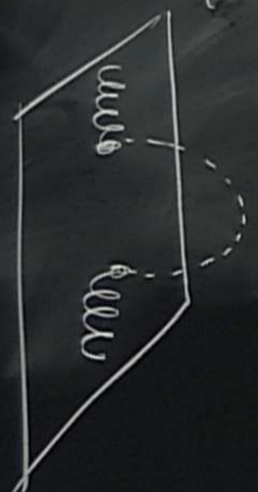
$$\boxed{S_{bulk} = \int \rho(Y)\, d^4x}$$

- string eom ($\tau = X^0 = t$, $A_{(2)} \to$ background)

$$\boxed{h_{\alpha\beta} = \partial_\alpha X_\mu \partial_\beta X_\nu u^\mu u^\nu}$$

$$u^\mu \propto \partial^\mu \phi \propto \epsilon^{\mu\nu\rho\sigma} \partial^\nu A^{\rho\sigma}_{(2)}$$

$$\partial_t \vec{X} \times \partial_\sigma \vec{X} = 0$$



$\partial_\sigma \vec{X}$

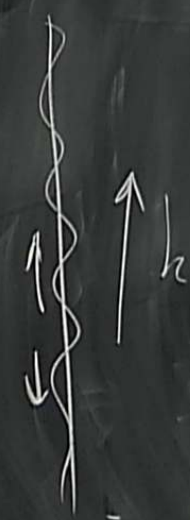
$$\boxed{S_{NG'} = \int \sqrt{\det g_{ind}}\; T\left(Y, g^{ind}_{\alpha\beta}, h^{\alpha\beta}\right)}$$

$$\boxed{S_{KR} = \lambda \int A_{(2)}\, d_t X\, d_\sigma X}$$

$$T \equiv \tau(n,1)$$

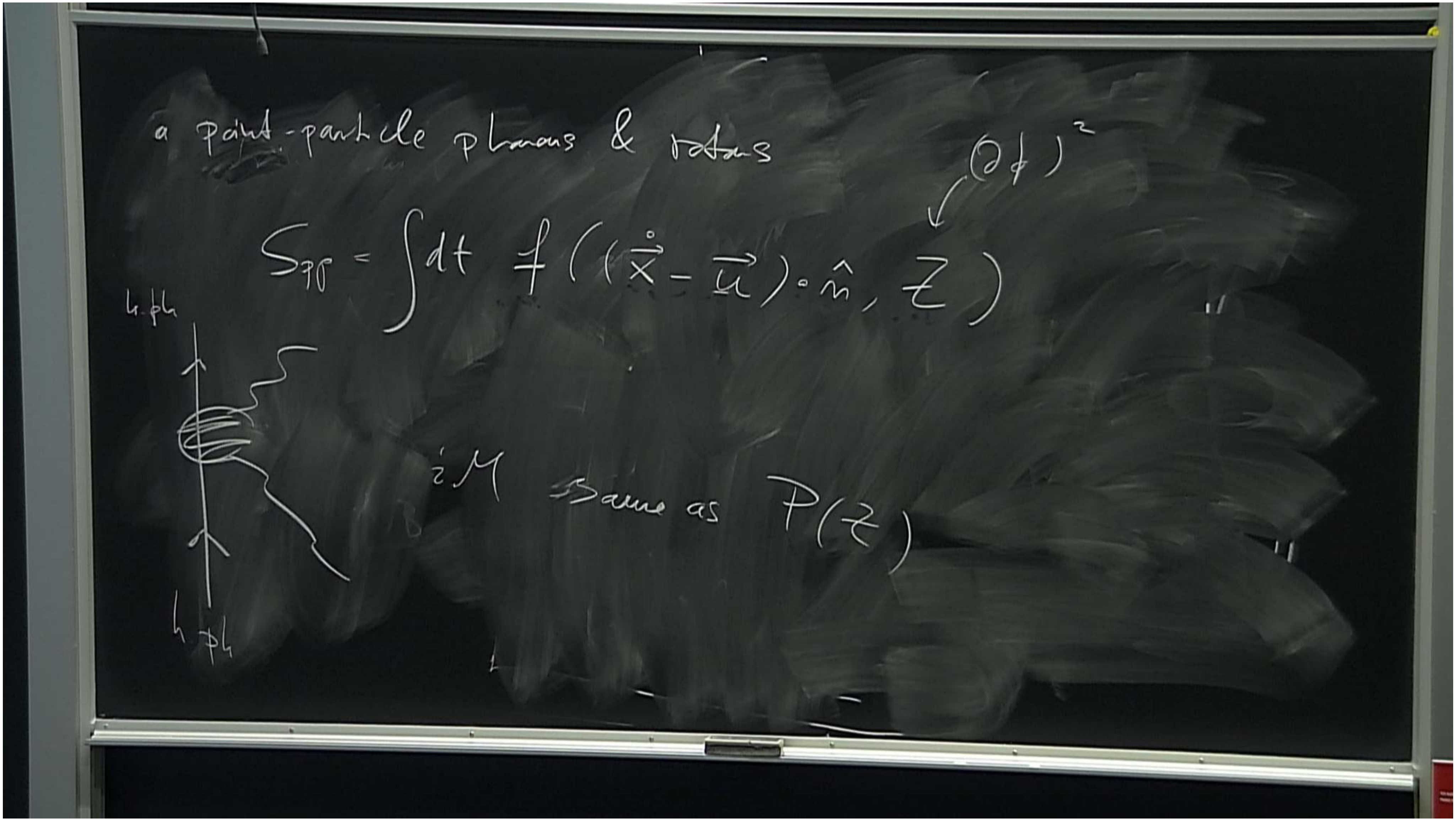
tension

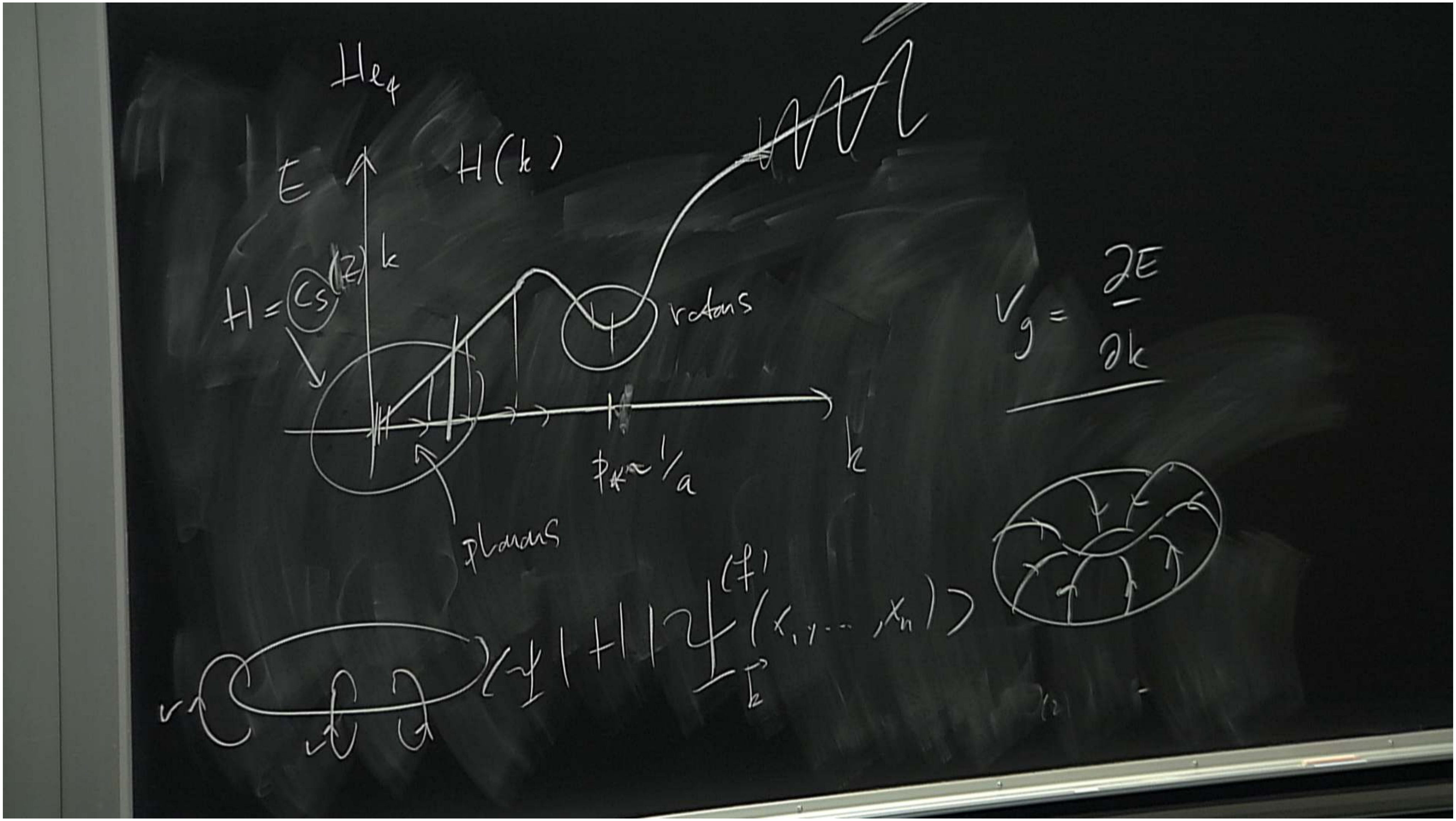
$$\frac{dT}{d\log\mu} = -\frac{n^2\lambda^2}{(\rho+p)}$$

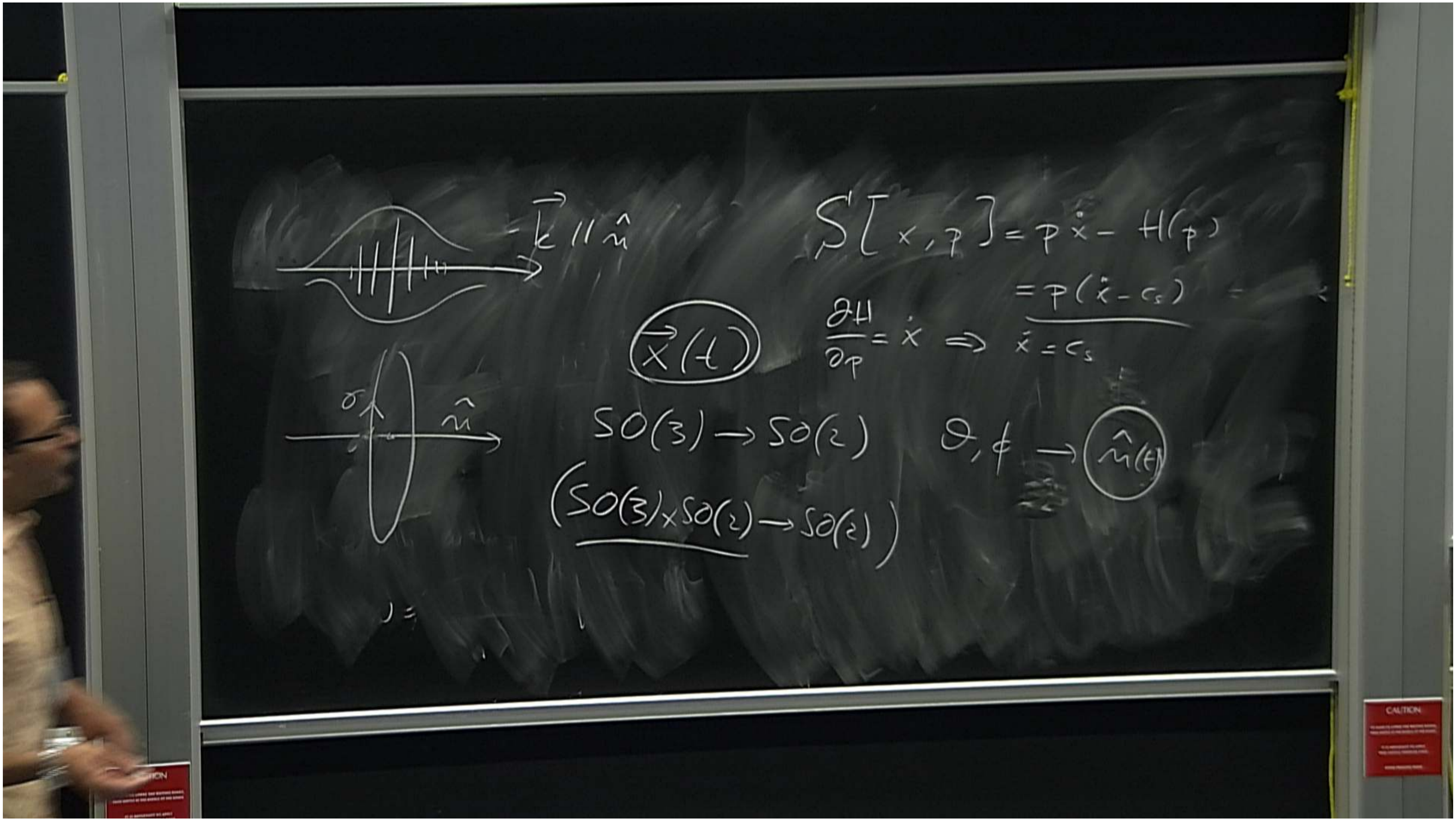


- kelvin waves

$$\omega = \frac{T(k)}{n\lambda}k^2$$


a point-particle phonons & rotons
$(\partial\phi)^2$
$S_{pp} = \int dt\, f((\dot{\vec{x}} - \vec{u})\cdot\hat{n}, Z)$
h.ph
iM
same as P(Z)
h.ph


H(k)
E
rotons
phonons
k
v_g = ∂E/∂k


k ∥ n̂
S[x, p] = p ẋ − H(p)
= p(ẋ − c_s)
x(t)
∂H/∂p = ẋ ⇒ ẋ = c_s
σ
n̂
SO(3) → SO(2)
θ, φ → n̂(t)
(SO(3) × SO(2) → SO(2))
CAUTION