Title: Special Topics in Physics - Lecture 4A

Date: Jan 30, 2008 07:00 PM

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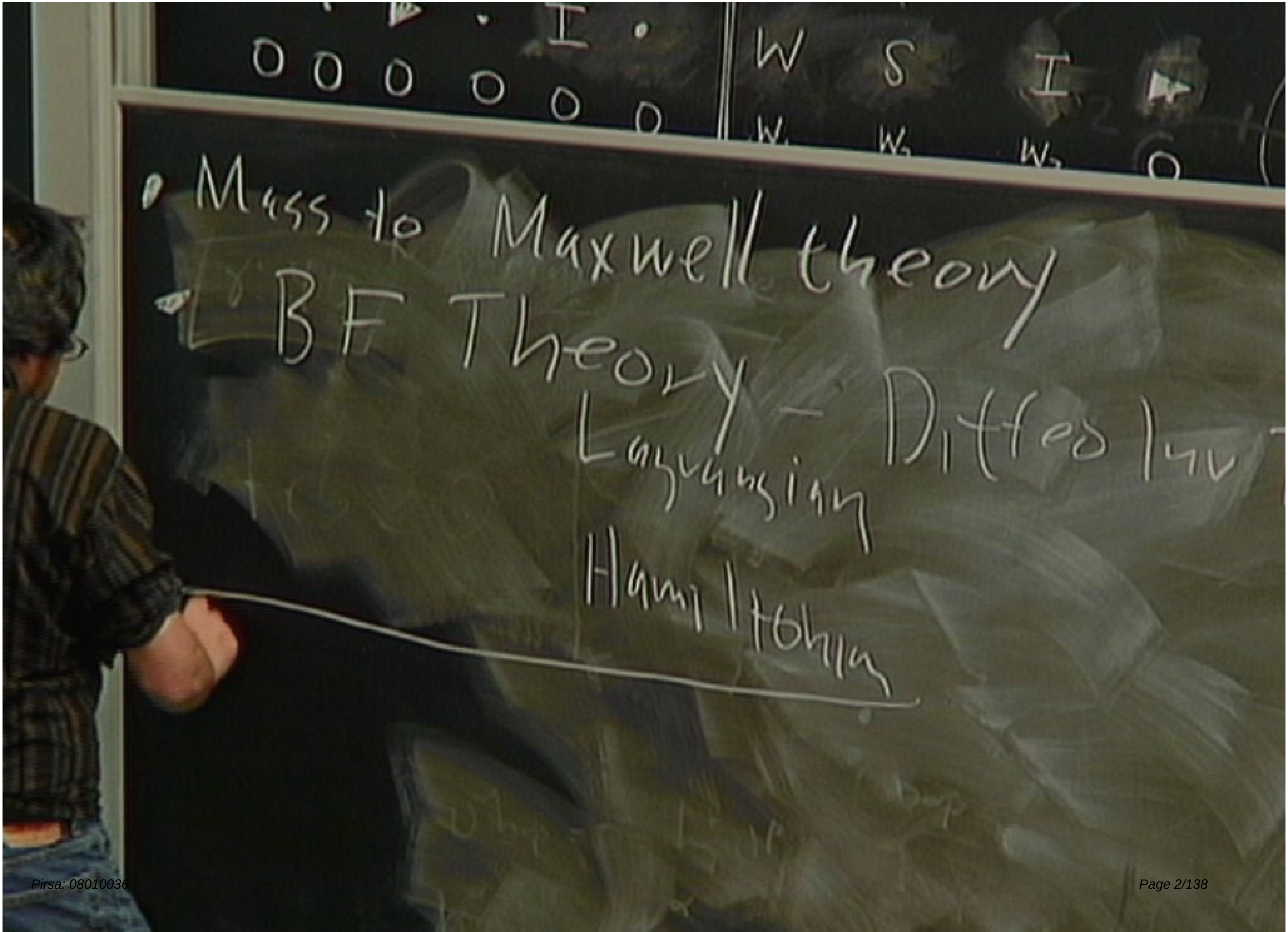
Abstract: The Problem of Time in Quantum Gravity and Cosmology


Mass to Maxwell theory
BF Theory - Diffeo Inv
Lagrangian
Hamiltonian

$$S = \int d^4x \left[-\frac{1}{4} F_{\mu\nu}F^{\mu\nu} + \frac{M^2}{2} A_\mu A_\nu \eta^{\mu\nu} \right]$$

$$\int d^4x \left[-\frac{1}{4} F_{\mu\nu}F^{\mu\nu} + \frac{M^2}{2} A_\mu A_\nu \eta^{\mu\nu} \right]$$

$$S = \int \sqrt{g}\left[g^{\mu\nu}\partial_\mu\phi\,\partial_\nu\phi - \frac{m^2}{2}\phi^2\right]$$

$$\left[\square + m^2\right]\phi = 0$$

$$\frac{1}{2} A_\mu A_\nu$$

$$\partial_\mu F^{\mu\nu} - m^2 A^\nu = 0$$

$$\Box A_\nu - \partial_\nu \partial_\mu A^\mu - m^2 A_\nu = 0$$

$\Big) \quad \Big[\tfrac{1}{4} F_{\mu\nu}$

Lorentz gauge

$$\partial_\mu A^\mu = 0$$

$$\partial_\mu F^{\mu\nu} - \ldots$$

$$\Box A_\nu - \partial_\nu \partial \ldots$$

$$(\Box - m^2 \ldots$$

$$\left[\ \tfrac{1}{4}F_{\mu\nu}\right.$$

Lorentz gauge

$$\partial_\mu A^\mu = 0$$

$$\partial_\mu F^{\mu\nu} - M$$

$$\Box A_\nu - \partial_\nu \partial$$

$$\delta A_\mu = \partial_\mu f$$

$$(\Box - m^2$$

gauge

$$\partial_\mu A^\mu = 0$$

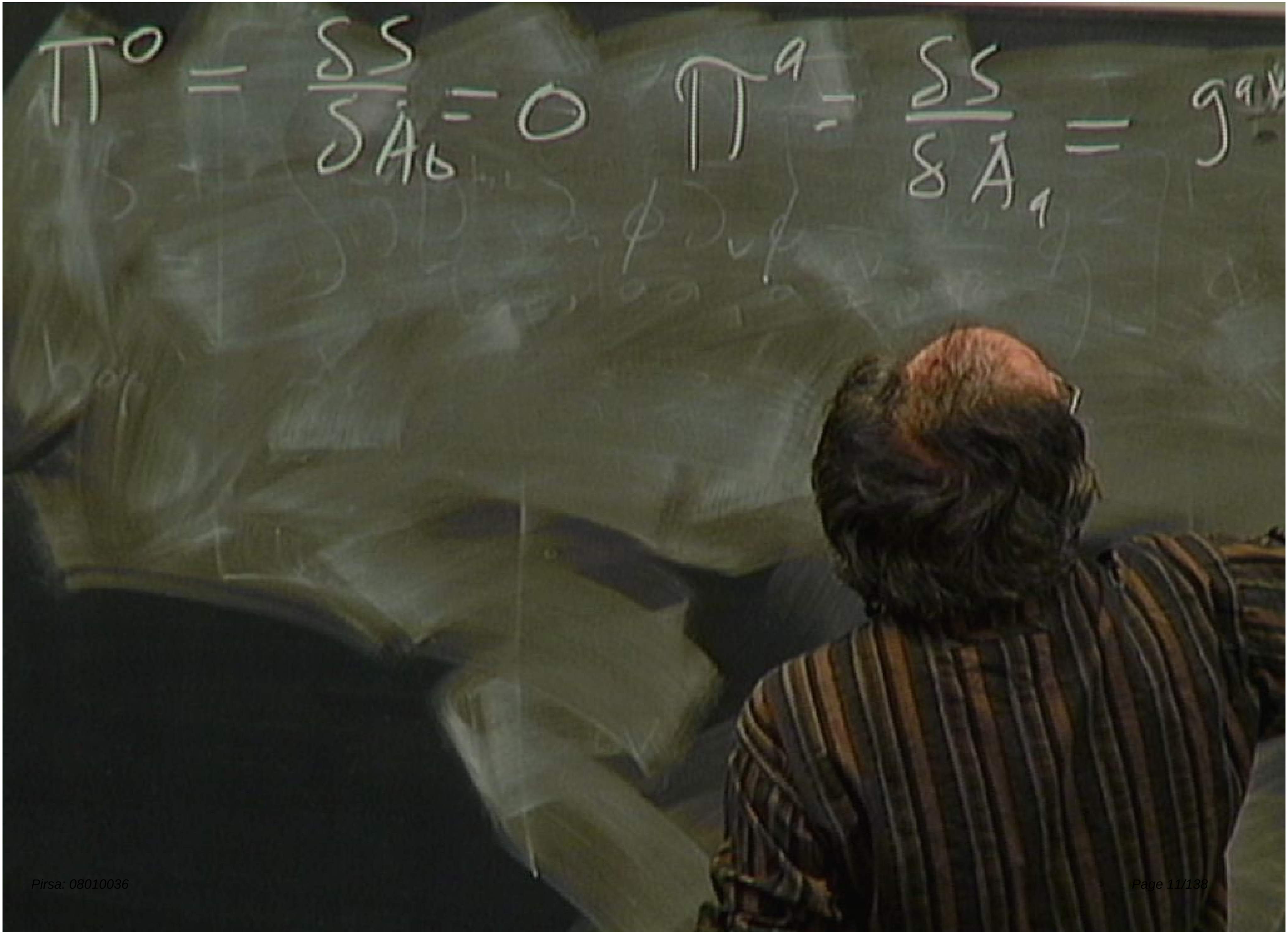
$$\partial_\mu F^{\mu\nu} - M^2$$

$$\Box A_\nu - \partial_\nu \partial_\mu A^\mu$$

$$\delta A_\mu = \partial_\mu f$$

$$[\Box - m^2] A_\nu$$

$$\delta S = m^2 \int \sqrt{g}\, g^{\mu\nu} A_\mu \partial_\nu f$$


$\Pi^0 = \frac{\delta S}{\delta \dot{A}_b} = 0$
$\Pi^a = \frac{\delta S}{\delta \dot{A}_a} = g^{a}$

$$\Pi^0 = \frac{\delta S}{\delta \dot{A}_0} = 0 \qquad \Pi^a = \frac{\delta S}{\delta \dot{A}_a} = g^{a\nu} F_{0\nu}$$

$$\Pi^0 = \frac{\delta S}{\delta \dot{A}_0} = 0 \quad \Pi^a = \frac{\delta S}{\delta \dot{A}_a} = g^{a\nu} F_{0\nu}$$

$\Pi^0 = 0$ - primary constraint

$$\Pi = \frac{\delta S}{\delta \dot{A}_b} = 0 \qquad \Pi = \frac{\delta S}{\delta \dot{A}_a} = g^{a\psi}$$

$\Pi^0 = 0$ - primary constraint

$$H = \int \Pi^a \dot{A}_a + \Pi^b \dot{A}_b - \mathcal{L}$$

$\Pi^0 = 0$ - primary constraint

$$H = \int \Pi^i \dot{A}_i + \Pi^0 \dot{A}_0 - \mathcal{L} = \int \frac{1}{2}(\Pi^i)^2 + \frac{1}{2} F_{ij}^2 +$$

y constraint

$$\bar{A}_0 \quad \mathcal{L} = \int \frac{1}{2}(\Pi^a)^2 + \frac{1}{2}F_{ab}^2 + A_0\left[\partial_a \Pi^a - \frac{m^2}{2} A_0\right]$$

$$+ \lambda \Pi^0$$

$$)^2 + \frac{1}{2} F_{ab}^2 + A_0 \left[\partial_a \Pi^a - \frac{m^2}{2} A_0 \right]$$

$$H = \int \Pi^a \dot{A}_a + \Pi^0 \dot{A}_0 - \mathcal{L} = \int \tfrac{1}{2}(\Pi^a)^2 + \tfrac{1}{2}$$

$$\dot{\Pi}^0 = 0 = \{\Pi^0, H\} = \partial_a \Pi^a - m^2 A_0 \equiv$$

$$\ldots_a + \Pi^0 \dot{A}_0 - \mathcal{L} = \int \frac{1}{2}(\Pi^a)^2 + \frac{1}{2} F_{ab}^2 + A_0 [\partial_a \ldots$$

$$\ldots^0, H\} = \partial_a \Pi^a - m^2 A_0 \equiv G = 0$$

$$H = \int \Pi^1 \dot{A}_1 + \Pi^0 \dot{A}_0 - \mathcal{L} = \int \tfrac{1}{2}(\Pi^1)^2 + \tfrac{1}{2} F_{45}^2 +$$

$$\dot{\Pi}^0 = 0 = \{\Pi^0, H\} = \partial_1 \Pi^1 - m^2 A_0 \equiv G$$

$$H = \int [\tfrac{1}{2}\Pi^{1\,2} + \tfrac{1}{2}F_{45}^2 + \lambda \Pi^0 + \mu G$$

$$H = \int \Pi^1 \dot{A}_1 + \Pi^0 \dot{A}_0 - \mathcal{L} = \int \frac{1}{2}(\Pi^1)^2 + \frac{1}{2} F_{15}^2 + \quad A$$

$$\dot{\Pi}^0 = 0 = \{\Pi^0, H\} = \partial_1 \Pi^1 - m^2 A_0 \equiv G = 0$$

$$H = \int \left[\frac{1}{2} \Pi^{1\,2} + \frac{1}{2} F_{15}^2 + \lambda \Pi^0 + \mu G \right]$$

$$\dot{G} = 0 =$$

$$\dot{C}_2(y) = 0 = -m^2 \int d^3x \, \lambda(x) \overbrace{\{ A_0(y), \Pi^0(x) \}}^{\delta^3(y,x)}$$

$$) \; \partial \overbrace{\left\{ A_0(y), \Pi^0(x) \right\}_0}^{\delta^3(y,x)} = -m^2 \lambda(y)$$

$$= \int \frac{1}{2}(\Pi^a)^2 + \frac{1}{2}F_{ab}^2 + A_0\left[\partial_a \Pi^a - \frac{m^2}{2} A_0\right]$$

$$\partial_a \Pi^a - m^2 A_0 \equiv G = 0$$

$$\frac{1}{2}F_{ab}^2 + \lambda \Pi^0 + \mu G + A_0 G + m^2 A_0^2$$

$$= -m \int d^3x \, \lambda(x) \{ A_0(y), \Pi^0(x) \} =$$

$$\boxed{\{ G(y), \Pi^0(z) \} = m^2 \delta^3(y, z)}$$

$$\{A_0(y), \Pi^0(x)\} = -m^2 \lambda(y))$$

$$\boxed{= m^2 \delta^3(y,z)}$$

2nd class

$$+\frac{M^2}{2} A_\mu A_\nu$$

$$- M^2 A^\nu = 0$$

$$\partial_\nu \partial_\mu A^\mu - m^2 A_\nu = 0$$

$$m^2] A_\nu = 0$$

$$= -m\,\lambda(y)$$

$$\boxed{z)}$$

2nd class

Dirac $\{\ \}$

$$= \partial_a \Pi^a - m^2 A_0 \equiv G = 0$$

$$\Pi^{a\,2} + \tfrac{1}{2} F_{ab}^2 + \lambda \Pi^0 + \mu G + A_0 G + m^2 A$$

$$d^3x \, \lambda(x) \{ A_0(y), \Pi^0(x) \} = -m \; \lambda(y)$$

$$\Pi^0(z) \} = m^2 \delta^3(y, z)$$

2nd cl

Dirac

M

$$[A_\mu]_A{}^B = A_\mu^i \, T^{iB}{}_A$$

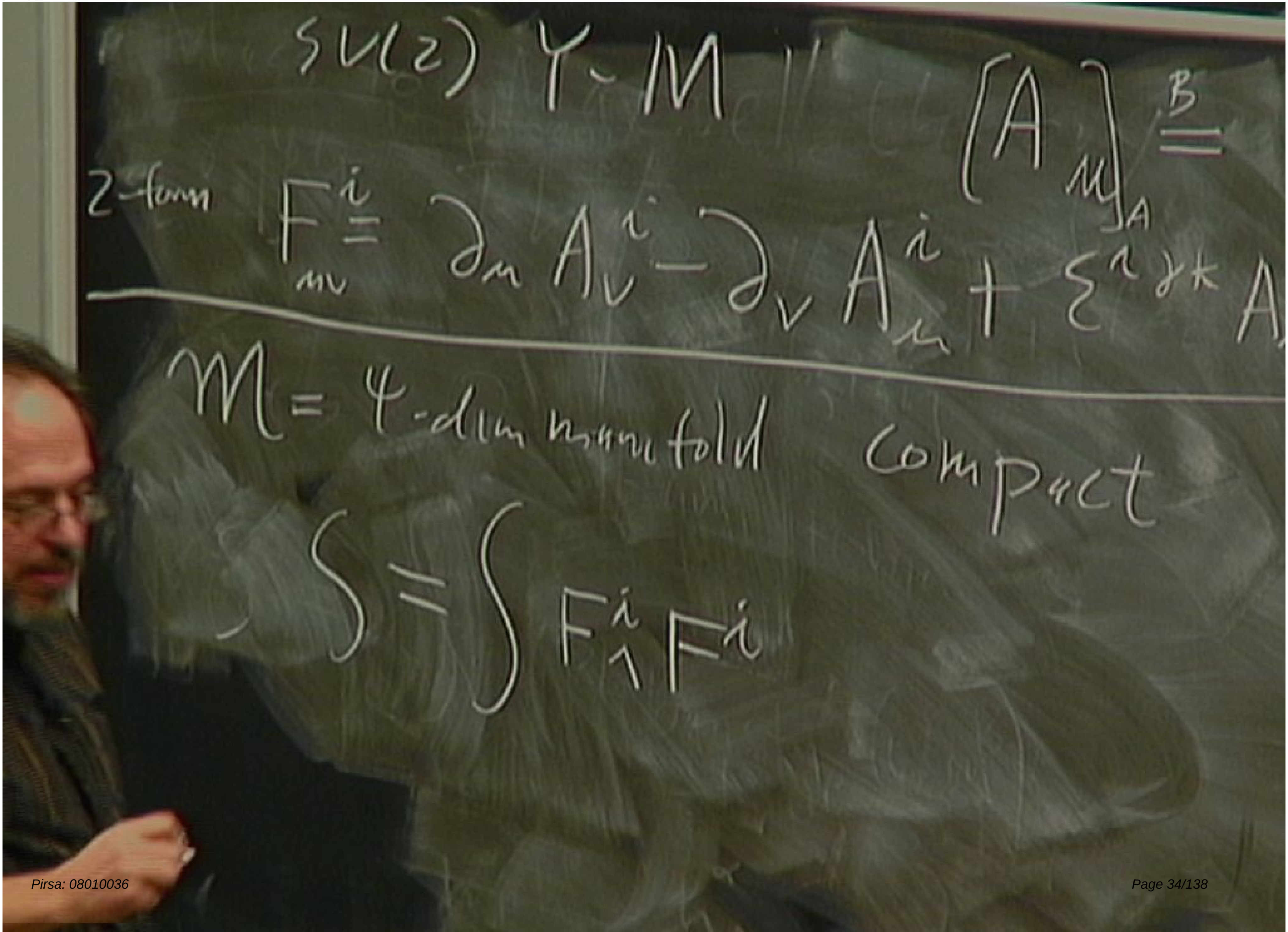
SU(2) Y-M

$$[A_\mu]_A{}^B = A^i_\mu \ldots$$

$$F^i_{\mu\nu} = \partial_\mu A^i_\nu - \partial_\nu A^i_\mu + \epsilon^{ijk} A^j_\mu A^k_\nu$$

$$F_{\mu\nu}^{i} = \partial_\mu A_\nu^i - \partial_\nu A_\mu^i + \varepsilon^{ij\ldots}$$

$\mathcal{M}$ = 4-dim manifold compact



SU(2) Y-M
$[A_\mu]_A{}^B =$
2-form $F^i_{\mu\nu} = \partial_\mu A^i_\nu - \partial_\nu A^i_\mu + \epsilon^i{}_{jk} A$
M = 4-dim manifold compact
$S = \int F^i \wedge F^i$

$M = 1$-dim manifold compu

$$S = \int F^i \wedge F_i$$

$B^i_{\mu\nu}$ 2 form valued in $SU(2)$

compact $\qquad B^i_{\mu\nu}$

$$S = \int \left[B_i \wedge F^i - \frac{\Lambda}{2} B_i \wedge B^i \right] = \int \varepsilon^{\mu\nu\alpha\beta} \left[B^i_{\mu\nu} F_{\alpha\beta i} - \right.$$

$\partial_\mu A_\nu - \partial_\nu A_\mu + \varepsilon \ldots A_\mu A_\nu$

4-dim manifold compact $\qquad B^i_{\mu\nu}$ 2 form valued in $SU(2)$

$$S = \int \left[B_i \wedge F^i - \frac{\Lambda}{2} B_i \wedge B^i \right] = \int \varepsilon^{\mu\nu\alpha\beta} \left[B^i_{\mu\nu} F_{\alpha\beta i} - \frac{\Lambda}{2} B^i_{\mu\nu} B^i_{\alpha\beta} \right]$$

$\partial_\mu f$

$[\Box - m^2] A_\nu = 0$

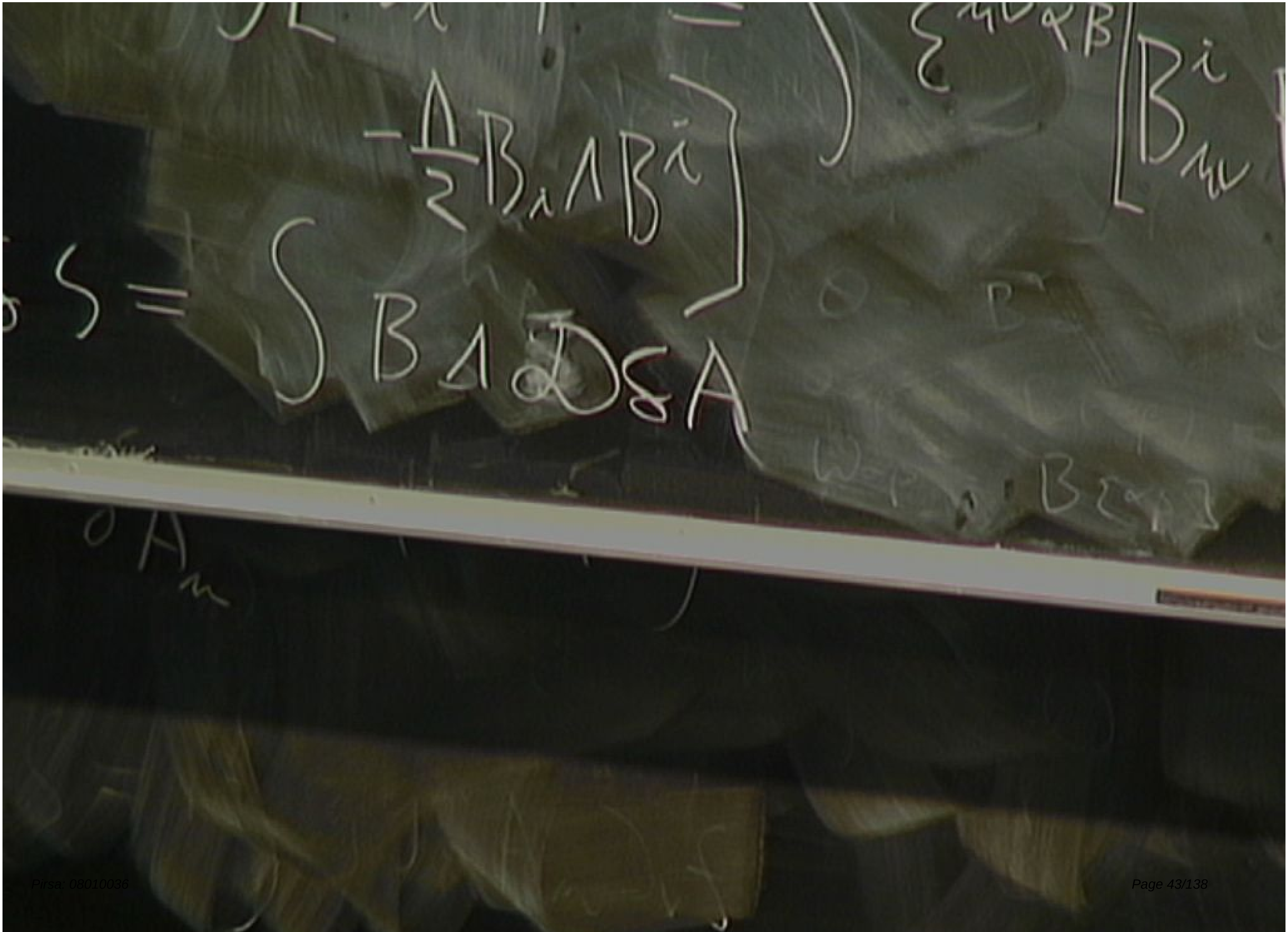
$$\frac{\delta S}{\delta B^{i}_{mn}} =$$

$$\frac{\delta S}{\delta B^i_{\mu\nu}} = F^i_{\alpha\beta} - \Lambda B^i_{\alpha\beta} = 0 = [F$$

$$F^i_{\alpha\beta} - \Lambda B^i_{\alpha\beta} = 0 = \boxed{F^i = \Lambda B^i}$$

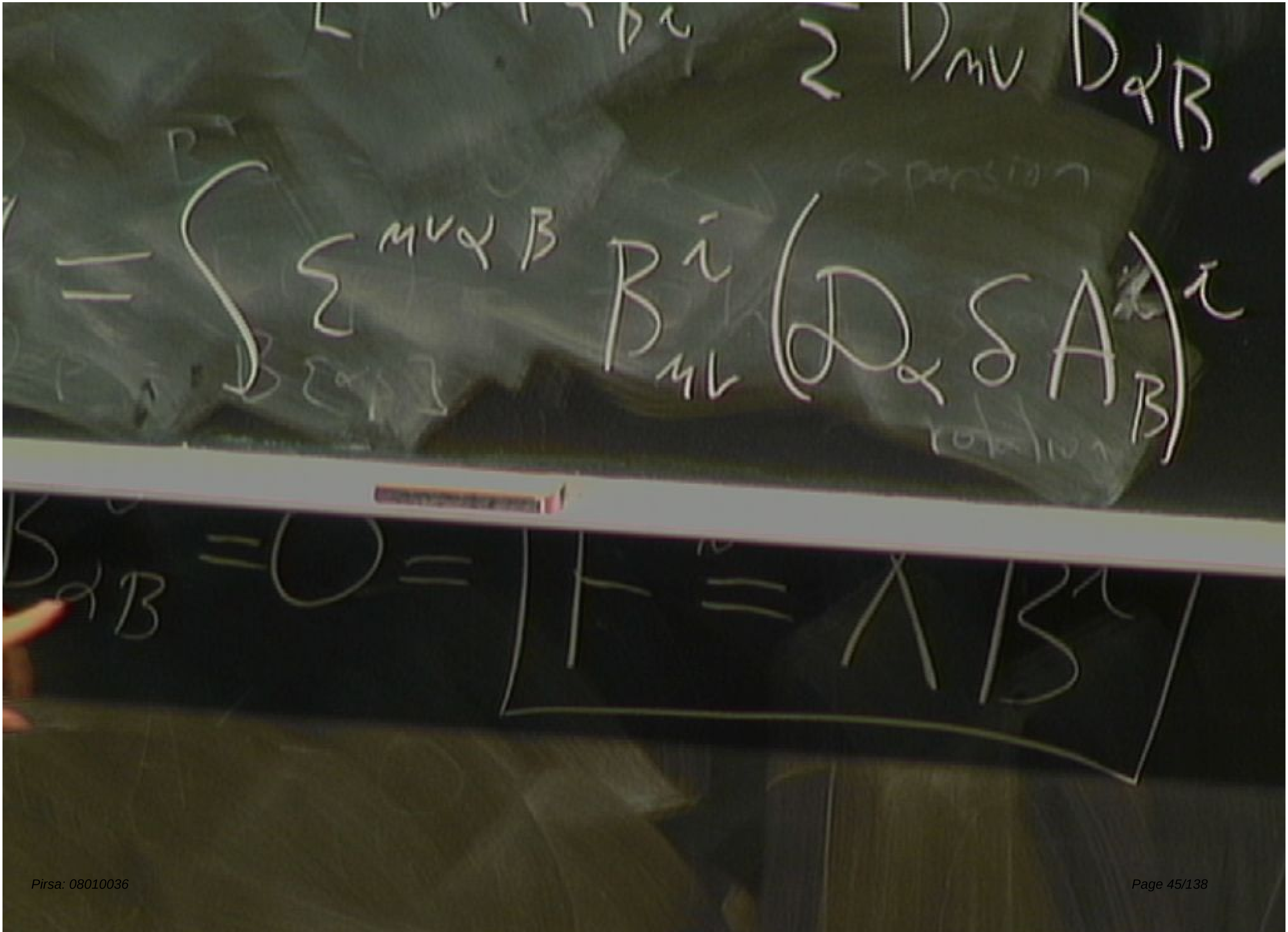
$$\frac{\delta S}{\delta B^{i}_{\mu\nu}} = F^{i}_{\alpha\beta} - \Lambda B^{i}_{\alpha\beta} = 0 =$$

$$\frac{\delta S}{\delta A_{\mu}} = (\mathcal{D} \wedge B)^{i} = 0$$


$-\frac{\Lambda}{2} B_i \wedge B^i$
$\delta S = \int B \wedge D \delta A$

$$-\frac{\Lambda}{2} B_i \wedge B^i$$

$$\boxed{\delta S = \int B \wedge D \delta A}$$


$\sum D_{\mu\nu} B_{\alpha\beta}$
expansion
$= \int \epsilon^{\mu\nu\alpha\beta} B^i_{\mu\nu} (D_\alpha \delta A_\beta)^i$
rotation
$= 0 = F = \Lambda B^i$

$$\boxed{F = \Lambda B^{i}}$$

$$0 = \varepsilon^{\mu\nu\alpha\beta}\left(\mathcal{D}_\alpha B_{\mu\nu}\right)^{i} = 0$$

$$= (\mathcal{D} \wedge B)^i = 0 = \epsilon^{\mu\nu\alpha\beta} (\mathcal{D}$$

$$= \frac{1}{\lambda} (\mathcal{D} \wedge F)^i = 0$$

Gauge Symmetries:

$$\mathcal{D}_\mu \to U^{-1} \mathcal{D}_\mu U$$

disturbed for some time T

$$\delta A_\mu^i = (\mathcal{D}_\mu \xi)^i = \partial_\mu \xi^i + \epsilon^{ijk} A_\mu^j \xi^k$$

$$\mathcal{D}_\mu \to U^{-1} \mathcal{D}_\mu U \qquad \delta A^i_\mu = (\mathcal{D}_\mu f)^i = \partial_\mu \xi^i + \varepsilon$$

$$B_{\mu\nu} \to U^{-1} B_{\mu\nu} U \qquad \delta B^i_{\mu\nu} = \varepsilon^{ijk} \xi_j B_{\mu\nu}$$

$$\delta A_\mu = \mathcal{D}_\mu \xi) = \partial_\mu \xi + \varepsilon^{ijk} A_\mu$$

$$\delta B^i_{\mu\nu} = \varepsilon^{ijk} \xi_j B^k_{\mu\nu}$$

$$B_{\mu\nu} \rightarrow U^{-1} B_{\mu\nu} U$$

Diffeomorphisms

$$B_{\mu\nu} \to U^{-1} B_{\mu\nu} U$$

Diffeomorphisms

δA

$$\delta B^i_{\mu\nu} = \epsilon^{ijk} \xi_j B_{\mu}$$

$$A^i_\mu = \mathcal{L}_v A_\mu \qquad \delta B^i_{\mu\nu} = \mathcal{L}_v B^i_{\mu\nu}$$

Li

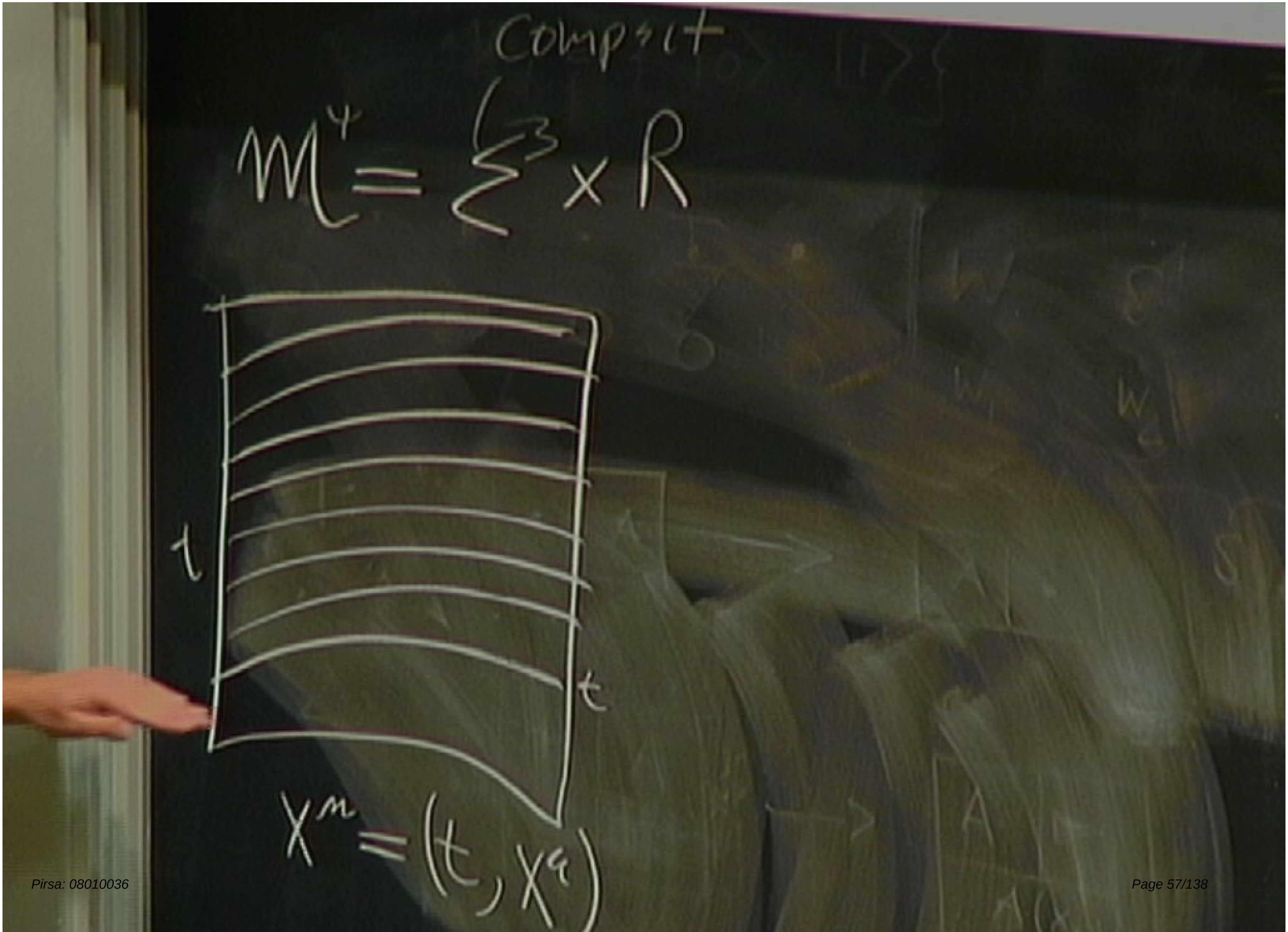
$$\epsilon^{ijk} f_j B^k_{\mu\nu}$$

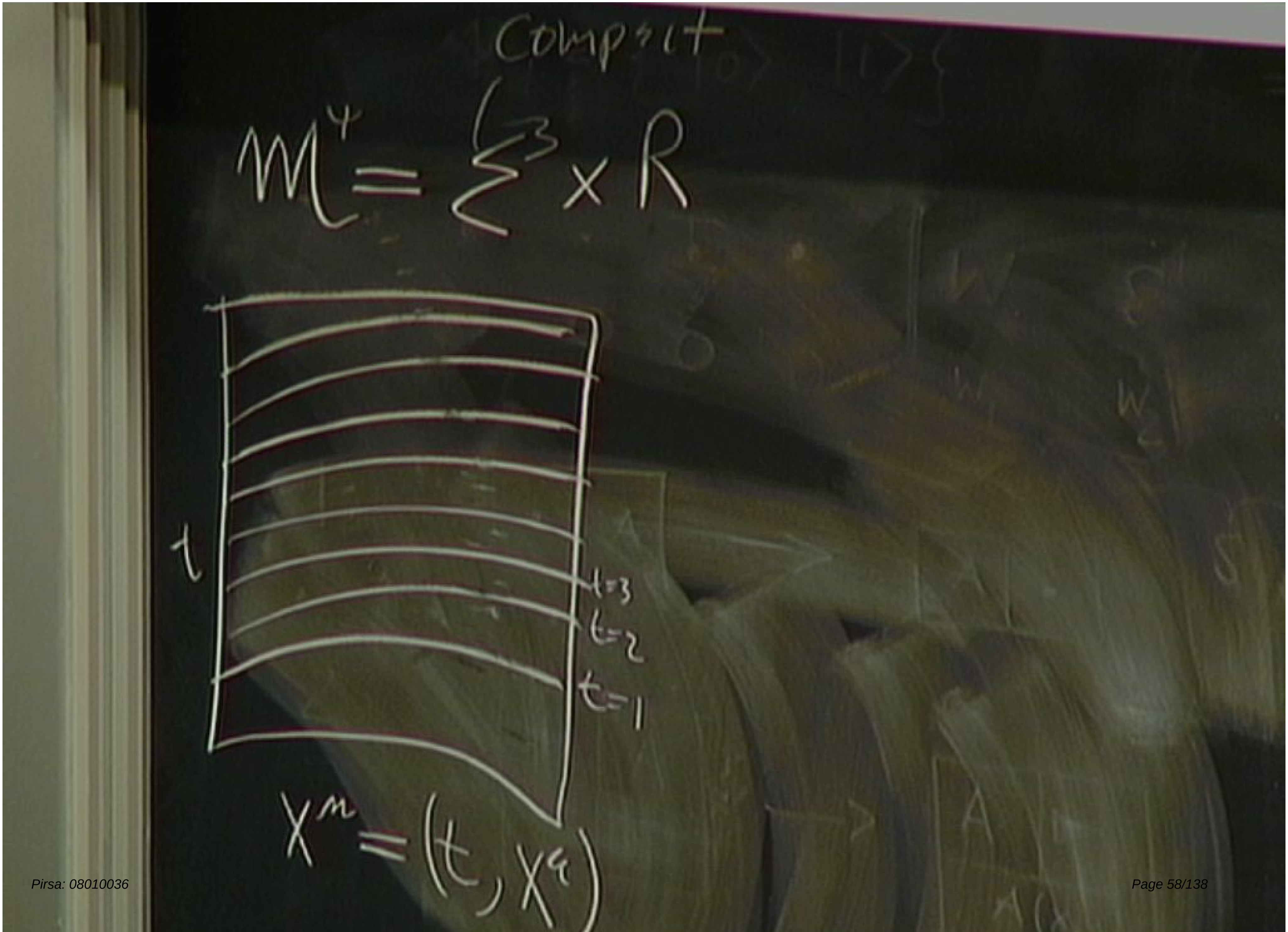
$$\delta B^i_{\mu\nu} = \mathcal{L}_v B^i_{\mu\nu}$$

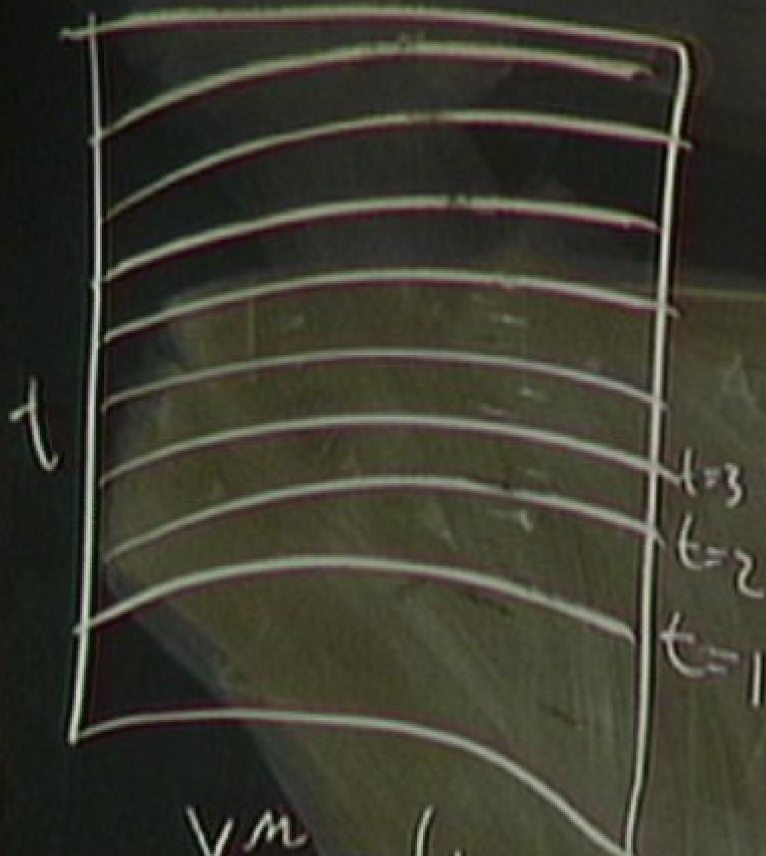
Lie derivatives

$\boxed{\text{Exercise } \delta S = 0}$

$$\mathcal{M}^4 = \Sigma^3 \times R$$

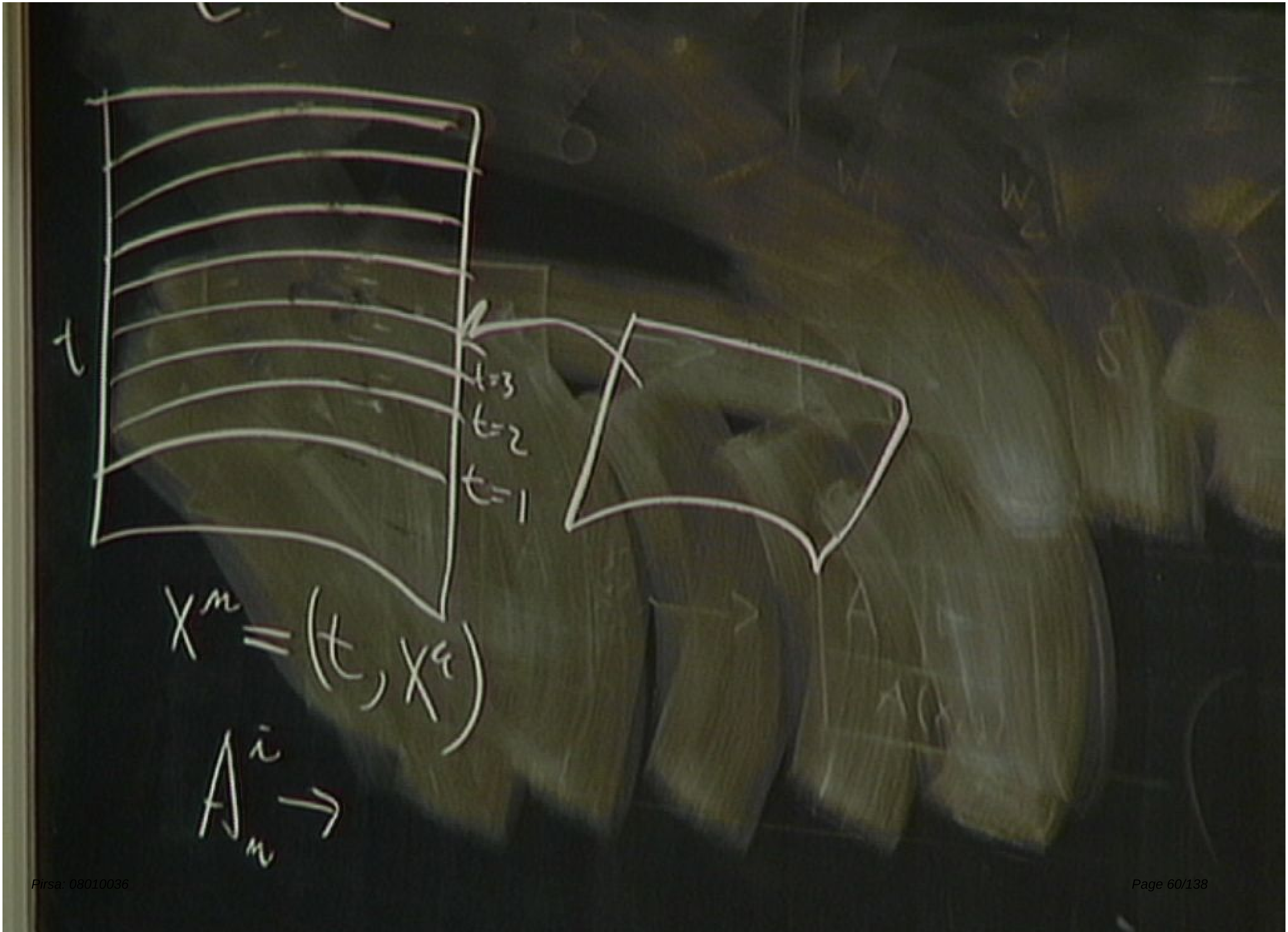

Compact
$\mathcal{M}^4 = \Sigma^3 \times R$
t
t
$X^\mu = (t, X^a)$

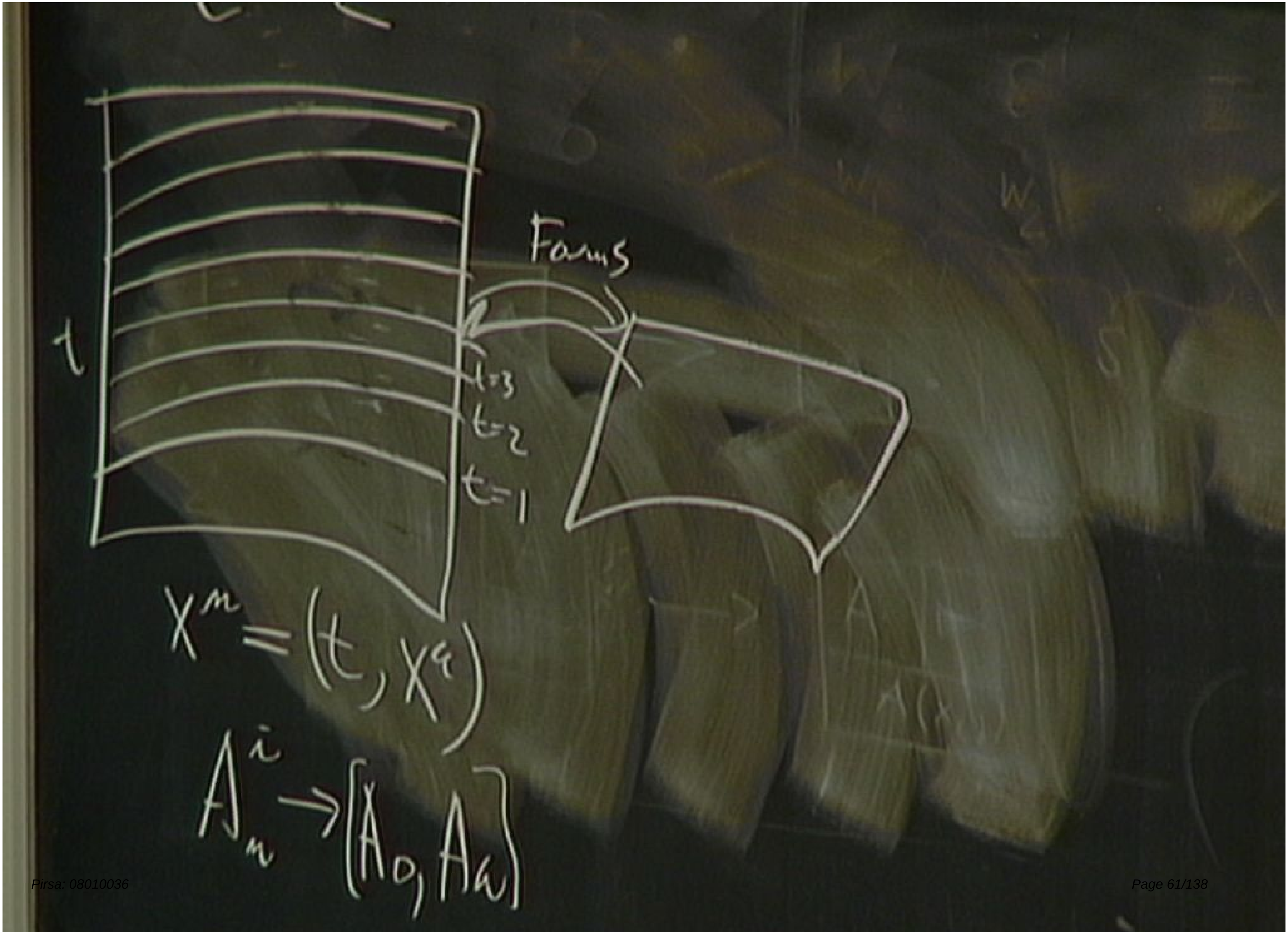

Compact
M^4 = Σ^3 × R
t
t=3
t=2
t=1
X^μ = (t, X^a)



$$X^\mu = (t, x^a)$$

$$A^i_\mu \to$$


t
t=3
t=2
t=1
X^m = (t, X^a)
A^i_m →


Forms
t
t=3
t=2
t=1
$X^m = (t, X^a)$
$A_m^i \to [A_0, A_a]$

$X^{\mu} = (t, X^a)$

$A^i_\mu \to [A_0, A_a]$

$B_{\mu\nu} \to [B_{0a}$

$B_{\mu\nu} \to (B_{0a}$

$$x^{\mu} = (t, x^{a})$$

$$A^{i}_{\mu} \to [A_0, A_a]$$

$$B_{\mu\nu} \to [B_{0a}$$

$$B_{\mu\nu} \to (B_{0a}, B_{ab})$$

$$S = \int \epsilon^{abc} \left[2 B^{i}_{0a} F^{i}_{bc} + 2 B^{i}_{bc} F^{i}_{0a} + \frac{\cancel{4}\Lambda}{2} B_{0a} B_{cd} \right]$$

$$2 B^i_{bc} E^i_{0a}$$

$$\partial_0 A^i_a - \mathcal{D}_a A^i_0$$

$$2 B^i_{bc} F^i_{0a}$$

$$\left[\partial_0 A^i_a - \mathcal{D}_a A^i_0 \right]$$

$$+\ \frac{4\Lambda}{2} B_{0a}\, B_{cd} \Big]$$

$$\Pi_i^0 = 0$$

$$P_i^{\mu\nu} = \frac{\delta S}{\delta \dot{B}_{\mu\nu}} = 0$$

$B_{0a} \; B_{cd} \Big] \quad \Big[\partial_0 A_a^i - \mathcal{D}_a A_0^i \Big]$

$$P_i^{\mu\nu} = \frac{\delta S}{\delta \dot{B}_{\mu\nu}} = 0$$ primary constraints

$$\Pi^0_i = 0 \qquad p^{\mu\nu}_i = \frac{\delta S}{\delta \ldots}$$

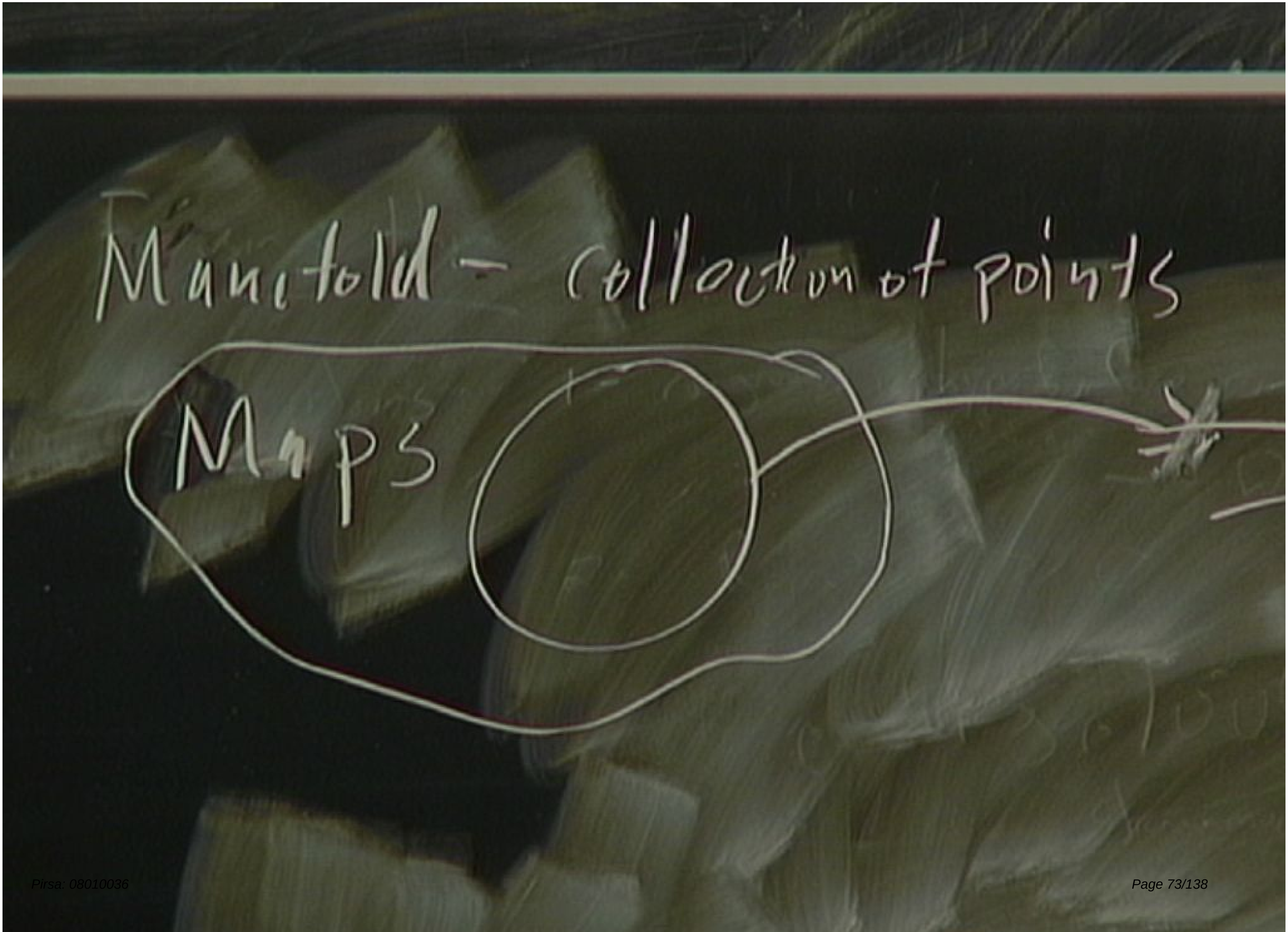
$$\Pi^a_i \triangleq \epsilon^{abc} \beta^i_{bc}$$

$$\delta B_{\mu\nu} = 0 \qquad \text{constraints}$$

$$E^a_i = \Pi^a_i - \epsilon^{abc} B^i_{bc} = 0$$

Manifold - collection of points

Maps

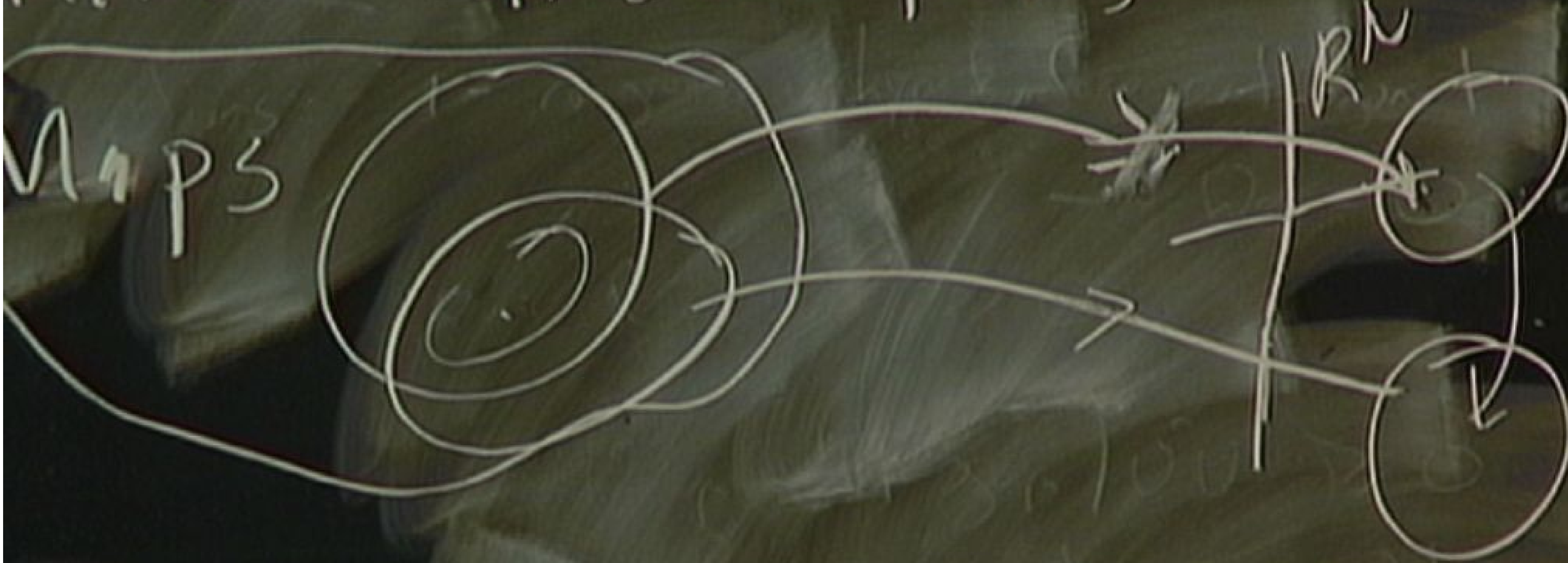

Manifold - collection of points
Maps

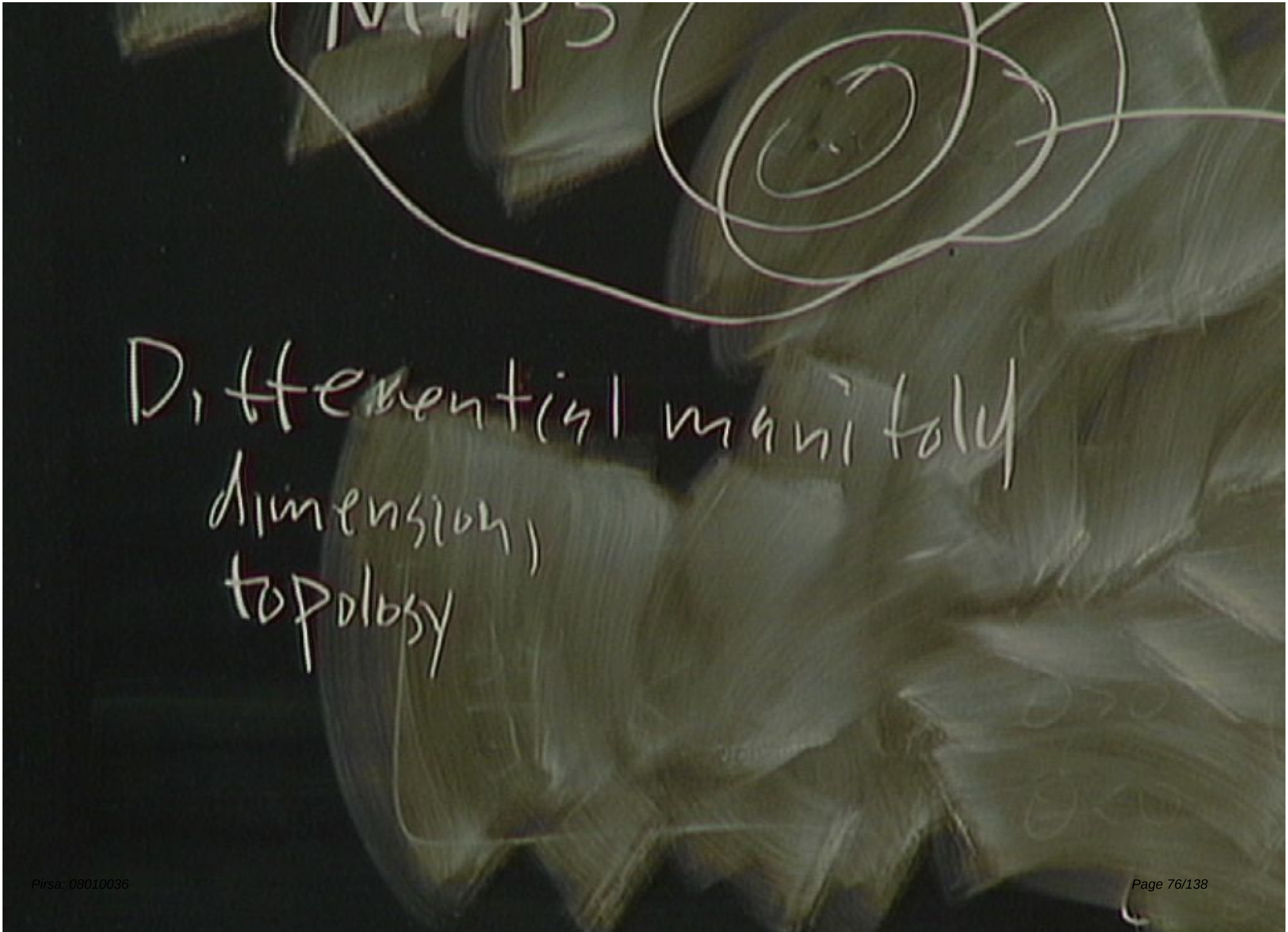
anifold – collection of points

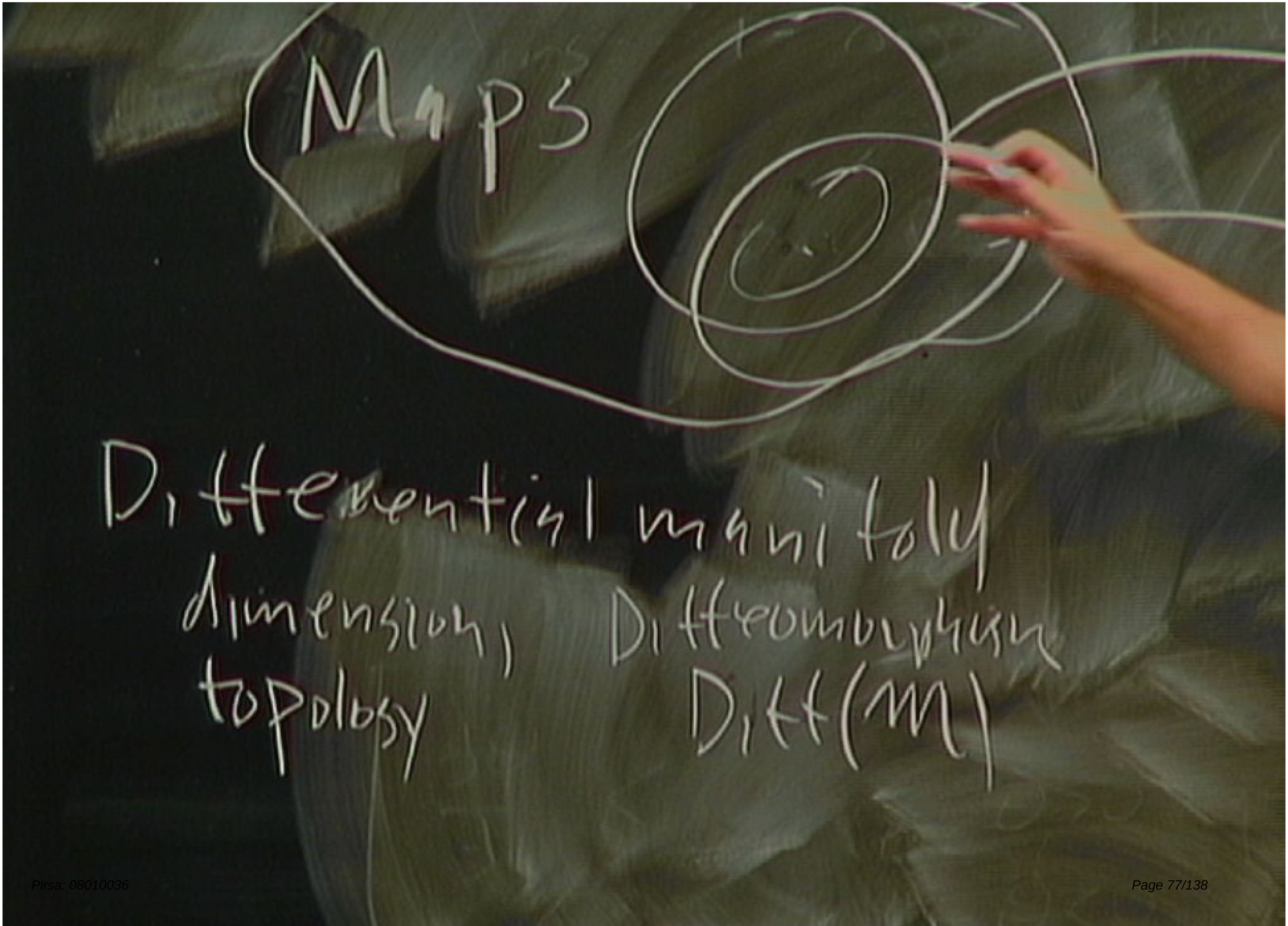
Maps

manifold – collection of points

Maps




Maps
Differential manifold
dimension,
topology


Maps
Differential manifold
dimension,
topology
Diffeomorphism
Diff(M)

① Differential manifold

dimension, Diffeomorphism

topology Diff(M)

② metric

③ fields A, ϕ ψ.

⊛ Differential manifold

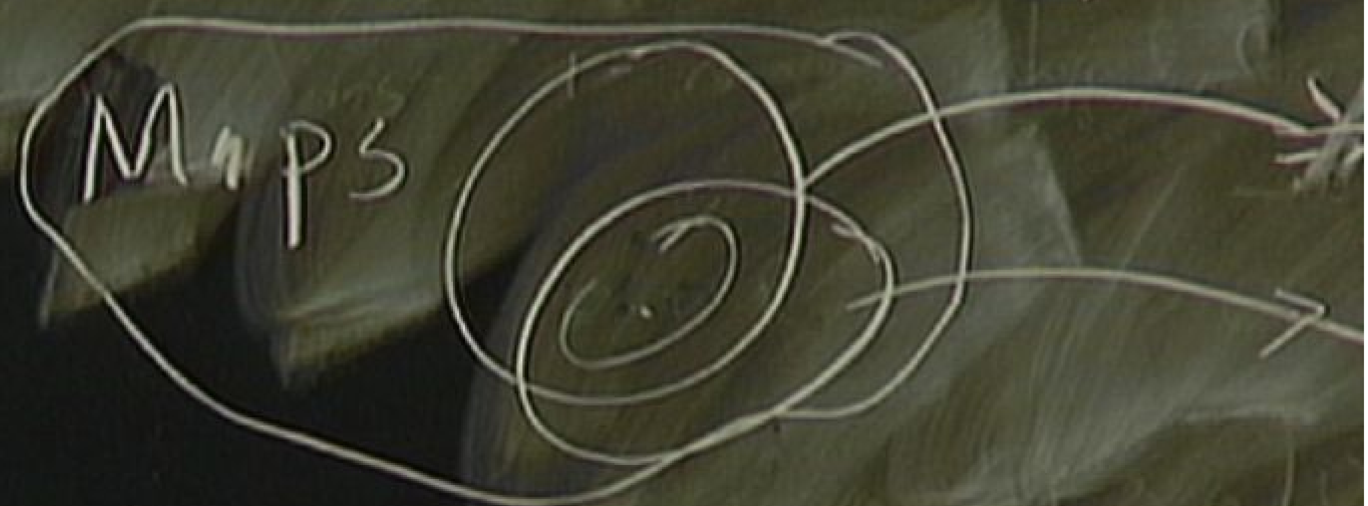
dimension, Diffeomorphism

topology Diff(M)

~~⊛ metric~~

⊛ fields A, ϕ, ψ.

Manifold – collection of points



• Differential manifold

dimension, Diffeomorphism

topology Diff(M)

~~• metric~~

• Fields A, ϕ, ψ. ...

$$H = \int_{\Sigma} \left[\Pi^a_i \dot{A}^a_i \right.$$

$$H = \int_{\Sigma} \Big[\tilde{\Pi}^{a}_{i} \, \dot{A}^{a}_{i}$$

$$\int_\Sigma \Big[\tilde{\Pi}^a_i \, \dot{A}^i_a + \tilde{\Pi}^0_i \, \dot{A}^i_0 + P^{\mu\nu}_i \, \dot{B}$$

$$H = \int_{\Sigma} \left[\tilde{\pi}^{a}_{i} \dot{A}^{i}_{a} + \tilde{\pi}^{0}_{i} \dot{A}^{i}_{0} + P^{\mu\nu}_{i} \dot{B}^{i}_{\mu\nu} - \right.$$

$$- \epsilon^{abc} B^{i}_{bc} \tilde{A}^{i}_{a}$$

$$\int_{\Sigma} \Big[\tilde{\Pi}^{a}_{i} \dot{A}^{i}_{a} + \tilde{\Pi}^{0}_{i} \dot{A}^{i}_{0} + P^{\mu\nu}_{i} \dot{B}^{i}_{\mu\nu} - \epsilon^{abc} B^{i}_{bc} \dot{A}^{i}_{a}$$

$$\int \Big[\tilde{\Pi}^a_i \dot{A}^i_a + \tilde{\Pi}^0_i \dot{A}^i_0 + P^{\mu\nu}_i \dot{B}^i_{\mu\nu} -$$

$$- \epsilon^{abc} B^i_{bc} \dot{A}^i_a - \epsilon^{abc} B^i_{bc} \mathcal{D}_a A^i_0$$

$$+ P^{\mu\nu}_i \dot{B}^i_{\mu\nu} - B^i_{0a}\epsilon^{abc}\left[F^i_{bc} - \frac{\Lambda}{2} B^i_{bc}\right.$$

$$- \epsilon^{abc} B^i_{bc}\, \mathcal{D}_a A^i_0$$

$$= \int_{\Sigma} \Big[\quad + \Pi^0_i \dot{A}^i_0 + P$$

$$\left(\Pi^a_i - \epsilon^{abc} B^i_{bc}\right) \dot{A}^i_a \qquad -$$

$$= \int_{\Sigma} \Big[\quad + \Pi^{0}_{i} \dot{A}^{i}_{0} + P$$

$$\left(\Pi^{a}_{i} - \epsilon^{abc} B^{i}_{bc}\right) \dot{A}^{i}_{a} \quad -$$

$$- \epsilon^{abc} B^{i}_{bc}) \dot{A}^{i}_{a} \quad - \quad \epsilon^{abc} B^{i}_{bc} \mathcal{D}_{a}$$

$$- \lambda^{i} \Pi^{0}_{i} + \Omega^{i}_{\mu\nu} P^{\mu\nu}_{i} + \rho^{i}_{a} E^{ai}$$

$$+ \quad \Pi^{0}$$

(1) prepare a basis state INPUT PROGRAM

$$H = \int_\Sigma \Big[+ \Pi^0_i \dot A^i_0 + P^{\mu\nu}_i \dot B^i_{\mu\nu} - B^i_{0a} \varepsilon^{abc} \Big[F^i_{bc} - \frac{\Lambda}{2} \ldots$$

$$\left(\Pi^a_i - \varepsilon^{abc} B^i_{bc}\right) \dot A^i_a - \varepsilon^{abc} B^i_{bc} \mathcal{D}_a A^i_0$$

$$+ \lambda^i \Pi^0_i + \Omega^i_{\mu\nu} P^{\mu\nu}_i + \rho^i_a E^{ai} \Big]$$

$$+\hat{\Pi}^{0}_{i}\,\dot{A}^{i}_{0}+P^{\mu\nu}_{i}\,\dot{B}^{i}_{\mu\nu}-B^{i}_{0a}\,\varepsilon^{abc}\Big[F^{i}_{bc}-\frac{\Lambda}{2}$$

$$)\,\dot{A}^{i}_{a}\;-\;\varepsilon^{abc}B^{i}_{bc}\,\mathcal{D}_{a}A^{i}_{0}$$

$$\Omega^{i}_{\mu\nu}P^{\mu\nu}_{i}+\rho^{i}_{a}E^{ai}\Big]$$

$$+ \lambda^i \Pi^0_i + \Omega^i_{ab} P^{ab}_i + \ldots$$

$$\Pi^0 \Rightarrow \sigma^i = \epsilon^{abc} D_a B^i_{bc} = 0$$

$$\Pi^0 \Rightarrow G^i = \epsilon^{abc} D_a B^i_{bc} = 0$$

$$P^{bc}_i(x) = 0$$

$$D_a B^i_{bc} = 0$$

$$\{E^a_i(x), P^{bc}_j(y)\} = \delta^3(x,y)\,\epsilon^{abc}$$

$$\epsilon^{abc} D_a B^i_{bc} = 0$$

$$\{E^a_i(x), P^{bc}_j(y)\} = \delta^3(x,y)\,\epsilon^{abc}\,\delta^j_i$$

$$+ \lambda\, \Pi^{0}_{i} + \Omega^{i}_{ab} P \ldots$$

$$\dot{\Pi}^{0} = > G^{i} = \epsilon^{abc} D_{a} B^{i}_{bc}$$

$$P^{bc}_{i}(x) = 0$$

$$\delta E^{a}_{i}(x) \ldots$$

$$\Rightarrow G^i = \mathcal{D}_a \Pi^{ai} = 0$$

$$H = \int A_0^i G^i + \lambda^i \Pi^0_i + p^{0a}_a$$

$$\int A_0^i G^i + \lambda^i \Pi^0_i + P^{0a}_i \dot{B}^i_{0a}$$

e^{-iHT}

$\{A_a^i, \Pi^{ai}\}$

$\Pi^0_i + P^{0a}_i \acute{B}^i_{0a}$ $\qquad \{A_0, \Pi^0\}$

$$G^{i} = \mathcal{D}_a \Pi^{ia} = 0$$

$$H = \int A_0^i G^i + \lambda^i \Pi^0_i + P^{0a}_i \dot{B}^i_{0a}$$

$$+ B_{0a} \epsilon^{abc} \left(F^i_{bc} - \frac{\Lambda}{2} B^i_{bc} \right]$$

$$\lambda^i \Pi^0_i + P^{0a}_i \dot{B}^i_{0a} \qquad \{A_0, \Pi^{0}\}$$

$$B_{0a}\, \epsilon^{abc}\left(F^i_{bc} - \frac{\Lambda}{2} B^i_{bc}\right) + \dot{\lambda}^i_a P^{0a}_i$$

$$\Rightarrow G^i = \mathcal{D}_a \Pi^{ai} = 0$$

$$\boxed{H = \int A_0^i G^i + \lambda^i \Pi^0_i + P^{0a}_i \dot{B}^i_{0a} + B_{0a}\epsilon^{abc}\left(F^i_{bc} - \frac{\Delta}{2} B^i_{bc}\right) + \lambda'^i_a P}$$

$\{A^i_a, \Pi$

$\{A_0, \Pi^0\}$

B_{0a}

$$- \frac{\Lambda}{2} B^i_{bc}] + \lambda^{ia}_{a} P^{0a}_{i}$$

$$\{ q^{117}, P_{117} \} = 1$$

$$q^{117} = 0 \quad P_{117} = 0$$

Crane-Yetter

$$\boxed{H = \int \mu^i G^i + \cancel{\lambda^i \Pi^0_i} + P^{0a}_i \dot{B}^i_{0a} + B_{0a}\,\varepsilon^{abc}\left(F^i_{bc} - \frac{\Delta}{2} B \ldots\right.}$$

$$\ldots \; {}_i \; B_{0a} \; \ldots$$

$$\ldots^{bc}\left(F^{i}_{bc} - \frac{\Delta}{2} B^{i}_{bc}\right) + \lambda'^{i}_{a} P^{0a}_{i}$$

$$\{q^{117}_{i}, P_{117}\} = 1$$

$$q^{117} = 0 \quad P_{117} = 0$$

$$+ B_{0a}\,\varepsilon^{abc}\left(F^{i}_{bc} - \frac{\Delta}{2}\right.$$

$\cdot\ P$

$$P_{0a} \approx 0 \Rightarrow \tilde{F}^{i}_{ab} = F^{i}_{ab} - \Delta B^{i}_{ab} = 0$$

$$+ \lambda B_i + \Pi_i B_{0a}$$

$$+ B_{0a} \varepsilon^{abc} \left(F_{bc}^i - \frac{\Lambda}{2}\right.$$

$$\dot{p}^{0a} \doteq 0 \Rightarrow \mathcal{F}_{ab}^i = F_{ab}^i - \Lambda \varepsilon_{abc} \Pi_i^c = 0$$

$$A_a^i \,,\ \Pi_i^a$$

$$G^i = \mathcal{D}_a \Pi^{ai} = 0$$

$$\mathcal{F}_{ab}^i = F_{ab}^i - \Lambda\, \epsilon_{abc} \Pi^{ci} = 0$$

$$A_a^i, \quad \Pi^a_i \qquad H = \int$$

$$G^i = D_a \Pi^{ai} = 0$$

$$\mathcal{F}^i_{ab} = F^i_{ab} - \Lambda \epsilon_{abc} \Pi^{ci} = 0$$

$$H = \int N_i G^i + \beta_i^{ab} F^i_{ab} = 0$$

$$\boxed{\Pi^{ci} = 0}$$

$$G^i = \mathcal{D}_a \Pi^{ai} = 0$$

$$\mathcal{F}^i_{ab} = F^i_{ab} - \Lambda \epsilon_{abc} \Pi^{ci} = 0$$

$$\{G^i(x), G^j(y)\}_P = \epsilon^{ijk} G_k(y) \delta^3(x, y$$

$$G^a + \xi^i \Sigma_{ab} = 0$$

$$\boxed{\begin{aligned} G^i:\quad & \delta A_a^i = D_a f \\ & \delta \Pi^a_i = \epsilon^{ijk} f_j \Pi^{ak} \end{aligned}}$$

$$\boxed{\delta^3(x,y)}$$

$$\left\{ G^{i}(x),\ \mathcal{J}^{\gamma}_{ab}(y) \right\}$$

$$\mathcal{L}_{ab} = F_{ab} - \lambda\, \epsilon_{abc}\, \Pi^{c} = 0$$

$$\{ G^{i}(x), G^{j}(y) \} = \epsilon^{ijk}\, G_{k}(y)\, \delta$$

$$\{ G^{i}(x), \mathcal{L}^{j}_{ab}(y) \} = \epsilon^{ijk}\, \mathcal{L}_{k\,ab}(y)\, \delta^{3}(x,y)$$

$$\{G^{-}(x), G^{-}(y)\} = 2 \ldots$$

$$\{G^{i}_{\alpha}(x), \mathcal{J}^{\gamma}_{\eta\beta}(y)\} = \varepsilon^{i\gamma k}\, \mathcal{J}_{k\eta\beta}(y)$$

$$\{\mathcal{J}, \mathcal{J}\} = 0$$

$$\left\{ G^{i}_{(x)}, \mathcal{J}^{\gamma}_{\eta}(y) \right\} = \epsilon^{i\gamma k} \mathcal{J}_{k\eta}(y \ldots$$

$$\left\{ \mathcal{J}, \mathcal{J} \right\} = 0 \ldots$$

$) \delta^3(x,y)$

3d Euclidean group

$y)$

check

$\times\ \mathcal{O}3$

ck

$$\boxed{\delta^3(x,y)}$$

3 translations,
+ rotations

check

$\times\, \infty^3$

$H = 0$

per. point: $A^i_a - 9$

$\Pi^a_i - 9$

dof 18

$$\mathcal{F}_{ab} = F_{ab} - \lambda\, \epsilon_{abc}\, \Pi^c = 0$$

$$\{G^i(x), G^j(y)\}_P = \epsilon^{ijk}$$

$$\{G^i(x), \mathcal{F}^j_{ab}(y)\} = \epsilon^{ijk}\, \mathcal{F}_{k\,ab}(y$$

$$\{\mathcal{F}, \mathcal{F}\} = 0$$

Gauge transformations

12 per part

Gauge transformations

12 per point

12 gauge fixing

24

$A_a^i \,, \; \Pi^a_i \qquad H = \int$

$$G^i = D_a \Pi^{ai} = 0$$

$$\mathcal{F}^i_{ab} = F^i_{ab} - \Lambda \epsilon_{abc} \Pi^{ci} = 0$$

$$\{ G^i(x), G^j(y) \} = \ldots \epsilon^{ijk} G_k (\ldots$$

$$\{ G^i, \mathcal{F}^j \ldots \} \ldots \epsilon^{ijk} \ldots$$

...mations

...t

...ing

$$\mathcal{D}_1 \tilde{\mathcal{F}} = 0$$

Gauge transformations

9 per point

9 gauge fixing

18

Gauge transformations

9 per point

9 gauge fixing

18 conditions

$\boxed{0 \text{ local dof}}$

dof 18

18 conditi

$\boxed{\Rightarrow \text{no local dof}}$

$\mathcal{D}_1 \mathcal{F} = 0$

part

ge fixing

ditions

δA_a^i

$$Z(g) = \int$$

$$\mathcal{Z}(g) = \int g_a \, \epsilon^{abc} \, \mathcal{Z}_{bc}$$

$$\mathcal{I}_{bc}^{i} = \int \epsilon^{abc} g_a^i F_{bc}^i - \Lambda\, g_a^i \Pi_i^a$$

$$\mathcal{F}(g) = \int g^i_a \, \epsilon^{abc} \, \mathcal{F}^i_{bc} =$$

$$\delta A^i_a(x) = \{ A^i_a(x), \mathcal{F}(g) \}$$

$$g^i_a \, \varepsilon^{abc} \, \mathcal{Z}^i_{bc} = \int \varepsilon^{abc} g^i_a F^i_{bc} -$$

$$\{\ , \mathcal{Z}(\sigma)\} = -\Lambda \, g^i_a(x)$$

$$\mathcal{F}(g) = \int g_a \, \epsilon \, \mathcal{F}^i_{bc} =$$

$$\delta A^i_a(x) = \{ A^i_a(x), \mathcal{F}(g) \} = -$$

$$A'^i_a = A^i_a + \delta A^i_a \stackrel{!}{=} 0$$

$$g) = \int g_a^i \epsilon^{abc} \mathcal{F}_{bc}^i = \int \epsilon^{abc} g_a^i F_{bc}^i -$$

$$= \{ A_a^i(x), \mathcal{F}(g) \} = -\Lambda g_a^i(x)$$

$$A'^i_a = A_a^i + \delta A_a^i \doteq 0 \qquad g = \frac{1}{\Lambda} A$$