

Title: Introduction to quantum gravity - Part 14

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Abstract: This is an introduction to background independent quantum theories of gravity, with a focus on loop quantum gravity and related approaches.

Basic texts:

-Quantum Gravity, by Carlo Rovelli, Cambridge University Press 2005  
-Quantum gravityy with a positive cosmological constant, Lee Smolin, hep-th/0209079

-Invitation to loop quantum gravity, Lee Smolin, hep-th/0408048  
-Gauge fields, knots and gravity, JC Baez, JP Muniain

Prerequisites:

- undergraduate quantum mechanics
- basics of classical gauge field theories
- basic general relativity
- hamiltonian and lagrangian mechanics
- basics of lie algebras

$$S_\lambda A \psi = \{A \otimes G(\lambda)\} \psi = D_\lambda X^*(\lambda)$$

$$S_\lambda E \psi = \{E \otimes C(\lambda)\} \psi = \varepsilon_{\mu*} \lambda^\mu E^{*\mu}$$

self dual solutions  $\lambda \neq 0$

$$\{A_i^a(x), \tilde{E}_j^b(y)\} = \delta^a(x, \tilde{y}) \epsilon_{ij}^{ab}$$

$$J = S + \sum_i \widehat{E}^i A_i - \underbrace{\lambda_i G^i}_{SAS^{-1}} - \underbrace{V^* D_k}_{N\tilde{C}}$$

$$\tilde{G}^i = D_i \tilde{E}^i = 0 \vee$$

$$D_i = E_i^k F_{ik} \vee$$

$$C = \epsilon^{ijk} \tilde{E}_i^a \tilde{E}_j^b (F_{ik} + \frac{1}{3} \epsilon_{ilm} E_l^m) = 0$$

$$H = \sum_k \tilde{h}_k$$

$$G(\lambda) = \sum_i \lambda_i G^i$$

$$D(\nu) = \sum_k \nu^k D_k$$

$$C(N) = \sum_k N \tilde{C}_k$$

$$\tilde{E}^a \tilde{E}^{bi} = \tilde{g}^{ab} \\ = (\eta^{11\dots}) \tilde{g}^{ab}$$

$$S_A A^k = \{A^k G(\lambda)\} \gamma = D_A X^k(\gamma)$$

$$S_A E^k = \{E^k C(\lambda)\} = \varepsilon_{\alpha\beta\gamma} \lambda^\beta E^k(\gamma)$$

selected solutions  $\lambda \neq 0$        $J_{ab}^k = 0$

Hamiltonian formulation

$$\{A_a^i(x), \tilde{E}_j^b(y)\} = S^3(x, y) S_i^a S_j^b$$

$$S = \int d^4x \int \tilde{E}^i A_i - \underbrace{\lambda_i G^i}_{S^4 S_\Sigma H} - \underbrace{V^a D_a}_{N \tilde{C}}$$

$$\tilde{G}^i = D_i \tilde{E}^a = 0$$

$$H = \int_\Sigma \tilde{H}$$

$$= \frac{E_i^k F_{ik}}{J_{15}} \vee$$

$$J_{15}^k$$

$$\frac{1}{3} \epsilon_{ijk} (E_k^l) = 0$$

$$G(\lambda) = \int_\Sigma \lambda_i \tilde{G}^i$$

$$D(\nu) = \int_\Sigma \nu^\alpha D_\alpha$$

$$C(N) = \int_N N^a \tilde{E}^a$$

$$\tilde{E}^a \tilde{E}^{bi} = \tilde{g}^{ab}$$
$$= (H^1 \dots) E^{ab}$$



$$S_\lambda A\psi = \{A\otimes G(\lambda)\}\psi = D_\lambda \lambda^*(\psi)$$

$$S_\lambda E^k\psi = \{E_A G(\lambda)\} = \varepsilon_{\alpha\beta\gamma} \lambda^\beta E^k(\psi)$$

self dual solutions  $\lambda \neq 0$   $J_{ab}^k = 0$

representation  $S = \int \varepsilon_{\alpha\beta\gamma} F + \lambda \varepsilon_{\alpha\beta} - g_{\alpha\beta} \varepsilon^{\alpha} \varepsilon^{\beta}$

$$S_A A^k = \{A^k G(\lambda)\} = D_A X^k(x)$$

$$S_A E^k = \{E_A G(\lambda)\} = \varepsilon_{\mu\nu} \lambda^\nu E^{k\mu}$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $\rho_{ab} = 3\Lambda$

regular motion  $S = \int \varepsilon_1 F + \Lambda \varepsilon_2 \varepsilon_3 - \underline{\Phi_{ab}} \underline{\varepsilon_1} \varepsilon^b$

$$F^a = \bar{e}^a_{\mu} \varepsilon^{\mu}$$

$$S_A A^\mu = \{A^\mu_i G(i)\}^\mu = D_A X^\mu(x)$$

$$S_A E^\mu = \{E_A(i)\}^\mu = \varepsilon_{\mu\nu} \lambda^\nu E^\mu(x)$$

Self dual solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $B_{kl} = 3\Lambda$

eqns of motion  $S = \int \Sigma_1 F + \Lambda \Sigma_2 \Xi - \underline{\Sigma_3 \Sigma_4 \Xi^3}$

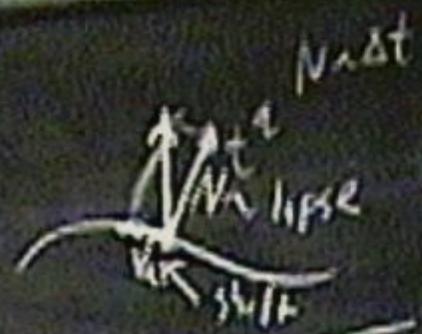
$$F^a = \bar{\Psi}^a_{ij} \Sigma^j \quad \bar{\Psi} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$$

$$m = \sum x R$$

$$t_a = \sigma_1 t$$

$[D^{\mu\nu} L_{\mu\nu} = -1]$  (unlike)

$$N = \frac{1}{\sqrt{2\pi\sigma_1^2}} N$$



$$a_{\text{amplitude}}(x, t) = \frac{E \sin(\omega t)}{1 + \sin(\omega t)}$$

$$g_{ab} = g_{ab} + h_{ab}$$

$$\{C(x), D(v)\} = \delta_v C$$

$$\{C(x), G(r)\} = 0$$

$$\Rightarrow \{C(N), D(v)\} = C(\delta_v N)$$

$$\Rightarrow \{C(N), C(M)\} = \left\{ (N \cdot M - M \cdot N) \hat{a}^{ab} D_b \right\}$$

Business  
Class

$$\{A_i^a(x), \hat{E}_j^b(y)\} = \delta^a(x, \hat{y}) S_i^a S_j^b$$

$$J = \int d\lambda \int \hat{E}^a A_i^a - \underbrace{\lambda_i G^i}_{S \int \tilde{G}} - \underbrace{V^a D_a}_{N \tilde{C}}$$

$$G^i = \partial_\lambda E^i = 0 \checkmark$$

$$D \quad F^a, F_{ab}^i \checkmark \quad J_{ab}^k \quad H = \int \tilde{G}$$

$\partial_\lambda (V^a D_a) = 0$

$$G(\lambda) = \int \chi_\lambda G^i$$

$$D(\nu) = \int V^a D_a$$

$$C(N) = \int N \tilde{C}$$

$$\hat{E}^a \hat{E}^{bi} = \hat{V}^{ab} \\ = (\text{Hil...}) U^{ab}$$

$$S_A A^k = \{A^k G(\lambda)\} = D_A \lambda^k$$

$$S_A E^k = \{E_A G(\lambda)\} = \varepsilon_{\alpha k} \lambda^k E^{\alpha}$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $\psi_{ab} = \pm 1$

eigen motion  $S = \int \varepsilon_1 F + \Lambda \varepsilon_2 \varepsilon_3 - \underline{\Phi_{ab}} \varepsilon_1^a \varepsilon_2^b$

$$F^a = -\Phi_{ab}^a \varepsilon_2^b$$
$$\Phi = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$$

Hamiltonian formulation

$$\{A_a^i(x), \tilde{E}_j^b(y)\} = \delta^i_j(x, y) \tilde{\epsilon}_a^b \tilde{\epsilon}_j^a$$

$$S = \int d^4x \int \tilde{E}^i \tilde{A}_i - \underbrace{\lambda_i G^i}_{S \int \tilde{\epsilon}^i} - \underbrace{V^a D_a}_{S \int \tilde{\epsilon}^a} - \underbrace{N \tilde{C}}_{S \int \tilde{\epsilon}^N}$$

$$\tilde{G}^i = \partial_\mu \tilde{E}^{im} = 0 \quad \checkmark$$

$$= \int d^4x F_{ik}^i V$$

$$E^i \tilde{E}^k (F_{ik} + \frac{1}{3} \epsilon_{ijk} E^j) = 0$$

$$H = \int \tilde{\epsilon}^N$$

$$G(N) = \int \tilde{\epsilon}^N \tilde{G}^N$$

$$D(N) = \int \tilde{\epsilon}^N D_N$$

$$C(N) = \int \tilde{\epsilon}^N \tilde{C}$$

$$\tilde{E}^i \tilde{E}^{bi} = \tilde{g}^{ab} \\ = (H \dots) \tilde{e}^{ab}$$



Hausmann formulation

$$\{A_\alpha^k(x), \tilde{E}_j^b(y)\} = S^3(x, \tilde{y}) S_\alpha^k S_j^b$$

$$J = \int_{\Omega} \int_{\Sigma} \tilde{E}^i A_i - \underbrace{\lambda_i G^i}_{S^4 S_\Sigma H} - \underbrace{V^i D_i}_{N \tilde{C}}$$

$$\tilde{G}^i = D_i \tilde{E}^m = 0 \checkmark$$

$$D_i = E_i^k F_{ik} \checkmark$$

$$C = \epsilon^{ijk} \tilde{E}_i \tilde{E}_j (F_{ask} + \frac{1}{3} \delta_{ikl} E_l^s) = 0$$

$$J_{ab}$$

$$H = \int_{\Sigma} \tilde{H}$$

$$G(\lambda) = \int_{\Sigma} \lambda_i G^i$$

$$D(M) = \int_{\Sigma} V^i D_i$$

$$C(N) = \int_{\Sigma} N \tilde{C}$$

$$\tilde{E}^i \tilde{E}^{bi} = \tilde{g}^{ab}$$
$$= (M \Gamma ..) \tilde{e}^{ab}$$

$$S_\lambda A = \{A\gamma G(\lambda)\} = D_\lambda X^*(*)$$

$$S_\lambda E = \{E\gamma C(\lambda)\} = \varepsilon_\lambda X^* E^{**}$$

self dual solutions  $\Lambda \neq 0$   $J_{ab} = 0$   $\Phi_{ab} = 3\Lambda -$

e.g. motion  $S = \int \varepsilon_1 F + \Lambda \bar{\epsilon} \bar{F} - \underline{\Phi_{ab}} \varepsilon^a \bar{\epsilon}^b$   
 $F^a = \bar{\epsilon}^a_{\;b} \varepsilon^b$   $\bar{\Phi} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$

$$\Rightarrow G = D = C = 0$$

$$S_\lambda A^\mu = \{A^\mu_i G(i)\}^\nu = D_\lambda X^\nu(x)$$

$$S_\lambda E^\mu = \{E_\lambda^i C(i)\}^\nu = \varepsilon_{\mu\nu} X^\nu E^\mu(x)$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^K = 0$   $P_{\alpha\beta} = 3\Lambda =$

representation  $S = \int \varepsilon_1 F + \Lambda \varepsilon_2 \times \varepsilon - \underline{\Phi_{ij} \varepsilon_i \varepsilon_j}$

$$F = -\bar{\Psi}^i_j, \varepsilon^j = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$$

$$\Rightarrow G = D = C = 0$$

$$S_A A^k = \{A^k G(\lambda)\} = D_A X^k(x)$$

$$S_A E^k = \{E_A C(\lambda)\} = \varepsilon_{\alpha k} X^k E^{\alpha}(x)$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $R_{\alpha\beta} = 3\Lambda =$

eigenvalue motion  $S = \int \varepsilon_1 F + \Lambda \varepsilon_2 \Phi - \frac{\Phi_{ij} \varepsilon_i^j \varepsilon^j}{}$

$$F^i = -\bar{\Psi}^i, \varepsilon^j \quad \Phi = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0$$

$$S_A A^k = \{A^k G(0)\}^k = D_A X^k$$

$$S_A E^k = \{E_A C(0)\}^k = \varepsilon_{\alpha\beta\gamma} X^\beta E^{\alpha k}$$

self dual solutions  $\Lambda \neq 0$  .  $J_{ab}^k = 0$   $R_{\lambda} = 3\Lambda$

egs of motion  $S = \int \Sigma_1 F + \Lambda \partial_\mu \Sigma - \frac{R_{\lambda}}{2} \Sigma^1 \Sigma^2$

$$F^k = \bar{e}^k_{\mu\nu} \Sigma^{\mu\nu} \quad \Phi = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix} \quad R_{\lambda} = 19_{AB}$$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0$$

$$S_A A^k = \{A^k G(\lambda)\} = D_A \lambda^k(x)$$

$$S_A E^k = \{E_A C(\lambda)\} = \varepsilon_{\alpha\beta\gamma} \lambda^\beta E^{\gamma k}(x)$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $R_{ab} = 3\Lambda I$

regularization  $S = \int \varepsilon_1 F + \Lambda \bar{\Phi} \times \Phi - \frac{1}{2} \varepsilon_i \varepsilon_j \varepsilon^i$

$$F^i = -\bar{\Phi}^j \varepsilon^i_j \quad \Phi = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{ab} = \Lambda g_{ab}$$

$$S_\lambda A \mathbb{1} = \{A\lambda_i G(\lambda)\} \mathbb{1} = D_\lambda \lambda^*(*)$$

$$S_\lambda E \mathbb{1} = \{E\lambda_i C(\lambda)\} \mathbb{1} = E_{**} \lambda^* E^* \mathbb{1}$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^K = 0$   $R_{\alpha\beta} = S\Lambda =$

regularization  $S = \int \varepsilon_1 F + \Lambda \bar{\Phi} \Phi - \frac{1}{2} \varepsilon_1 \varepsilon^i \varepsilon^j$

$$F^a = -\bar{\varepsilon}^a_{ij} \varepsilon^{ij} \quad \bar{\Phi} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix} \quad R_{ab} = \Lambda g_{ab}$$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{\alpha\beta} = 0$$

$$S_\lambda A^\mu = \{A^\mu, G(\lambda)\} = D_\lambda X^\mu(x)$$

$$S_\lambda E^\mu = \{E^\mu, C(\lambda)\} = \varepsilon_{\mu\nu} X^\nu E^\mu(x)$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $R_{\lambda} = 3\Lambda =$

regularization  $S = \int \Sigma_1 F + \Lambda \Sigma \Phi - \frac{\Phi_{ij} \Sigma^i \Sigma^j}{}$

$$F = -\bar{\epsilon}_{ijk} \Sigma^j \quad \Phi = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix} \quad R_{ab} = \Lambda g_{ab}$$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{ab} = 0 \quad R = 0$$

$R_{\text{Riemann}} = \text{Weyl}^\dagger$

$$S_\lambda A \mathbb{M} = \{A \otimes G(\lambda)\} \mathbb{M} = D_\lambda X^*(\lambda)$$

$$S_\lambda E \mathbb{M} = \{E \otimes G(\lambda)\} \mathbb{M} = E_{\lambda \ast} X^* E^*(\lambda)$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^K = 0$   $R_{\lambda} = S \Lambda -$

regular motion  $S = \int \Sigma_1 F + \Lambda \Sigma \Phi - \underline{\Phi_{ij} \Sigma^i \Sigma^j}$

$$F^i = -\bar{\omega}_{ij} \Sigma^j \quad \Phi = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix} \quad R_{ab} = \Lambda g_{ab}$$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{ab} = 0 \quad R = 0$$

$$R_{ab} = Weyl^+ = F = 0$$

$$\delta_\lambda \bar{E}^k = \{ \bar{E}_\lambda \} G(\lambda) = \varepsilon_{ijk} \lambda^j \bar{E}^{1k}(x)$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $\varphi_{\alpha\lambda} = 3\Lambda$

e.g. solution  $S = \int \varepsilon_1 F + \Lambda \varepsilon_2 \tilde{F} - \frac{1}{2} \varepsilon_{ijk} \varepsilon^{ij}$

$$F^{\hat{a}} = -\tilde{\Phi}_{\hat{a}}^{\hat{b}}, \quad \tilde{\Phi} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix} \quad R_{ab} = \Lambda g_{ab}$$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{ab} = 0 \quad R = 0$$

$$R_{\mu\nu} = Weyl^+ = F = 0 \quad \text{locally } A = 0$$

$$\{A_i^k(x), \tilde{E}_j^l(y)\} = \delta^3(x, y) S_i^k S_j^l$$

$$J = S + \int_{\Sigma} \tilde{E} : \tilde{A} - \underbrace{\lambda_i G^i}_{SAS_{\Sigma} H} - \underbrace{V(D_k)}_{N\tilde{C}}$$

$$G^i = D_i \tilde{E}^{11} = 0 \quad \checkmark$$

$$F_{ab}^i \quad \checkmark$$

$$J_{1b}^K$$

$$H = \int_{\Sigma} \tilde{H}$$

$$C = \epsilon^{ijk} \tilde{E}_i^1 \tilde{E}_j^2 (F_{1b}{}^k + \frac{1}{3} S_{111} E_1^1) = 0$$

$$G(N) = \sum_{\mu} \lambda_{\mu} G^{\mu}$$

$$D(N) = \sum_{\mu} V^{\mu} D_{\mu}$$

$$C(N) = \sum_{\mu} N^{\mu} \tilde{C}$$

$$\tilde{E}^i \tilde{E}^{bi} = \hat{g}^{ab} \\ = (111..) g^{ab}$$



$$S_A A^B = \{A^B, G(A)\} = D_A X^B$$

$$S_A E^B = \{E^B, G(A)\} = \varepsilon_{AB} X^C E^B$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $R_{ab} = 3\Lambda I$

eigen motion  $S = \int \varepsilon_{ij} F + \Lambda \varepsilon_{ijk} \tilde{F} - \frac{1}{2} \varepsilon_{ijk} \varepsilon^{ij}$   
 $F = -\tilde{F}$   $\tilde{F} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$   $R_{ab} = \Lambda g_{ab}$

$\Rightarrow G = D = C = 0$   $\Lambda = 0$   $R_{ab} = 0$   $R = 0$

$R_{abmn} = Weyl^+ = F = 0$  locally  $A = 0$

$G^A = \partial_A E^A = 0$

$$\{D(\omega), G(\lambda)\} = 0$$

$$A^{\pm} = \{A(\mu), C(M)\} = N E^{\pm} F_{\mu} E_M + N_{\mu} E^{\pm} E_{\mu} E_M$$

$$E^{\pm} = \{E, C(M)\} = D_{\pm}(NEE)$$

$$a_{\text{anyons}}(x, t) =$$

$$\psi_B = \frac{t_{AB} + t_{B\bar{A}}}{2}$$

$$\{C(\omega), D'(v)\} = 0$$

$$\{C(x), G(\lambda)\} = 0$$

$$\{C(N), D'(v)\} = C(d_v N)$$

$$\Rightarrow \{C(N), D'(v)\} = \int (N d_v N - N d_v N)$$

$$\{C(N), E(M)\} = \int (N d_v N - M d_v N)$$

$$P(D(\omega), G(\lambda)) = \mathbb{Q}$$

$$A_{\omega} = \{A_{\omega}^n(\lambda), C(n)\} = \mathbb{N}\left\{E^n \cap \omega + n \in \mathbb{N} \mid E_n\right\}$$

$$E^{\text{tr}} = \{E, C(M)\} = \mathcal{D}_M(N)$$

$\alpha_{\omega}(x, t) =$

$$\vartheta_{\omega} = \vartheta_{ab} + \vartheta_{abc}$$

$$\{C(x), G(\lambda)\} = 0$$

$$\{C(x), D(v)\}$$

$$\Rightarrow \{C(N), D(v)\} = C(d_v N) \quad \text{EE}$$

$$\Rightarrow \{C(N), E(M)\} = \int (N \Delta M - M \Delta N)$$



$$\{D(\alpha), G(\lambda)\} = \dots$$

$$A^{\alpha} = \{A_{\alpha}^{\alpha}(x), C(M)\} = \text{INF} \{E^{\alpha}, E^{\beta}, \epsilon_{\alpha\beta} + N \epsilon_{\alpha\beta} \epsilon^{\mu\nu} E^{\mu} E^{\nu}\}$$

$$E^{\alpha} = \{E, C(M)\} = D_{\alpha}(N E E) \quad \text{Ansatz}$$

Anyons ( $x, t$ )

$$J_{ab} = \underline{q_{ab}} + \underline{e_{ab}}$$

$$\{C(x), G(\lambda)\} = 0 \quad \{C(x), D(v)\} = \delta_v C$$

$$\Rightarrow \{C(N), D'(v)\} = C(N) \quad \text{EE}$$

$$\Rightarrow \{C(N), C(M)\} = \int \left( N \partial M - M \partial N \right) \tilde{q}^{ab} D_a$$

Braids  
class

$$S_\lambda A = \{A^\lambda G(\lambda)\} = D_\lambda \lambda^r(x)$$

$$S_\lambda E = \{E_\lambda C(\lambda) = \varepsilon_{\mu\nu\lambda} \lambda^r E^\mu\}$$

selected solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $R_{ab} = 0$

gravitation  $S = \int \Sigma_A F + \Lambda \varepsilon_{ijk} - \frac{1}{2} \varepsilon_{ijk} \varepsilon^{ijk}$   
 $F^i = \bar{\nabla}^i_j \Sigma^j$   $\bar{\nabla} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$   $R_{ab} = \Lambda g_{ab}$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{ab} = 0 \quad R = 0$$

$R_{\text{Riemann}} = \text{Weyl}^+$   $= F = 0$  locally  $A = 0$   $E^{ab}$

$$G^a = \partial_a E^b \cdot \partial_b$$

$$\boxed{G^a = \epsilon^{abc} \partial_c E_b}$$

$$\delta_\lambda A^\mu = \{A^\mu, G(\lambda)\} = D_\lambda X^\mu(x)$$

$$\delta_\lambda E^{\dot{\mu}} = \{E^{\dot{\mu}}, G(\lambda)\} = \varepsilon_{\mu\nu\lambda}{}^\nu E^{\dot{\nu}}(x)$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^K = 0$   $\phi_{ab} = \text{const}$

e.g. solution  $S = \int \varepsilon_{12} F + \Lambda \varepsilon_{123} \tilde{\Phi} - \frac{1}{2} \tilde{\Phi}_{ij} \varepsilon^{ij} \tilde{\varepsilon}^{abc}$

 $F^i = -\tilde{\Phi}^i, \quad \tilde{\varepsilon}^{abc}, \quad \tilde{\Phi} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$ 
 $R_{ab} = \Lambda g_{ab}$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{ab} = 0 \quad R = 0$$

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$R_{\mu\nu\lambda\tau} = Weyl^+ = F = 0$   $\therefore$  locally  $A = 0$   $\tilde{E}^{ab}$

$G^i = \partial_a E^{ai} = 0$   
 $E^{ai} = \epsilon^{ijk} \partial_k (E^i, E^j)$

$$\partial_\lambda A^\mu = \{A^\mu, G(\lambda)\} = \omega_\lambda \wedge G$$

$$\delta_\lambda \tilde{E}^\mu = \{\tilde{E}^\mu, G(\lambda)\} = \varepsilon_{\mu\nu\rho} \tilde{E}^\rho$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $\phi_{ab} = 3\Lambda$

e.g. solution  $S = \int \varepsilon_1 F + \Lambda \varepsilon_{ijk} \tilde{E} - \frac{\phi_{ab}}{2} \varepsilon^a_i \varepsilon^b_j$   
 $F^a = -\tilde{E}^a_{;j} \varepsilon^{ij}$   $\tilde{E} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$   $R_{ab} = \Lambda g_{ab}$

$\Rightarrow G = D = C = 0$   $\Lambda = 0$   $R_{ab} = 0$   $R = 0$

$R_{\text{min}} = \text{Weyl}^+ = F = 0$  locally  $A = 0$   $\sqrt{-g} = \Lambda \tilde{E}^a$

$$G^a = \partial_a E^b - \square E^a$$

$$\tilde{E}^a = \varepsilon^{abc} \partial_b (E^c, E_c)$$

$$\partial_\lambda A^\mu = \{A^\mu, G(\lambda)\} = \omega_\lambda \wedge G$$

$$\delta_\lambda \tilde{E}^\mu = \{\tilde{E}^\mu, G(\lambda)\} = \varepsilon_{\mu\nu\lambda} E^\nu$$

solid solutions  $\Lambda \neq 0$   $J_{ab}^k = 0$   $R_{ab} = 3\Lambda$

e.g. solution  $S = \int \varepsilon_1 F + \Lambda \varepsilon_2 \varepsilon_2 - \frac{\Phi_{ij} \varepsilon_i \varepsilon_j}{R_{ab}}$

$$F = -\bar{\Psi}_{,j} \varepsilon^j \quad \bar{\Psi} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix} \quad R_{ab} = \Lambda g_{ab}$$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{ab} = 0 \quad R = 0$$

$$R_{ab}m^a = Weyl^+ = F = 0 \quad \text{locally } A = 0 \quad V_a^a = N \tilde{E}_i^i \quad \partial_i N = 0$$

$$\boxed{G^i = \partial_a \tilde{E}^{ai} = 0}$$

$$\boxed{\tilde{E}^{ai} = \varepsilon^{ijk} \partial_k (\tilde{E}^i, \tilde{E}^j)}$$

$$\partial_\lambda A^\mu = \{A^\mu, G(\lambda)\} = \epsilon_{\mu\nu} \wedge G^\nu$$

$$\delta_\lambda E^\mu = \{E^\mu, G(\lambda)\} = \epsilon_{\mu\nu} \lambda^\nu E^\mu$$

self dual solutions  $\Lambda \neq 0$   $J_{ab}^K = 0$   $R_{ab} = 3\Lambda$

reconstruction  $S = \int \epsilon_1 F + \Lambda \epsilon_2 \times \epsilon - \frac{R_{ab} \epsilon^a \epsilon^b}{2}$   
 $F = -\bar{\Psi}^i \epsilon_i$   $\bar{\Psi} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$   $R_{ab} = \Lambda g_{ab}$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{ab} = 0 \quad R = 0$$

$$R_{ABCD} = Weyl^+ = F = 0 \quad \text{locally } A = 0 \quad \nabla_\lambda^m = \lambda \hat{E}^m \quad \partial_\lambda \lambda = 0$$

$$\boxed{G^a = \partial_a E^b \wedge \epsilon_b}$$

$$\boxed{\hat{E}^a = \epsilon^{abc} \partial_b (E^c, E^d)}$$

$$\partial_\lambda A^\mu = \{A^\mu, G(\lambda)\} = \epsilon_{\mu\nu} \wedge G^\nu$$

$$\delta_\lambda E^\mu = \{E^\mu, G(\lambda)\} = \epsilon_{\mu\nu} \lambda^\nu E^\nu$$

solid solutions  $\lambda \neq 0$   $J_{ab}^k = 0$   $R_{ab} = 3\Lambda$

e.g. solution  $S = \int \epsilon_1 F + \lambda \epsilon_2 \epsilon - \frac{\Phi_{ab} \epsilon^a \epsilon^b}{R_{ab}}$   
 $F^a = \bar{E}^a, \epsilon^a$   $\bar{E} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$   $R_{ab} = \Lambda g_{ab}$

$$\Rightarrow G = D = C = 0 \quad \Lambda = 0 \quad R_{ab} = 0 \quad R = W_N$$

$$R_{ab} = W_N \Gamma^a_b = F = 0 \quad \text{locally } A = 0 \quad V_a^m = \lambda \bar{E}^a \quad \partial_a \lambda = 0$$

$$\boxed{G^a = \partial_a E^a = 0}$$

$$\boxed{\epsilon^{abc} = \epsilon^{ijk} \partial_a (\bar{E}_i^b E_j^c)}$$

$$\boxed{\partial_a V_a^m = 0}$$

$$\boxed{V_a^m = \epsilon_{abc} [V^b, W^c]}$$

$$\partial_\lambda A^\mu = \{A^\mu, C(\lambda)\} = \omega_\lambda \wedge C(\lambda)$$

$$\delta_\lambda E^\mu = \{E^\mu, C(\lambda)\} = \epsilon_{\mu\nu\lambda}^* E^\nu(\lambda)$$

selected solutions  $\Lambda \neq 0$   $J_{ab}^K = 0$   $\phi_{ab} = 3\Lambda$

e.g. solution  $S = \int \Sigma_1 F + \Lambda \Sigma_2 \Sigma - \frac{\Phi_{ab} \Sigma^a \Sigma^b}{R_{ab}}$   
 $F = -\bar{\Phi}^a \Sigma_a$   $\bar{\Phi} = \begin{pmatrix} \Lambda & 0 \\ 0 & \Lambda \end{pmatrix}$   $R_{ab} = \Lambda g_{ab}$

$\Rightarrow G = D = C = 0$   $\Lambda = 0$   $R_{ab} = 0$   $R = 0$

$R_{abmn} = Weyl^+ = F = 0$  ... locally  $A = 0$   $V_a^m = \lambda \hat{E}_a^m$   $\partial_m V_a^m = 0$

$$G^a = \partial_a E^a = 0$$

$$\hat{E}^a = \epsilon^{abc} \partial_b (E^c, E^c)$$

$$\partial_a V_a^m = 0$$

$$\vec{V}_a^m = \epsilon_{abc} [V^b, W^c]$$

ADM

Boundary conditions

ADM

Boundary conditions

Always looks

ADM

Boundary conditions

As we've learnt

ADM

Boundary conditions

Always looks



ADM

Bowling conditions

Always books

ADM

Browder conditions



$$\Sigma = \mathbb{R}^3$$

Always  $\Sigma$

flat metric  $g_{ab}$



ADM Boundary conditions



Always banks

$$\Sigma = R^3 \quad \text{flat metric } g_{ab}^0$$
$$r \rightarrow \infty \quad q_{ab} \rightarrow q_{ab}^0 + O(\frac{1}{r})$$

ADM

Boundary conditions

Ahluwals book S

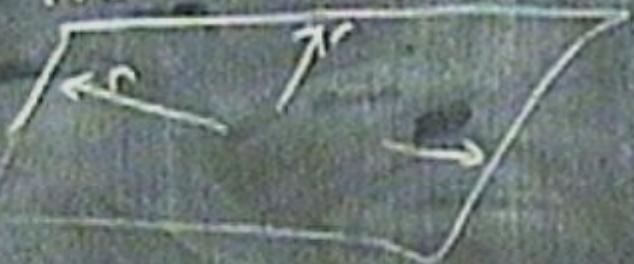
$$\Sigma = R^3 \quad \text{flat metric } g_{ab}^0$$

$$r \rightarrow \infty \quad g_{ab} \rightarrow g_{ab}^0 + O(\frac{1}{r})$$



ADM

Boundary conditions



Ashby's book 5

$$\Sigma = R^3$$

flat metric  $g_{ab}^0$

$$r \rightarrow \infty \quad g_{ab} \rightarrow g_{ab}^0 + O\left(\frac{1}{r}\right)$$

$$g^{ab} ds^2 = dr^2 + r^2 d\Omega^2$$

distance  $r_0$



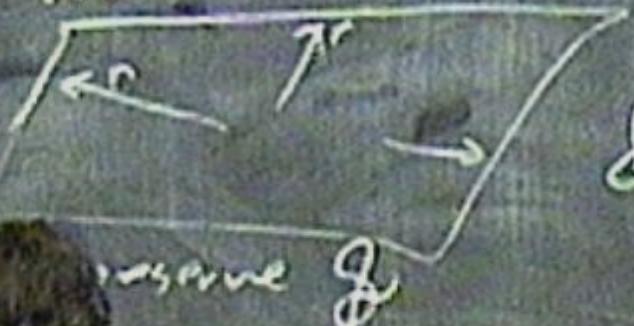
## ADM Boundary conditions

Assy's book S

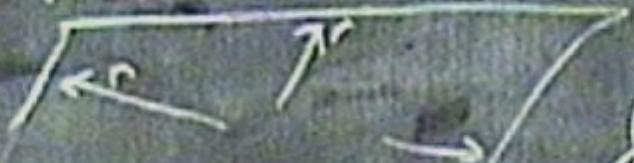
$$\Sigma = R^3 \text{ flat metric } q_{ab}^0$$

$$\delta r \rightarrow \infty \quad q_{ab} \rightarrow q_{ab}^0 + O(\frac{1}{r}) \text{ derivative } q_{ab}^0$$

$$r^2 + d\zeta^2 = dr^2 + r^2/52^2$$



ADM Boundary conditions



Preserve  $\bar{g}$

$$\nabla^* = O(\frac{1}{r})$$

Always books  
 $\Sigma = \mathbb{R}^3$  flat metric  $g_{ab}^0$

$$\text{for } r \rightarrow \infty \quad g_{ab} \rightarrow g_{ab}^0 + O(\frac{1}{r}) - \text{dilaton } q_0$$

$$q^0 \wedge d\zeta^2 = dr^2 + r^2/52^2$$

## ADM Boundary conditions



primary  $\phi$

$$\nabla^4 = O(\frac{1}{r^2})$$

$$\Sigma = \mathbb{R}^3$$

Always looks

$$\text{elasticitic } q_{ab}^0$$

$$\text{at } r \rightarrow \infty \quad q_{ab} \rightarrow q_{ab}^0 + \alpha(t) - \text{dissipation } q^0$$

$$q^0 \sim 1/r^2 = 1/r^2 + r^2/16$$

$$\delta q_{ab} = \delta_V q_{ab} = \nabla_a V_b + \nabla_b V_a =$$

ADM

Boundary conditions

Adams books

$$\Sigma = R^3 \quad \text{flat metric } g_{ab}^{(0)}$$

$$r \rightarrow \infty \quad g_{ab} \rightarrow g_{ab}^{(0)} + O(\frac{1}{r}) - \text{dilaton } \phi_0$$

$$ds^2 = dr^2 + r^2 d\Omega^2$$

pressure  $p$

$$V' = O(\frac{1}{r^2})$$

$$g_{ab} = \delta_{ab} g_{ab}^{(0)} = \nabla_a V_b + \nabla_b V_a \Rightarrow \text{dilaton } V \neq 0$$

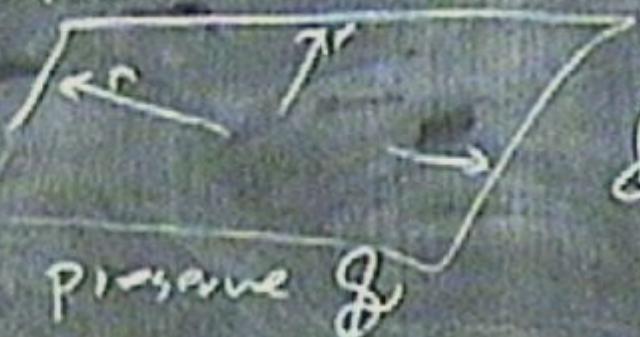
ADM

Boundary conditions

Ashley's books

$$\Sigma = \mathbb{R}^3$$

flat metric  $g_{ab}^0$



$$\text{for } r \rightarrow \infty \quad g_{14} \rightarrow g_{14}^0 + O(\frac{1}{r}) - \text{dilaton } \phi^0$$

$$g^{0\mu} ds^2 = dr^2 + r^2 d\Omega^2$$

preserve  $\delta$

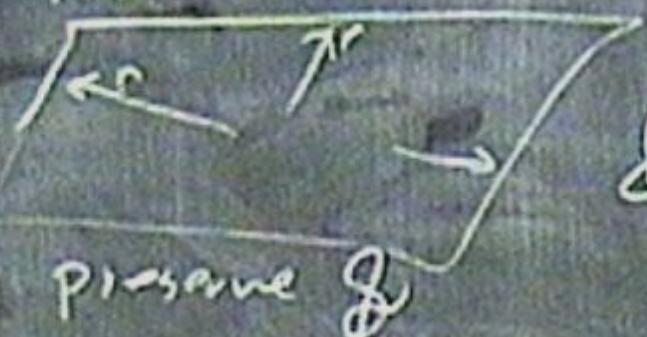
$$V^a = O(\frac{1}{r^2})$$

$$\delta U_{16} = \delta_U q_{16} = \nabla_1 V_6 + \nabla_6 V_1 \Rightarrow \text{check } V \sim \frac{1}{r^2}$$

ADM

Boundary conditions

Ashley's books



$$\Sigma = R^3 \quad \text{flat metric } q_{ab}^0$$

$$\delta r \rightarrow \infty \quad q_{15} \rightarrow q_{15}^0 + O(\frac{1}{r}) - \text{discretize } q_{15}^0$$

$$q^{0\alpha} \quad ds^2 = dr^2 + r^2/d\theta^2$$

Preserve  $\delta$

$$V^i = O(\frac{1}{r^2})$$

$$\delta q_{15} = \delta_V q_{15} = \nabla_1 V_5 + \nabla_5 V_1 \Rightarrow \text{check } V \sim \frac{1}{r^2}$$

E:

ADM

Boundary conditions

Ahluwalia's books

$$\Sigma = R^3$$

flat metric  $g_{ab}^0$



$$\delta r \rightarrow \infty \quad g_{ab} \rightarrow g_{ab}^0 + O(\frac{1}{r}) \quad \text{distance } l^0$$

$$l^0 \sim d\zeta^2 = dr^2 + r^2/d\theta^2$$

Preserve  $\delta$

$$\nabla^a = O(\frac{1}{r^2})$$

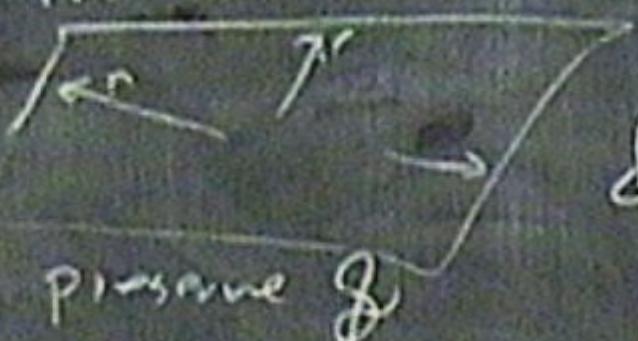
$$\delta g_{ab} = \delta_V g_{ab} = \nabla_a V_b + \nabla_b V_a \Rightarrow \text{constant } V \sim \frac{1}{r^2}$$

$$- \hat{E}_A^a = E_{0a}^a + O(\frac{1}{r})$$

$$\Rightarrow A \sim \frac{1}{r^2}$$

ADM

Boundary conditions



$$\Sigma = R^3$$

Abhay's books

$$\Lambda=0$$

flat metric  $g_{ab}^0$

$$\delta r \rightarrow \infty \quad g_{ab} \rightarrow g_{ab}^0 + O(\frac{1}{r}) \quad \text{distance } q^0$$

$$q^0 \sim ds^2 = dr^2 + r^2 d\Omega^2$$

Preserve  $\delta$

$$V^a = O(\frac{1}{r^2})$$

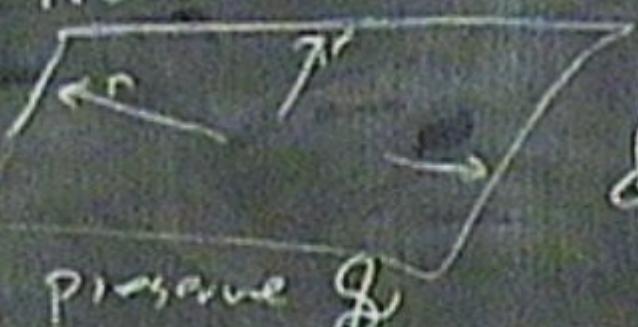
$$\delta g_{ab} = \delta_V g_{ab} = \nabla_a V_b + \nabla_b V_a \Rightarrow \text{check } V \sim \frac{1}{r}$$

$$\boxed{\tilde{E}_a^i = E_{D_a}^i + O(\frac{1}{r})}$$

$$\Rightarrow A \sim \frac{1}{r^2}$$

ADM

Boundary conditions



$$\Sigma = R^3$$

Almey's books

$\Lambda = 0$

flat metric  $g_{ab}^0$

$$\delta r \rightarrow \infty \quad g_{ab} \rightarrow g_{ab}^0 + O(\frac{1}{r}) - \text{discrepancy}$$

$$ds^2 = dr^2 + r^2/52^2$$

preserve  $g$

$$V^a = O(\frac{1}{r^2})$$

$$\delta g_{ab} = \delta_V g_{ab} = \nabla_a V_b + \nabla_b V_a \Rightarrow \text{check } V^a = 0$$

$$\boxed{\tilde{E}_a^a = E_{D_a}^a + O(\frac{1}{r})}$$

$\Rightarrow$

$$A \sim \frac{1}{r^2}$$



ADM

Boundary conditions



Primitive  $\delta$

$$V^a = O(\frac{1}{r^2})$$

$$\boxed{\tilde{E}^a = E_{0a} + O(\frac{1}{r})}$$

$\Rightarrow A \sim \frac{1}{r^2}$

$$\Sigma = R^3$$

Ashby's books

$$\Lambda = 0$$

flat metric  $g_{ab}^0$

$$\delta r \rightarrow \infty \quad g_{15} \rightarrow g_{15}^0 + O(\frac{1}{r}) - \text{distance } l^0$$
$$l^0 \wedge ds^2 = dr^2 + r^2 d\Omega^2$$

$$\delta g_{15} = \delta_U g_{15} = \nabla_a V_b + \nabla_b V_a \Rightarrow \text{link } V \sim \frac{1}{r^2}$$

$$\Rightarrow D(V) = \int V^a D_a$$



ADM

Boundary conditions

Ashley's books

$\Lambda=0$

flat metric  $g_{ab}^0$

$$\int_{r_0}^{\infty} \pi' dr$$

$$\delta r \rightarrow \infty \quad g_{ab} \rightarrow g_{ab}^0 + O(\frac{1}{r}) \quad \text{distance } l^0$$
$$l^0 \wedge ds^2 = dr^2 + r^2 d\Omega^2$$

preserve  $\delta$

$$V' = O(\frac{1}{r^2})$$

$$\delta g_{ab} = \delta_V g_{ab} = \nabla_a V_b + \nabla_b V_a \Rightarrow \text{check } V \sim \frac{1}{r}$$

$$\Rightarrow D(v) = \int v^a D_a \quad \text{converges}$$

$$\{D(v), D(w)\} = D([v, w])$$

$$\boxed{\tilde{E}_a^i = E_{0a}^i + O(\frac{1}{r})}$$
$$\Rightarrow A \sim \frac{1}{r^2}$$

Hamilton formulation

$$\{A_\alpha^i(x), \tilde{E}_j^b(y)\} = \delta^i_j(x, y) \epsilon_{ik} \epsilon_{jl}$$

$$S = \int d^4x \int \tilde{E}^i A_i - \underbrace{\lambda_1 G^i}_{S_1 S_2 H} - \underbrace{V^a D_a}_{S_3 H} - \underbrace{N \tilde{C}}_{S_4 H}$$

$$G^i = \partial_\mu E^{i\mu} = 0$$

$$= E^i_\mu F_{i\mu}^a$$

$$H = \sum_k \tilde{H}_k$$

$$G(\lambda) = \sum_k \lambda_k G^k$$

$$D(\nu) = \sum_k V^a D_a$$

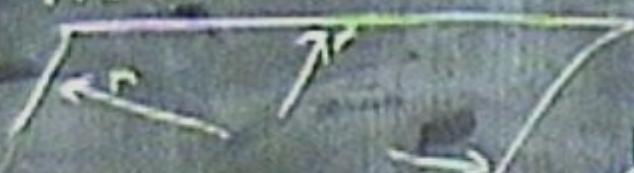
$$C(N) = \sum_k N \tilde{E}_k$$

$$\tilde{E}^i \tilde{E}^{bi} = \tilde{g}^{ab} \\ = (1, 0, 0, 0)$$

$$E^i \tilde{E}_i \tilde{E}^b (F_{abk} + \frac{1}{3} \sum_{abc} E^c_k) = 0$$



## ADM Boundary conditions



$$\Sigma = R^3$$

Adm's books

$$A=0$$

flat metric  $g_{ab}^{(0)}$

$$\text{for } r \rightarrow \infty \quad q_{16} \rightarrow g_{16}^{(0)} + O(\frac{1}{r}) - \text{dissip. } g_{16}^{(0)}$$

$$g^{(0)} \sim ds^2 = dr^2 + r^2/d\Omega^2$$

preserve  $g$

$$V' = O(\frac{1}{r^2})$$

$$\delta q_{16} = \delta V q_{16} = \nabla_i V_{;j} + V_{;i} V_{;j} \Rightarrow \text{check } V \sim \frac{1}{r^2}$$

$$\Rightarrow D^{(1)} = S V^{(1)} D_1 \quad \text{converges}$$

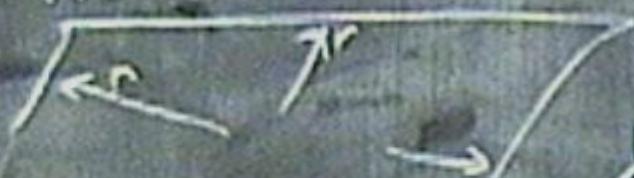
$$k = D[V^{(1)}]$$

$$\tilde{E}_a^{(1)} = E_{D_a}^{(1)} + O(\frac{1}{r})$$

$$\Rightarrow A \sim \frac{1}{r^2}$$

$$\lambda \sim \frac{1}{r}$$

ADM Boundary conditions



Preserve  $g^0$

$$V^1 = O(\frac{1}{r^2})$$

$$\hat{E}^1 = E_{0i}^1 + O(\frac{1}{r})$$

$$\Rightarrow A \sim \frac{1}{r^2}$$

$$\lambda^1 \sim \frac{1}{r}$$

Always books

$$A=0$$

$$\Sigma = R^3$$

flat metric  $g_{ab}^0$

$$\delta r \rightarrow \infty \quad g_{16} \rightarrow g_{16}^0 + O(\frac{1}{r}) \quad \text{distance } \frac{q^0}{r^0}$$

$$g^0 \wedge ds^2 = dr^2 + r^2/d\Omega^2$$

$$\delta g_{16} - \delta V g_{16} = \nabla_A V_B + \nabla_B V_A \Rightarrow \text{char. } V \sim \frac{1}{r^2}$$

$$\Rightarrow D(V) = \int V^* D_i \quad \text{converges}$$

$$\{D(V), D(W)\} \simeq D[V, W]$$

$G(\lambda)$  converges absolutely

$$\begin{aligned} S_{\partial x \times W^1(\lambda)} = & \{D'(\omega), D(v)\} = \{W^1(\lambda), D(v)\} \\ = & -\{(\delta_v w) D(\lambda) \Rightarrow -D[L_v w] = -D[L_v w]\} \end{aligned}$$

$$\{D'(\omega), G(\lambda)\} = 0$$

$$\begin{aligned} A_i = & \{A_i(\lambda), C(N)\} = N [E^{\leftarrow} F_{ik}^k \varepsilon_{ik} + \lambda \varepsilon_{ik} \varepsilon^{ik} E^k E_k] \\ E^{\leftarrow} = & \{E, C(N)\} = D_a (N E^b E_b) \varepsilon^{ak} \quad \text{Asymmetrisch} \end{aligned}$$

$N = \sqrt{t+1}$

$\Delta t$

$a_{\text{welle}}(x, t) = \text{Einsatz f. r's}$

$\mathcal{G}_{ab} = \frac{\partial_{ab} + \epsilon_{abc}\epsilon_{abc}}{\sqrt{C(x), G(\lambda)}} = 0$

$\{C(\lambda), D(v)\} = \delta_v C$

$C(\varphi_N) = F$

Topological conditions on  $N$  in  $C(X)$



Final conditions on  $\tilde{N}$  in  $C(W)$

Hausmann formulation

$$\{A_a^i(x), \tilde{E}_j^b(y)\} = S^3(x, \tilde{y}) S^a_i S^b_j$$

$$J = \int_a^b \int_{\Sigma} \tilde{E}^i A_i - \underbrace{\lambda_i G^i}_{S^a S_\Sigma H} - \underbrace{V^a D_a}_{N \tilde{C}}$$

$$\tilde{G}^i = D_a \tilde{E}^{ai} = 0 \checkmark$$

$$D_a = E^k_a F_{ik} \checkmark$$

$$C = \epsilon^{ijk} \tilde{E}_i \tilde{E}_j (F_{ask} + \frac{1}{3} \sum_{abc} E^c) = 0$$

$$J_{ab}$$

$$H = \int_{\Sigma} \tilde{H}$$

$$G(N) = \int_{\Sigma} \lambda_i G^i$$

$$D(N) = \int_{\Sigma} V^a D_a$$

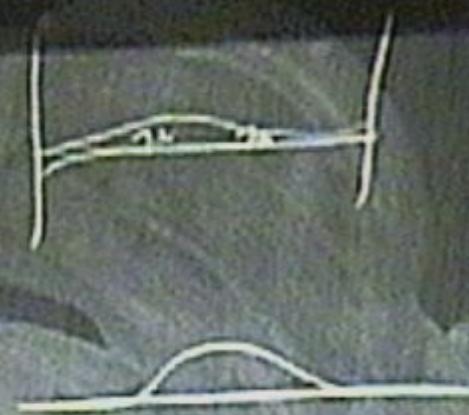
$$C(N) = \int_{\Sigma} N \tilde{C}$$

$$\tilde{E}^i \tilde{E}^{bi} = \tilde{g}^{ab} \\ = (M!) \tilde{e}^b$$

$$\Rightarrow A \sim \frac{1}{r^2}$$
$$r^2 \sim \frac{1}{A}$$

$G(\lambda)$  converges when  $\lambda$  closes

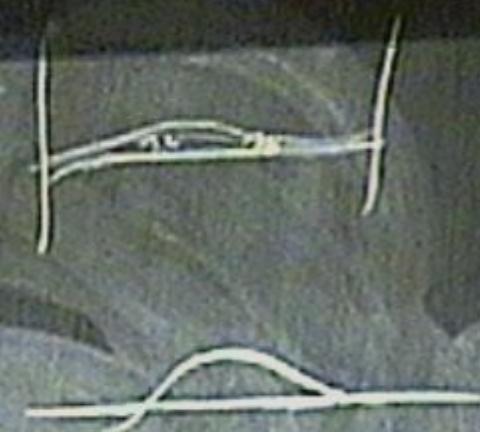
closed contours on  $\tilde{N}$  in  $C(\Omega)$



$$\boxed{A \sim \bar{\gamma}^2}$$
$$\gamma_i \sim \frac{1}{r}$$

$G(\lambda)$  convergent absolutely

fixed conditions on  $N$  in  $C(X)$



Helmholtz formulation

$$\{A_a^k(x), \tilde{E}_j^b(y)\} = \delta^3(x, y) S_a^k S_j^b$$

$$J = \int_{\Omega} \int_{\Sigma} \tilde{E}^i A_i - \underbrace{\lambda_i G^i}_{S \int_{\Sigma} R} - V^i D_i - N \tilde{C}$$

$$\tilde{G}^i = D_i E^m = 0 \vee$$

$$D_i = E^k F_{ik} \vee$$

$$C = \epsilon^{ijk} \tilde{E}_i \tilde{E}_j (F_{ik} + \frac{1}{3} \sum_m E_m^i) = 0$$

$$S \int_{\Sigma} R$$

$$H = \int_{\Sigma} \tilde{H}$$

$$G(\lambda) = \int_{\Sigma} \lambda_i G^i$$

$$D(M) = \int_{\Sigma} V^i D_i$$

$$C(N) = \int_{\Sigma} N \tilde{C}$$

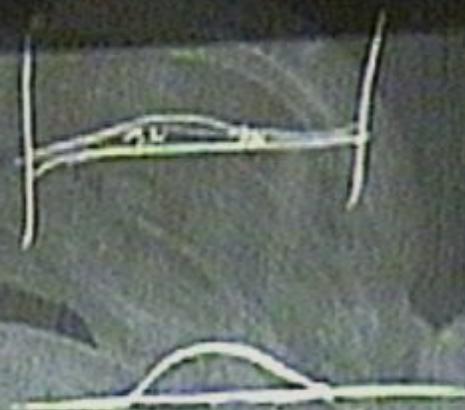
$$\tilde{E}^i \tilde{E}^b \nu =$$

$$= 0$$

$$P \sim r^2$$
$$\lambda \sim \frac{1}{r}$$

$G(\lambda)$  convergent within class

first condition on  $N$  in  $C(\lambda)$



$$\{D'_x(x), D'(v)\} = \delta_{vx} D'_x(v)$$

$$S^P_{\alpha x} W^M(\omega) = \{D'(\omega), D'(v)\} = \int \omega f_P(\omega, D'_v)$$

$$= - \int (\delta_{vx} \omega) D'_x(v) = - D'_x(v, \omega) = - D'_x(L^M, \omega)$$

$$\{D'(\omega), G(\lambda)\} = 0$$

$$A_x^{\perp} = \{A_x^{\perp}(v), C(N)\} = \text{IN} \left[ E^{xx} F_{av}^{\perp} \epsilon_{xav} + N \epsilon_{av} S^{xx} E_r^{\perp} E_m^{\perp} \right]$$

$$E^{\perp v} = \{E, C(N)\} = D_x(N E_r^{\perp} E_m^{\perp}) \epsilon^{xx} \quad \text{Ansatz}$$

$$N = \sqrt{n} n^{1/4}$$

$$\text{Angulars}(x, t) = \text{Einstrom 915}$$

$$\zeta_{11} = \frac{t_{ab} + t_{ba}}{2}$$

$$\{C(x), D'(v)\} = \delta_{vx} C$$

$$\{C(x), G(\lambda)\} = 0$$

$$\{C(N), D'(v)\} = C(d_v N) \frac{E}{E}$$

$$\Rightarrow \{C(N), M\} = \left( N \Delta M - M \Delta N \right) \tilde{I}^{\perp b} D'_b$$

Basis "1  
Class "

$$\frac{P^n - P^c}{\lambda^n} \sim \frac{1}{r}$$

$G(\lambda)$  converges when  $\lambda < r$

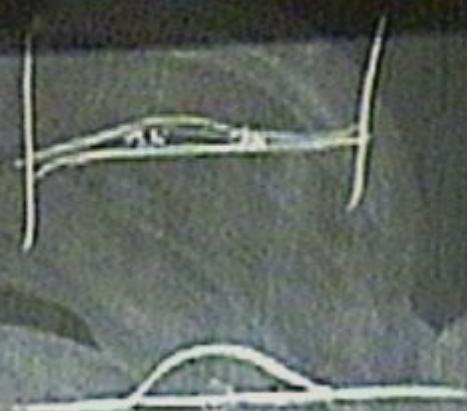
Final conditions on  $N$  in  $C(\mathbb{R})$



$$P^n = r^2 \frac{dr}{dt} \quad \lambda^2 \sim \frac{1}{r}$$

$G(\lambda)$  contractible within class

full conditions on  $\tilde{N}$  in  $C(X)$   
a constraint = generator of a gauge trans.



$$P \propto r^{-\alpha}$$

$$\lambda \sim \frac{1}{r}$$

$G(\lambda)$  convergent within class

first condition on  $\tilde{N}$  in  $C(\lambda)$

a constraint = generator of a gauge trans.  
should take local fields to local fields



$$P \propto r^{-\gamma} \quad \gamma \sim \frac{1}{r}$$

$G(\lambda)$  converges within class

first conditions on  $N$  in  $C(X)$

a constraint = generator of a gauge trans.  
should take local fields to local fields

$$\delta \phi(x) = -\{ \text{const}, \phi(x) \} = -[\partial_\mu \phi](x) + \partial_\mu (\hat{\phi})$$

$$P \propto r^{-\gamma} \quad \gamma \approx \frac{1}{r}$$

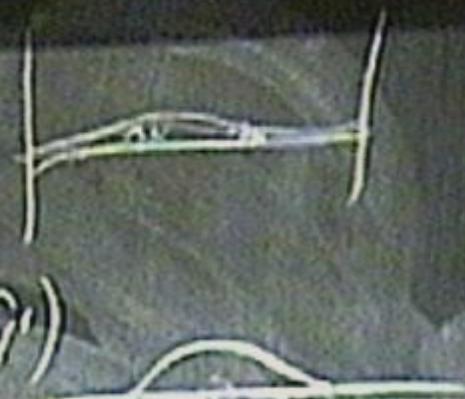
$G(r)$  converges within class

initial conditions on  $\tilde{N}$  in  $C^1(\mathbb{R})$

a constraint = generator of a gauge trans.  
should take local fields to local fields

$$\delta \phi(x) = -\{ \text{const}, \phi(x) \} = -[\partial_\mu l(x) + \partial_\mu (\tilde{V}')]$$

$$-\{ S_\lambda G, \phi \} = -[\partial_\mu l + \int_{\partial\Sigma} (\cdot)]$$



$\Gamma^{\mu} \cdot \nabla_{\mu}$

$$\lambda^i \sim \frac{1}{r}$$

$G(\lambda)$  convergent within circles

full off conditions on  $N$  in  $C(\lambda)$

a constraint = generator of a gauge trans.  
should take local fields to local fields

$$\delta \phi(x) = -\{(\text{const})\phi(x)\} = \text{local}(x) + \partial_a(\tilde{v}')$$

$$\{S_\lambda G, \phi\} = \text{local} + \cancel{\partial_a(\tilde{v}')}$$

$\cancel{\partial_a(\tilde{v}')} \Rightarrow$  full off conditions on Lagrange multipliers  
 $v' < \frac{1}{r}, \lambda < \frac{1}{r}$

$$\lambda^* \sim \frac{1}{r}$$

$G(\lambda)$  converges within class

full conditions on  $N$  in  $C(X)$

a constraint = generator of a gauge trans.  
should take local fields to local fields

$$\delta \phi(x) = -\{ \text{const}, \phi(x) \} = \text{local}(x) + \partial_\alpha (\tilde{v}^\alpha)$$

$$= -\{ S_\lambda G, \phi \} = \text{local} + \cancel{\partial_2}$$

$\cancel{\partial_2} \Rightarrow$  full off conditions on Lagrange multiplier  
 $v^* < \frac{1}{r} \quad \lambda < \frac{1}{r} \quad N \lesssim \frac{1}{r^2}$

$$\mathcal{S} = \int_A \int_{\Sigma} \widehat{E}^i A^i - \cancel{\int_A G^i} - \cancel{\int_V D_A} - \cancel{\int_N \widehat{C}}$$

$$G^i = \partial_a \widehat{E}^{ai} = 0 \checkmark$$

$$D_A = E^i F_{ib} V$$

$$C = \epsilon^{ab} \widehat{E}_i \widehat{E}_j (F_{ijk} + \dots)$$

$$H = \int_{\Sigma} \widehat{H}$$

$$\left| \begin{array}{l} G(\lambda) = \int_{\Sigma} \lambda_i \widehat{G}^i \\ D(\nu) = \int_V V^a D_a \\ C(N) = \int_N \widehat{C} \end{array} \right.$$

$$\begin{aligned} E^i \widehat{E}^{bi} &= \widehat{q}^{ab} \\ &= (\eta^{ab}) \widehat{L}^{ab} \end{aligned}$$

$$\boxed{A \sim \frac{1}{r^2}} \\ \lambda^i \sim \frac{1}{r}$$

$(D^\mu)_{\mu} = \nabla - D(\lambda^i)$   
 $G(\lambda)$  convergent abelian class

all conditions on  $N$  in  $C(N)$

a constraint = generator of a gauge trans.  
 should take local fields to local fields

$$\delta \phi(x) = -\{(\text{const})\phi(x)\} = \text{local}(x) + \partial_\alpha(\hat{v}')$$

$$-\{S_\lambda G, \phi\} = \text{local} + \cancel{\partial_\alpha}$$

~~$\times$~~   $\Rightarrow$  all off conditions on Lagrange multipliers  
 $v' < \frac{1}{r}, \lambda < \frac{1}{r}, N \lesssim \frac{1}{r^2}$

$$\boxed{A \sim \frac{1}{r^2}}$$

$$\lambda^i \sim \frac{1}{r}$$

$G(\lambda)$  convergent Abelian class

full off conditions on  $\lambda$  in  $C^0(N)$

a constraint = generator of a gauge trans.  
should take local fields to local fields

$$\delta \phi(x) = -\{(\text{const})\phi(x)\} = \text{local}(x) + \partial_\lambda(\tilde{\psi})$$

$$-\{S_\lambda \phi, \phi\} = \text{local} + \cancel{\partial_\lambda(\tilde{\psi})}$$

$\cancel{\lambda} \Rightarrow$  full off conditions on Lagrange multipliers  
 $\lambda^i < \frac{1}{r} \quad \lambda^i > \frac{1}{r} \quad \lambda \lesssim \frac{1}{r^2}$

Fixing coordinate  $T_{\text{affine}}$   
quadrilateral  $90^\circ$

Fixe time coordinate  $T$   $\text{new}^{(0)}$   
spacetime metric  $g^0$   $ds^2 = -dt^2 + dr^2 + r^2/\Omega^2$

$$P^{\mu\nu} = \frac{r^2}{\lambda^2} \partial^\mu \partial^\nu$$

$$\lambda^2 \sim \frac{1}{r}$$

$G(\lambda)$  converges when close

initial conditions on  $N$  in  $C^1(\mathbb{R})$

a constraint = generation of a gauge trans.  
should take local fields to local fields

$$\delta \phi(x) = -\{ \text{const}, \phi(x) \} = \text{local}(x) + \partial_\mu (\hat{v}')$$

$$-\{ S_{\lambda} G, \phi \} = \text{local} + \cancel{\partial_\mu}$$

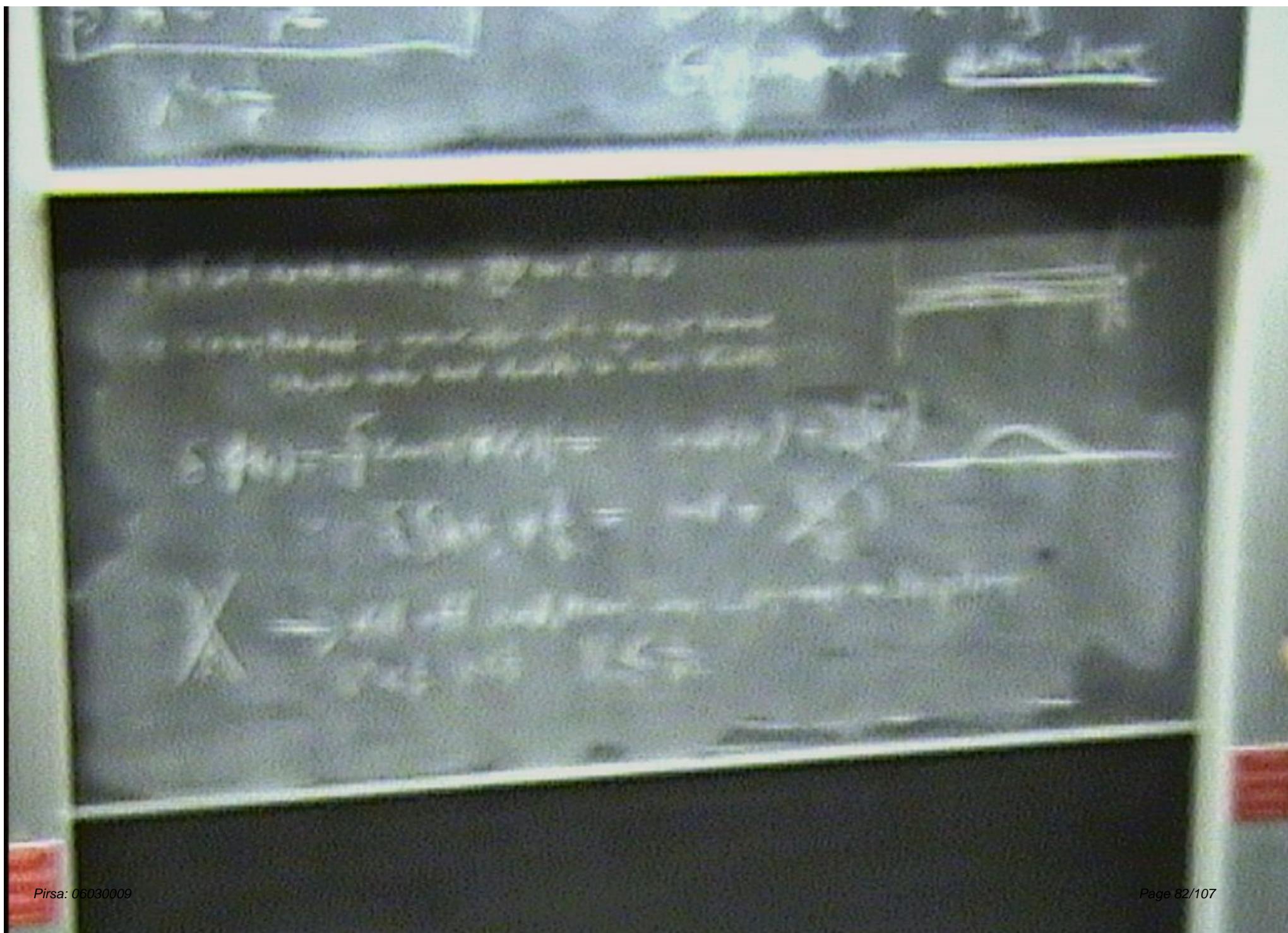
$\cancel{\lambda} \Rightarrow$  kill off constraints on Lagrange multiplier  
 $v' < \frac{1}{r}$   $\lambda < \frac{1}{r}$   $N \lesssim \frac{1}{r_2}$

Fix time coordinate  $T \rightarrow t = \infty$   
spacetime metric  $\mathcal{g}^{ij}$   $ds^2 = -dt^2 + dr^2 + r^2/d\Omega^2$

$$H = \int N C$$

Fix 3 time coordinate  $T$   $\rightarrow r \rightarrow \infty$   
spacelike  $\partial^0$ ,  $d\zeta^2 = -dt^2 + dr^2 + r^2/\Omega^2$   
 $r \rightarrow \infty \Rightarrow \frac{1}{\sqrt{r}} \propto r^{-1}$

$$H = \int N C$$



$$\begin{aligned}S(p) &= \int_{-\infty}^{\infty} \delta(p - \omega) \cdot S(\omega) d\omega \\&\rightarrow S(p) = \sum_{n=1}^{\infty} S_n(p)\end{aligned}$$

$$\frac{P^N}{\lambda} \sim \frac{r^N}{r}$$

$G(\lambda)$  converges within circles

full off conditions on  $N$  in  $C(\mathbb{R})$

a constraint = generator of a generation.  
should take local fields to local fields

$$\delta \phi(x) = -\{ \text{const}, \phi(x) \} = \text{local}(x) + \partial_\mu(\tilde{v})$$

$$= -\{ S_{\lambda} \sigma, \phi \} = \text{local} + \cancel{\partial_\mu \sigma}$$

~~$\lambda$~~   $\Rightarrow$  full off conditions on Lagrange multiplier  
 $v^* < \frac{1}{r}$   $\lambda < \frac{1}{r}$   $N \lesssim \frac{1}{r}$

Fix time coordinate  $T$   $\rightarrow r \rightarrow \infty$   
spacetime  $g^{ij}$   $ds^2 = -dt^2 + dr^2 + r^2/d\Omega^2$   
 $r \rightarrow \infty \rightarrow \frac{1}{r} \rightarrow 0$

$$H = \int N C$$

$$\boxed{A \sim \frac{1}{r^2}} \\ \lambda \sim \frac{1}{r}$$

$(D^\mu A)_\mu = 0$   
 $G(\phi)$  convergent within class

field conditions on  $N$  in  $C^\infty(\Omega)$

a constraint = generator of a gauge trans.  
 should map local fields to local fields

$$\delta \phi(x) = -\{ \text{const}, \phi(x) \} = \text{local}(x) + \partial_\alpha(V^\alpha)$$

$$-\{ S_\lambda G, \phi \} = \text{local} + \cancel{\text{local}}$$

$\cancel{\text{local}} \Rightarrow$  field conditions on Lagrange multipliers  
 $V^\alpha < \frac{1}{r} \quad \lambda < \frac{1}{r} \quad N \leq \frac{1}{r^2}$

$$\{D_a(x), D(v)\} = \mathcal{L}_v D_a(x)$$

$$S_{\partial x}^{\partial x} W^W T - \{D'(w), D'(v)\} = \int_{\Sigma} w^* J_v D_a(w)$$

$$= - \{(\varphi_v w) D_a(v) = - D'([x, w]) - D'([w, v])]$$

$$\{D'(w), G(\lambda)\} = 0$$

$$\boxed{A_i = \{A_i(x), C(N)\} = \text{INF}[E^{(i)} \cap \epsilon_{\infty} + \Lambda \epsilon_{\infty}, \epsilon^{(i)} E_r E_k^c]}$$

$$E^{(i)} = \{E, C(M)\} = D_a(N E_k E_i) \epsilon^{(i)}$$

First time constant  $T_{\text{new}} \propto 1/l^2 + d^2 + r^2 / \Omega^2$

spacetime metric  $g^{ij}$   $ds^2 = -dt^2 + dr^2 + r^2 / \Omega^2$

$r \rightarrow \infty N \rightarrow \frac{1}{r^2}, e^{-t} = 1$

$$\begin{aligned} \{D(\omega), D(\nu)\} &= \delta_{\nu} D(\omega) \\ \{D(\omega), D'(\nu)\} &= -\delta_{\nu} D'(\omega) \\ \{D(\omega), D'_r(\nu)\} &= -D'[\rho_r \omega] = -D'[\nu, \omega] \end{aligned}$$

$$\{D(\omega), G(\lambda)\} = 0$$

$$\begin{aligned} A^{\alpha} &= \{A^{\alpha}(\nu), C(N)\} = N \left[ E^{\alpha} \Gamma_{\nu}^k \epsilon_{\nu k} + \Lambda \sum_{\mu, \beta} S^{\alpha \mu \beta} E^{\mu}_r E^{\beta}_k \right] \\ E^{\alpha r} &= \{E^{\alpha}, C(N)\} = D_a(N E^{\alpha}_k) \epsilon^{k \ell} \quad \text{Angular terms} \end{aligned}$$

Fix 4-dimensional  $T^{\text{new}}{}^\infty$

spacetime metric  $g^0$   $ds^2 = -dt^2 + dr^2 + r^2/\Omega^2$

$$E^{\text{irr}} = \{E, \mathcal{E}(N)\} = \mathcal{D}_n(N E_i) \mathcal{E}$$

Fix time coordinate  $T$  now  
spacelike  $\mathcal{S}^0$   $d\sigma^2 = -dt^2 + r^2/\Omega^2$

$$r \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{dt^2/r^2}} = 1$$

$$H = \sum_N C - \int_{\partial\Sigma}$$

$$A^* = \{A(w), C(N)\} = \text{INF}^{(P)} \cap \text{INF}^{(N)}$$

$$E^* = \{E, C(N)\} = D_a(N E E^*) \in \text{INF}^{(N)}$$

First time coordinate  $T \rightarrow \infty$   
 angle  $\theta = 90^\circ$   $d\theta = -dt + d\pi \approx 1/10^2$   
 $t \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{\pi}} e^{-t}$

$$H = \int_N C - \int_{\partial S} B$$

$$A^* = \{ A^*(x), C(N) \} = IN [E^0 F_{ab} \epsilon_{ijk} + N \epsilon_{abc} \epsilon^{ijk}] \quad (7)$$

$$E^* = \{ E, C(N) \} = D_a (N E^b) \epsilon^{abc}$$

Ashwinkumar

Fix time coordinate  $T \rightarrow i\infty$   
 space-angle  $g^0$        $ds^2 = -dt^2 + dr^2 + r^2/\Omega^2$   
 $r \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{\Omega}} \approx 1$

$$H = \int_N C - \int_{\partial\Sigma} B$$

$$\int_B = \int_A^2 s_a$$

$$\int d\theta d\phi \hat{r}^2$$

$$\hat{A}^{\text{irr}} = \{A_i^*(x), C(N)\} = IN[E^a F_{ab} \epsilon_{abc} + N E_a E_b] \epsilon^{abc}$$

$$\hat{E}^{\text{irr}} = \{E, C(N)\} = D_a(N E_a E_b) \epsilon^{abc}$$

Asymptotic limits

Fix 4-dim coordinate  $T^{\mu\nu\alpha\beta}$   
 3+1-dimensional  $g^{ij}$   $ds^2 = -dt^2 + dr^2 + r^2/\Omega^2$

$r \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{r} \sin \theta} - 1$

$$H = \int_N C - \int_B$$

$$\int_B = \int_A^2 s_a N E_a^c E_c^b A_{b\kappa} \epsilon^{abc}$$

$$\int d\theta d\phi \hat{r} -$$

$$A^r = \{A^r_i(\chi), C(N)\} = IN[E^r]_{\mu}, \epsilon_{\nu k} + N \sum_{\mu \nu \ell} \epsilon_{\nu k}^{r \ell} + \dots$$

$$E^r = \{E^r, C(N)\} = D_r(N E^b_i) \epsilon^{r k \ell}$$

Abstract basis

Fix time coordinate  $T \rightarrow \infty$   
 spindirectional  $90^\circ$   $ds^2 = -dt^2 + dr^2 + r^2/\Omega^2$

$$r \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{dr/dt}}$$

$$H = \int_N C - \int_B$$

$$\int_B = \int_A s_a N E^r_a A_{b \kappa} \epsilon^{r b \kappa}$$

$$\int_A s_p \hat{p}_p \quad E^r_i(i) = \{\dot{e}_i, H\}$$

$$\boxed{\{D(\omega), G(\lambda)\} = 0}$$

$$A^N = \{A_i(x), C(N)\} = N \left[ E^{ij} \int_{\omega}^x \epsilon_{ijk} + \Lambda \epsilon_{ijk} \delta^{ij} E_r^k E_r^l \right]$$

$$E^N = \{E, C(N)\} = D_a(N E_r^b) \epsilon^{abc}$$

First time coordinate  $T$   $\text{new}^{\infty}$

spacelike  $\partial^0$   $d\sigma^2 = -dt^2 + dx^2 + dy^2/\Omega^2$

$$t \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{4\pi t}} \Omega^{-1}$$

$$H = \sum_N C - \int_{\partial\Sigma} B$$

$$\int B = \int_A s_a N E_r^b A_{bkl} \epsilon^{ljk}$$

$$\text{Slechte } \dot{E}(A) - \{\dot{e}, \|\cdot\|\}$$

$$\{D(\omega), G(\lambda)\} = 0$$

$$A^c = \{A_c(x), C(N)\} = IN \left[ E^{ij} F_{ik} \epsilon_{ijk} + A \epsilon_{ijk} \epsilon^{ijk} E_r^a E_r^c \right]$$

$$E^r = \{E, C(N)\} = D_a(N E_i^b) \epsilon^{abc}$$

Fix time coordinate  $T$  new $^\infty$   
spacetime metric  $g^0$   $ds^2 = -dt^2 + dx^i dx^i / \Omega^2$

$$r \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{r} \ln r}, \quad 1$$

$$H = \sum NC - \int_{\partial\Sigma} B$$

$$\int B = \int d^2 s_a N E_r^a A_{bck} \epsilon^{bck}$$

$$\text{Slope of } \vec{B}: \vec{E}(t) = \{\vec{E}(t)\}$$

$$\boxed{D(\lambda), \delta(\lambda) = 0}$$

$$A^* = \{A^*(\lambda), C(N)\} = IN \left[ E^b \Gamma_{\lambda}^b \epsilon_{\lambda, k} + A \epsilon_{\lambda, k} \epsilon^{bb} E^b_{\lambda} E^b_k \right]$$

$$E^* = \{E, C(N)\} = D_a(N E^b_{\lambda} E^b_k) \epsilon^{bb} \quad \text{Assume b=1}$$

Fix time coordinate  $T$  now

$$\text{spacelike } 90^\circ \quad ds^2 = -dt^2 + d\vec{r}^2 + r^2/\Omega^2$$

$$r \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{r} H(t)} \cdot 1$$

$$H = \int_N C - \int_B$$

$$\int_B = \int_A^2 s_a N E^b E^b_{\lambda} A_{b,k} \epsilon_{\lambda, k}$$

$$\int_A^2 d\mu^2 - E^b(\mu) = 1$$

$$\boxed{\{D'(n), C(N)\} = 0}$$

$$A^b = \{A^b(x), C(N)\} = N \left[ E^b \int_{\text{res}}^t \epsilon_{bR} + A \epsilon_{ab} \epsilon^{bc} E_r E_R \right]$$

$$E^b = \{E^b, C(N)\} = D_a(N E^b_r) \epsilon^{abc}$$

Finite time coordinate  $T \rightarrow \infty$

spacetime  $\mathcal{S}^0$   $dS^2 = -dt^2 + d\vec{r}^2 + r^2/\Omega^2$

$$r \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{r+1}} e^{-\frac{1}{r}}$$

$$H = \sum N C - \oint_{\partial\Sigma} B \quad H \neq 0$$

$$\oint B = \int_A S_a N E^b A_{bR} \epsilon^{cR}$$

$$\int_{\text{left}} d\vec{r} \cdot \vec{E}(t) = \{ \vec{E}, H \} = 0$$

link

Fix time coordinate  $T$   $\rightarrow \infty$   
spacetime metric  $g^0$   $ds^2 = -dt^2 + dr^2 + r^2/\Omega^2$

$$r \rightarrow \infty \Rightarrow \frac{1}{\sqrt{g_{tt} g^{rr}}} = 1$$

$$H = \sum N^c - \oint_{\partial\Sigma} B$$

$$H \neq 0 \quad H = H_{ADM} > 0$$

$$\oint B = \int d^2 S_a N^c E^b \epsilon_{bck} A_{ak} \epsilon^{ijk}$$

$$\int d\Omega^2 \quad E^a_i(\theta) = \{E_i, H\} = 10\pi$$

link

$$\frac{E^2}{r^2} \sim \frac{r^2}{\lambda^2}$$

$G(\lambda)$  converges ~~within class~~

Initial conditions on  $N$  in  $C^1(\mathbb{R})$

$\eta$  constraint = generator of a gauge trans.  
should like test fields in test fields

$$\delta \phi(x) = -\{ \text{const}, \phi(x) \} = -\text{local}(x) + \partial_\alpha(\tilde{v}^\alpha)$$

$$\{ S_\lambda \phi, \phi \} = \text{local} + \cancel{\partial_2}$$

~~$\cancel{\partial_2}$~~   $\Rightarrow$  all off constraints on Lagrange  
 $v^\alpha < \frac{1}{r}, \lambda < t, N \lesssim \frac{1}{r^2}$

Fix time coordinate  $T$  now  $\infty$   
spacelike  $\theta^0$   $d\sigma^2 = -dt^2 + dr^2 + r^2/\Omega^2$

$$r \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{r}\Omega} \approx 1$$

$$H = \sum_{\Sigma} NC - \int_{\partial\Sigma} B$$

$$H \neq 0 \quad H = H_{ADM} > 0$$

$$\int B = \int A^a S_a N E^b \epsilon_{ab} A_{bK} \epsilon^{bK}$$

$$\text{Sleutel: } \dot{E}_i(t) = \{E_i, H\} = 10\pi$$

Link

$$\Rightarrow w = \underbrace{(\omega_1 \omega)^{\frac{1}{2}}}_{E_1 - i \sum E_i} = E_{\text{tot}}^{\frac{1}{2}} \quad \text{and} \quad A_1' = A_1^{\frac{1}{2}}$$

$$\Rightarrow S^{\text{eff}} = \int F_1 F_2 \Phi^{-1} \quad \Phi_{11} = \Phi_{22} \quad \Phi_{12} = 3A$$

on columns non-jacent to detector  $\Rightarrow \int dA E_1 + D$   
 volume  $\Rightarrow S^{\text{eff}} \sim S^{\text{ext}} \sim S^{\text{ext}} \sim S^{\text{Eisenhart}}$

Hamiltonian formulation  $\{A_\mu^\alpha(x), E_\nu^\beta(y)\}_j = \delta(x,y) S_\mu^\alpha S_\nu^\beta$

$$S = \int dA \int \sum_i E_i A_\mu^\alpha - \underbrace{\lambda_i G^i}_{S \sqrt{\det g}} - V(D_\mu) - NC$$

$$G^i = \partial_\mu E^{i\mu} = 0 \quad \checkmark$$

$$D_\mu = E_\mu^\alpha F_{\alpha\beta}^\nu V$$

$$C = \epsilon^{\mu\nu\lambda} E_\mu^\alpha E_\nu^\beta (F_{\alpha\beta\lambda} + D_\lambda - \epsilon) = 0$$

$$G(\lambda) = \sum_i \lambda_i G^i$$

$$D(V) = \sum_i V^i D_i$$

$$C(N) = \sum_i N^i C_i$$

$$\hat{E}^\mu \hat{E}^\nu = \hat{g}^{\mu\nu} = (111..) t^\mu$$

$$\Rightarrow \omega = \underline{\underline{E}}_{\lambda} - \underline{\underline{E}}^{\mu} \underline{\underline{A}}_{\mu} + \underline{\underline{A}}_{\mu} \underline{\underline{E}}^{\mu} = \underline{\underline{E}}_{\lambda} - \underline{\underline{E}}^{\mu} \underline{\underline{A}}_{\mu} \Rightarrow A_{\mu} = A_{\mu}^{\text{in}}$$

$$\Rightarrow S^{(0)} = \int F_1 F^2 \Phi^{-1}$$

on solutions non-invariant  $\det Q + D \Rightarrow \det E_1 \neq 0$   
 column  $\rightarrow S^{(0)} \sim \text{States } S^{(R)} \sim S^{\text{Einstein-Hilbert}}$

ADM

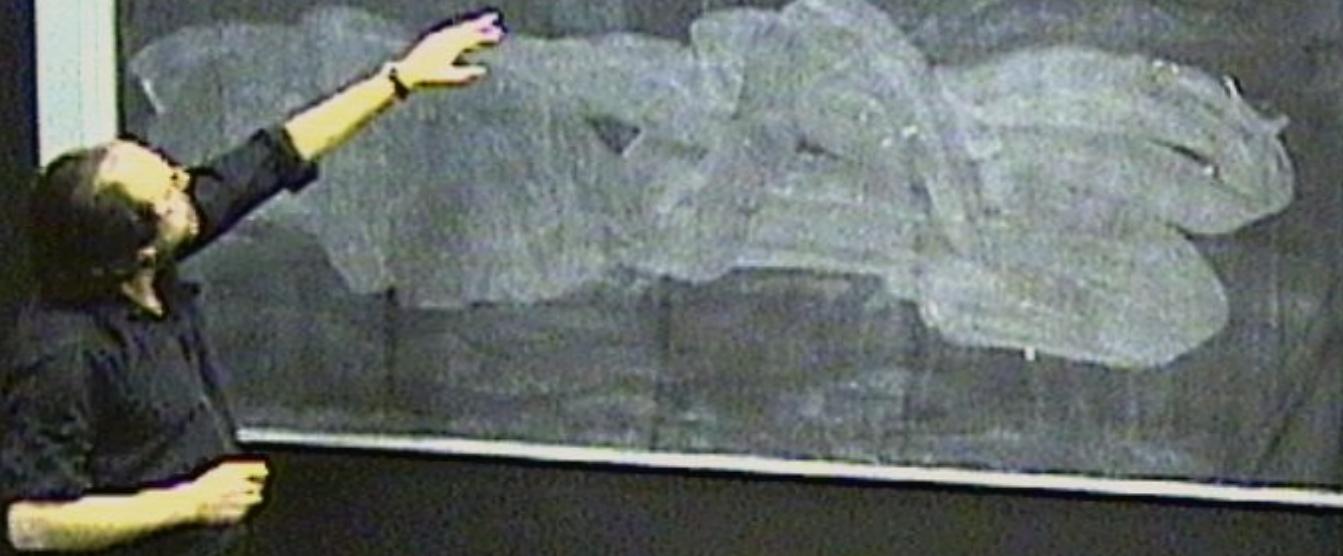
$$V^1 =$$

$$E_2 -$$

$$\rightarrow A \sim$$

$$\lambda^{\alpha}$$

$$S = \int S^{\mu}_{\nu} F^{\nu} + \dots \phi \epsilon_{12}$$



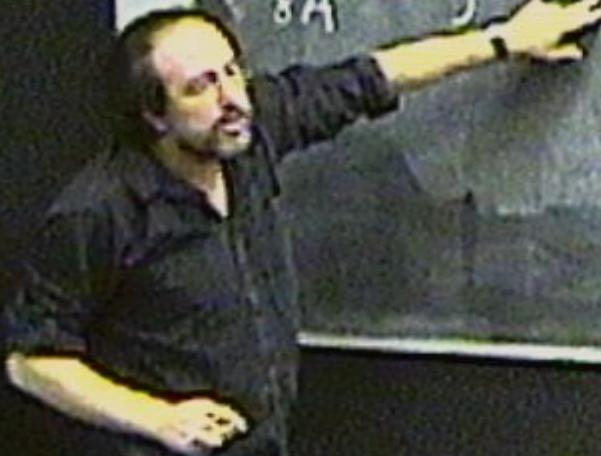
$$\Rightarrow w = \underline{E_1} - \sum_{i=1}^n E_i \xrightarrow{\text{long}} \underline{E_1} = E_1^* \Rightarrow A_1^* = A_1^{**}$$

$$\Rightarrow S^0 = \int F_1 F^2 \Phi_1 \quad \Phi_{11} = \Phi_{12}, \quad \Phi_{12} = 3\Lambda$$

on addition non-zero defect  $D \Rightarrow \int F_1 F^2 \neq 0$   
 volume  $\Rightarrow S^{0T} \sim S^{0R} \sim S^{R1} \sim S^{\text{Einstein-Hilbert}}$

$$S = \int \varepsilon_1 F_1 + \dots + \phi \varepsilon_1 \varepsilon$$

$$\frac{\delta S}{\delta A} = \int \varepsilon_1 \lambda_A \dots$$



= P(011..) L

$$S = \sum \varepsilon_1^i F^i + \dots \phi \varepsilon_1 \varepsilon$$

$$\frac{\delta S}{\delta A} = \sum_{\Sigma} \varepsilon_1^i \delta A_i + \dots$$
$$= \sum_{\partial \Sigma} \varepsilon_1^i \delta A_i - \sum_{\Sigma} d \varepsilon_1 \delta A^i, \dots$$

$$= \mu_0 I \cdot l$$

$$S = \sum_m \varepsilon^i_n F_i + \dots \phi \varepsilon_1 \varepsilon - \int \varepsilon^i_n A_i$$

$$\frac{\delta S}{\delta A} = \sum_i \varepsilon^i_n \delta A_i + \dots$$

$\xrightarrow{dM \varepsilon = 0}$

$$= \cancel{\int \varepsilon^i_n \delta A_i} - \int_{\Sigma \times R} d\varepsilon^i_n \delta A_i + \dots - \int_{\Sigma \times R} \varepsilon^i_n \delta A_i$$

Pirsa: 06030009

$$S = \sum_m \varepsilon_1^i F_i + \dots \phi \varepsilon_1 \varepsilon - \int_{\partial M} \varepsilon_n A_c$$

$$\frac{\delta S}{\delta A} = \sum_i \varepsilon_1^i \delta A_i + \dots$$

$\Rightarrow dA \varepsilon = 0$

$$= \cancel{\int_{\partial M} \varepsilon_n \delta A} - \int_{\Sigma \times R} d\varepsilon_1 \delta A^i + \dots - \int_{\Sigma \times R} \varepsilon_n \delta A^i$$

$$- \int_{\partial M} \delta \varepsilon_1 A$$

$$\varepsilon|_{\partial M} = \sum$$

Fix 4dime coordinates  $T$  now  $\infty$

spacetime metric  $g^0$   $ds^2 = -dt^2 + dr^2 + r^2/\Omega^2$

$$r \rightarrow \infty \quad N \rightarrow \frac{1}{\sqrt{r}\Omega} \approx 1$$

$$H = \sum_{\Sigma} NC - \oint_{\partial\Sigma} \bar{B}$$

$$H \neq 0 \quad \text{and} \quad \Delta DM > 0$$

$$\oint B = \int d^2 s_a N E^a F^b A_{bK} \epsilon^{aK}$$

$$\text{Sledder} \quad E^a(\lambda) = \{C^a\}$$

link