Gross

Anomaly : charm for GIM

free heterotic

string = massless free field on cylinder

interaction. introduced. 1st quantiz. surfaces

↳ but built in as topology (still orientable)

heterotic :

Right $\boxed{X^\mu, \psi}$ $\quad X, X$

Left X, ψ $\quad \boxed{D=24 = 8+16}$

$D=10.$

$$\begin{pmatrix} X_R \\ X_L \end{pmatrix} \oplus \begin{pmatrix} \psi_{80} \\ X_{16} \end{pmatrix} \to 24 \text{ dim} \Big) \text{ inherently chiral}$$

$D=10$

16 K-K Instantons

480 massless solitons

$$S = \int d^2\xi\, e \left[(e\partial X) + \tfrac{1}{2}\psi^\mu \rho \partial \psi + \tfrac{1}{2}(e\partial X)^2 + \overset{\lambda^a}{\cancel{\tfrac{1}{2}}}(\xi\rho\rho\psi)\partial X + \lambda(e\partial X)^2 \right]$$

↓

Lagr. multiplier for left mov. only

Bosons → $\underset{10}{X^\mu_{LR}}$ + $\underset{16}{X_L^{\text{internal}}}$ + $\overset{S^\alpha}{\text{fermi}}$

↳ modified canon. comm.

new constr. on σ & p

$$\frac{1}{4} M^2 = N + \tilde{N} - 1 + \tfrac{1}{2}(p^+)^2$$

$$N = \sum(\alpha\alpha + \tfrac{n}{2}\tilde{S}\gamma S) \qquad \tilde{N} = \sum(\tilde{\alpha}^i\tilde{\alpha}^i + \tilde{\alpha}^I\tilde{\alpha})$$

$$X^I \in T_{16} = \square = R/\Gamma_{16}$$

$$\text{string } S^2 \to T_{16} \to \pi_1(T_{16}) = Z_{16}$$

$$X^\pm(\tau\pm\sigma) = x^\pm + p^\pm(\sigma\pm\tau) + L^\mp\sigma + \cdots$$

$$p^\pm = \frac{1}{\sqrt{2}} \sum \frac{m_i}{R_i} e_i^I \qquad x^\pm = L^\mp\sigma \pm \sqrt{2}\sum \cdots$$

integer, even, selfdual
$\downarrow$ $\quad$ $\hookrightarrow$ interacting th.
$(p^{+})^2 = 2, 4, \ldots$

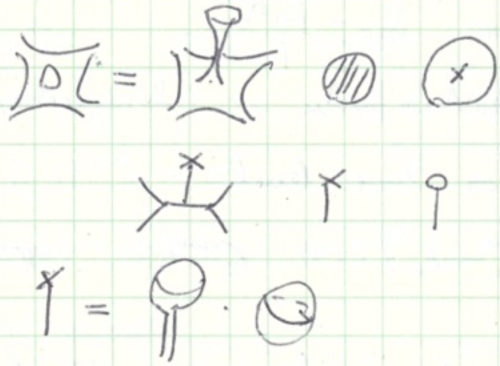
self-d: $\quad d=8, \quad 16, \quad 24$ $\quad E_8 \times E_8$

$\Gamma_8 \quad \Gamma_8 + \Gamma_8 \quad --24$

Γ_{16}

~~480~~ 480

Proof of finiteness:



Conclusions

Disc. ~~E_8~~ heterotic str $\rightarrow$ Kac-Moody sym
Type I $\quad$ not

T. Banks $\quad$ gauge inv & coord inv. (Kaku, Siegel)

$\Phi[X^{\mu}(\sigma)] \sim A_\mu(x)$

Φ
projection $\perp$ and long

$L_n = :\sum_m \alpha_m \alpha_{n-m}$

$L_{-n} \quad n>0 \quad$ gauges. $\quad \delta\phi = \sum_{\Phi} L_{-n}$

$\langle \phi | P(L_0 - 1) P | \Phi \rangle \quad L_n|\phi\rangle = 0$

Lowest: $|0, p\rangle \quad L_0 = p^2/2 + N \quad \int d^D p \; \varphi(p)\varphi(p)(p^2-1)$

next $\quad \int d^D p \; A_\mu(p)\, \alpha^\mu \Rightarrow$ transverse projection

Reproduces maxwell action.

2nd level: $L_n^\mu, \tilde{L}_n^\mu$ $\quad \alpha_n^\mu \; \tilde{\alpha}_n^\mu$

$\langle\phi|P(L_0+\tilde{L}_0-2)P|\phi\rangle$ $\qquad (L_0=\tilde{L}_0=0$ constraint$)$

First excited states $\qquad t^{\mu\nu} \sim \alpha_{-1}^\mu \tilde{\alpha}_{-1}^\nu |0,p\rangle$

$= S + A$ → gauge field action

$T^{\mu\nu} = \Pi^{\mu\nu} D(p)$ → dilaton

→ projector $\delta_{\mu\nu} - \frac{p_\mu p_\nu}{p^2}$

→ $\delta T_{\mu\nu} = p_\mu \Lambda_\nu + p_\nu \Lambda_\mu$ $\quad$ linearized gen. coord.

More gauge inv. on 2nd level

$(T_\mu(p) - \alpha_\mu - \alpha_\nu)$: $\sigma^{\mu\nu}$, $\quad \Pi\Pi - \frac{1}{d-1}\Pi\cdot\Pi$

2nd $\quad \delta T^{\mu\nu} = \frac{1}{4}\eta_{\mu\nu}\Lambda$ $\quad$ linearized Weyl

$\delta T_\mu = \partial_\mu \Lambda$

$\delta\varphi = A$

Each level has a rich gauge structure (in $D=26$)

but nonlocal effective $\mathcal{L}$.

Reproduce Siegel

~ Lorentz gauge → $L_0 - 1$

Fadden-Pop. $\sum_{m,n>0} \langle C_m L_m L_{-n} C_n\rangle$

$\sim (\partial_\mu V^\mu)^2$ $\qquad \psi_{nm} = -\psi_{mn}$

inv under $\delta|C_n\rangle = \sum L_m |\psi_{nm}\rangle + \sum_{k} C_{nmk}|\psi_{nk}$

⇒ New Ghosts. $\quad C_{mn}$ etc. ...

$\Phi[X_\mu, \theta, \hat{\theta}]$ → expansion in $\theta, \hat{\theta}(\sigma)$

E. Witten Global Grav Anomalies

$$\delta \mathcal{L}_{eff} \to \int D_\mu (\ )^\mu \neq 0$$

Global: $S^d \to G \qquad \pi_d(G) \neq 0$

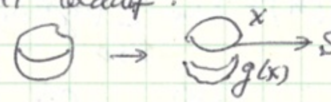
3 reps.
1. real $\quad \det \not{D} > 0$
2. pseudoreal $\quad \det$ ~~not~~ real, not definite $\to$ sgn anomaly
3. complex $\quad \det \not{D} =$ complex

even if L.A. $= 0$, may be $\exists$ G.A.

Grav. anom. $\quad D_\mu \langle T^{\mu\nu} \rangle \overset{?}{=} 0 \quad$ Local

Disconn. orient conv. diffeo $\quad S^{10}$ has 992 components

Imbed S^n in $N+1$-manif.

S^n : S^{n+1}  $S_0^n \qquad x \to g(x) S$

$S^{n+1} \to S_g^{n+1} \qquad$ If S_g homeomorph (not diffeo): exotic shere S^{n+1}
$\Leftrightarrow$ diffeo classes of S^n

Next $\quad S_g^{n+1} = \partial B$

B: $d = 12 \qquad \left.\begin{array}{l} P_1^3 = \int (\mathrm{Tr} R^2)^3 \\ P_1 P_2 = \cdot\cdot \end{array}\right)$ top inv.

$$d \, \mathrm{Tr} R^2 = 0 \not\Rightarrow \mathrm{Tr} R^2 = dH$$

But it may be so on ∂B. (sugy..)

def: $P_1^3 = \int (\mathrm{Tr} R^2)^3 - \int H (\mathrm{Tr} R^2)^2$, etc

But no analog of P_3 exists

$$\det i\not{D} = \text{integer} = \text{fn (top inv.)}$$

Milnor's work on $S^{11} \quad \to 992$

Generalization 10 dim spin man.

cylinder $Q \times I$ $I = [0,1]$

$(Q\times I)_g : (x,0) = (g(x),1)$

Consider $\mathcal{L}_{eff} = \ln \det i\not{D} + \text{counterterms}$

$h \to h^g$

$\delta\mathcal{L}_{Dirac} = \mathrm{Tr}\frac{1}{i\not{D}}\gamma^\mu \delta A_\mu$

Choose $h_{\mu\nu}^t = h_{\mu\nu}^0 + h_{\mu\nu}^1(1-t)$

$\Delta = \int_0^1 \frac{d}{dt}\mathcal{L}_{eff}(h^t)$ compute in terms of top. inv.

Atiyah-Singer : $\eta(M) = \lim_{s\to 0} \sum (\mathrm{sign}\,\lambda_i)\cdot(\lambda_i)^{-s}$ $\not{D}$ on M.

$\to \eta = \mathrm{index}(i\not{D})_B - \int \hat{A}$ $\hat{A}$: curvature polyn.

if $M = \partial B$

$\Delta \to \eta((Q\times S)_g)$

Let $\mathcal{L}_{eff} = \frac{1}{2}\ln\det i\not{D}\left(\frac{1+\bar{\Gamma}}{2}\right)$ $\Gamma = \Gamma^1 \cdots \Gamma^{10}$

$\to \frac{d\mathcal{L}_{eff}}{dt} = \cdots \frac{i}{4}\sum \frac{1}{\lambda_i}\langle\psi_i|i\not{D}'|\psi\rangle$

$i\not{D}''$: $(i\Gamma\frac{d}{dt} + i\not{D}^t)\Psi = \lambda\Psi$: adiabatic sol.

$\Psi = A(t)\psi_0^t + B\bar{\Gamma}\psi_0^t$

$u\binom{A}{B} = \lambda\binom{A}{B}$ $u = i\sigma_1\frac{d}{dt} + \mu_0(t) + \sigma_3\lambda_i$

$\mu = \langle|\bar{\Gamma}|\rangle$

$\lambda_n^\pm = \mu_0 \pm \sqrt{(2\pi n)^2 + \lambda_0^2} \to \eta_\mu = \mu_0$

$= \int_0^1 dt\,\mu_0(t)$ in general

$\eta = \int dt \sum \frac{1}{\lambda_i - \lambda_j}\langle\psi_i|\Gamma|_j\rangle\langle\psi_j|\frac{d}{dt}i\not{D}^t|i\rangle$

$\to \sum\frac{1}{2\lambda_i}\langle\frac{d}{dt}i\not{D}\rangle\Gamma$

IIB $\Delta S_{ef} = 2\pi i \sigma(B)/8$

$O(32)$, $E_8 \times E_8$: ..

Milnor : $(S^{10} \times S^1)_g = \partial B$, $P_1 = P_2 = 0$ $\sigma(B) = 8Z$

$\rightarrow$ $\Delta S_{eff} = 0 \mod 2\pi i$ $\rightarrow$ $e^{i S_{eff}}$ = single valued.

String th

i) one-par fam of metrics on Σ (mod. transf)

ii) " mapp $\Sigma \rightarrow$.

$\Sigma \times S^1 \rightarrow Q$ (sp-time)

P_1 (

Case of torsion :

Schrieffer — Frac charge & topol ~~…~~ kinks

1. Dyn. sym br. in coupled ~~in~~ ferm–bos sys in 1+1

Piers Thm

2. Stable exc. are top. kinks

3. sharp frac. ch.

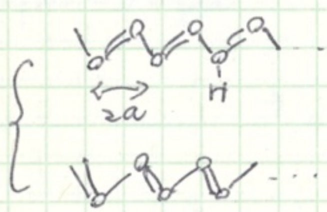
4. frac. q. Hall eff.

5. $^3He_3$ in A.

c_n spin fermion

u_n boson boson.

Peierls instab. $\langle u_n \rangle \neq 0$



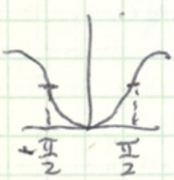
π-electrons

Su, Heeger, .. kinks width ~ 14a

mass ~ 6 me

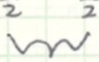
$\phi_n \equiv (-1)^n u_n$ staggered field

⇒ Bloch states.

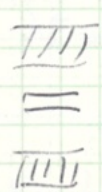


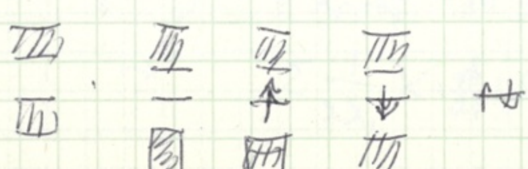
$$H_{cont} = \int v_F \psi \sigma_3 i \frac{\partial}{\partial t} \psi + g \psi_s^{+} \tau_1 \phi \psi$$

(Jackiw & Rebbi)

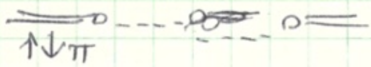


~ spin ½ fermion

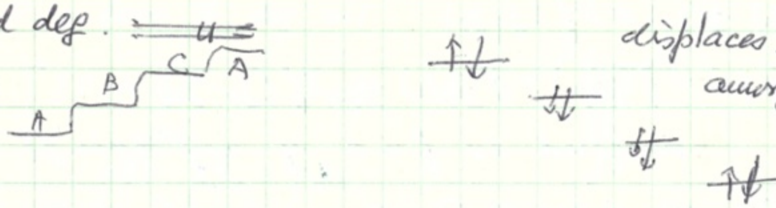




TTF-TCNQ at 18 kbars ~~3~~ 2 el/3 atoms



3 fold deg.

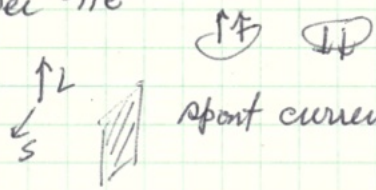


displaces 2 electrons among 3 kinks

Sharpness? Bell-~~Fath~~ Rajaraman : $\delta Q^2 = 0$ $(L \to \infty)$
Jackiw

Q. Hall: heterojunction

Super ^3He



spont current.

Zumino Coho & anomalies

Simplicial homoge. group coho.

$g_0, \cdots g_n \in G, \to f(g_i)$ cochain

$\delta f(g_0) = f(g_1) - f(g_0) \equiv \delta f(g_0 g_1)$

$\delta f(g_0 g_1) = f(g_1 g_2) - f(g_0 g_2) + f(g_0 g_1) \equiv \delta f(g_0 \cdots g_2)$

$\delta^2 = 0.$ normalized so $f = 0$ if any pair $g_i = 0$

f may be in the rep space of G.

$f(A; g_0, \cdots g_n)$ $A \to A_g$ rep space.

$\Rightarrow$ inv: $g_f \equiv f(A_g, g^{-1} g_0, \cdots) = f(A, g_0, \cdots)$: $\delta(g_f) = g(\delta f)$

inhomo gr coho.

$g_0 = \gamma_0 \quad g_1 = \gamma_0 \gamma_1, \cdots \quad g_n = \gamma_0 \cdots \gamma_n$

$f(A, g_i) = \tilde{f}(A; \gamma_i)$

Let f be inv.

Def: $\varphi(A; \gamma_i) \equiv \tilde{f}(A; 1, \gamma_1, \cdots \gamma_n)$: inhomo cocye.

$\delta\varphi(A) \equiv \varphi(A\gamma) - \varphi(A) \equiv (\delta\varphi)(A; \gamma)$ etc.

$\delta^2 = 0$ $\delta\varphi(A; \gamma_1) = \varphi(A\gamma_1, \gamma_2) - \varphi(A; \gamma_1\gamma_2) + \varphi(A; \gamma_1)$

$\equiv (\delta\varphi)(A; \gamma_1, \gamma_2)$

(Faddeev cocycl.)

$\to$ proj. rep. of G (Bargmann & Wigner)

$U(A; \gamma)$

$U(A; \gamma_1\gamma_2) = U(A; \gamma_1)\, U(A\gamma_1; \gamma_2) \times e^{-i\varphi(A; \gamma_1, \gamma_2)}$

Associativity : cond. $U(A; \gamma_1(\gamma_2\gamma_3)) = U(A; (\gamma_1\gamma_2)\gamma_3)$

$\Rightarrow \delta\varphi = 0$ (Frobenius)

$\Rightarrow$ anomalous Schwinger terms in Lie alg.

Lie alg.: diff forms in group sp.

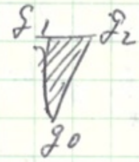
δ ext. diff $v = g^{-1}\delta g$

$\delta v = -v^2$

Let $A_g = Ag \Rightarrow \delta A_g = A\,\delta g = A_g v$

$$\begin{cases} \delta v = -v^2 \\ \delta A_g = A_g v \end{cases} \quad \text{BRST}$$

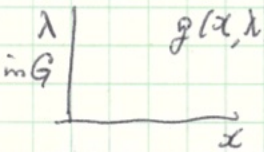
Let P a form of deg n-1

$0 = \int_{V_n} \delta P = \int_{\partial V_n} P$ exp. $V_2 =$ 

$\int_{\partial V_2} = \int_{g_0}^{g_1} + \int_{g_1}^{g_2} + \int_{g_2}^{g_0} =$ (non. cocycl.)

If $\delta P = 0 \rightarrow$ for small path change, $\delta \int = 0$

Gauge gr. case.



$d = dx^\mu \frac{\partial}{\partial x^\mu}$

$\delta = d\lambda^i \frac{\partial}{\partial \lambda^i}$

$A = A_\mu(x)\, dx^\mu$

$A_g \equiv g^{-1} A g + g^{-1} dg$

Local coho.
(not well defined)

$v = g^{-1} \delta g$

Find $P(v, A_g)$: $\delta P = 0$ (polyn.)

descent eqs

$F = dA + A^2$; $F_g = dA_g + A_g^2 = g^{-1} F g$

$\omega_{g\,n-1} = n \int dt\, P(A_g, F_t, \cdots)$, $P = d\omega_{2n-1}$ $\delta P = 0$

$\delta \omega_{2n-1} = -d\omega^1_{2n-2}$,

$\delta \omega^1_{2n-2} = -d\omega^2_{2n-3}$: .. Anom. sequence

$\delta \omega_0^{2n-1} = 0$ (Russian formula)

Integrating over $X \rightarrow \int_X \omega^K_{2n-1-K} = \alpha_K$ $\delta \alpha_K = 0$ closed.

integ over λ $\int$ $\rightarrow$ Schwinger form.

Recent develop — . 1. improve & streamline
2. minimal form of the ω
3. backgr field.

generat~~ion~~or of gauge-transf.

$$\tilde{G}^a = \partial_i E^{ia} + f^{abc} A E$$

$$G^a = \tilde{G}^a - \bar{\psi}\gamma^0 t^a \psi$$

Calc. ETCom. by BJL limit

$$[G^a(x), G^b(y)] = i f^{abc} G^c(x)\, \delta^3(x-y)$$
$$+ \frac{i}{12\pi^2} d^{abe}\, \varepsilon_{ijk}\, \partial_j A_i^e\, \partial_k \delta^3(x-y)$$

$G^a \Psi = 0$ not consistent. (obstruction to quantization)

Kobayashi + Sugawara

$$G = \tilde{G} - \bar{\psi}\gamma^0 t^a \psi \quad \rightarrow \quad G^a \Psi = 0$$

Susy anomaly. (rigid)

$A, \lambda, D.$

perturb. cal. Nielsen; Guadagnini, Konishi, Mintchev

coho. Piguet Sibold

Sonora et al

Ciccardi et al

Anomalies in SUGY

Einstein

Local Lorentz $\updownarrow$ $\rightarrow$ when this happens $\xrightarrow{(?)}$ no susy anom. too

Local SUSY

Baulieu

~~M. Bowick~~ ~~Susp lat chiglet~~

Brink Uniquess of Susp action

Functional basis $\leftrightarrow$ oscillator basis

2. Field th in light cone gauge & light cone frame.

$x^+, p^- = H, \quad A^+ = 0 \to$ solve for A^-

$A^\pm$ (transv.) — dynamical

$L \simeq \frac{1}{2} \bar{A}^a \Box A^a + g'' A'' + g^I A$

nonlinear ~~R~~. Poincaré : $J^{+-}, J^{i-}, P^- = H$

Susy $\quad \phi(x^\mu, \theta^m, \bar{\theta}_m) \qquad Q \to \begin{array}{l} Q_+ \text{ linear} \\ Q_- \text{ nonl.} \end{array}$

$\{Q_-, Q_-^+\} \to H$

$d=10 \quad$ SuYM $\quad \phi(x, \theta_A)$

$\hookrightarrow$ ~~8~~ $\bar{4}$ under $SU(4) \times SO(10)$

$\mathrm{II}\overset{D}{\underset{a}{\phi}}$ SUGY $\quad \psi(x^\mu, \theta^A)$

$\hookrightarrow 8_s$ of $SO(8)$

$\mathrm{II}b \quad$ str. $\Psi[x^\mu(\sigma), \theta(\sigma)]$

$\to \mathcal{L} = \Psi \Box \bar{\Psi} + W \text{"}\delta^2 \Psi^3\text{"}$

3. Kinetic counterterms

$\mathcal{L} = \bar{\phi} \Box \phi + \frac{\alpha}{2} \bar{\phi} \Box^2 \phi \quad ?$

Unique if local terms only

$\alpha = 0 \to \quad \pi \sim \partial\phi \quad$ primary constraint

$\alpha \neq 0 \to$ first order form.

$$\to \mathcal{L} = \frac{1}{2}\Big(\bar{\psi}_1 \Box \psi_1 - \underbrace{\psi_2 \Box \bar{\psi}_2 - \frac{1}{\alpha^2} \bar{\psi}_{\mathrm{I}} \psi_{\mathrm{I}}}_{\text{ghost}}\Big)$$

Check Poincaré inv.

II b SWGY with counter term : OK too. ~~SU~~

Sust. II b $\Sigma = (x^+ x^-, x^i(\sigma), \theta^a(\sigma))$

~~For~~ $\delta^i = \delta/\delta x^i$, $d^a = \delta/\delta\theta^a(\sigma)$

$$P^- = h = \frac{i}{\partial_-}\int d\sigma \{ \delta^i\delta^i + x'^i x'^i + \cdots)$$ good only for $d=10$.

Q: In general, add counter terms?

$$q_{1\,new}^{-\dot a} = M\tilde\theta^{\dot a} + F^{\dot a}(\hat\theta, \tilde d)$$
$$q_{2\,new} = -\frac{M}{\partial_-}\tilde d^{\dot a} - \frac{1}{\partial_-}G^{\dot a}(\hat\theta, \tilde d)$$

Close the alg on V_3 Higher V's not allowed.

Q. Can change the str dim from 10 (26) to any by similar way

Gervais: yes.

J. Harvey Heterotic str.

1. Fermionic formulation
2. Interactions

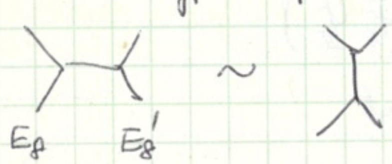
2 fermions for each ~~dege di~~ boson

1. 16 bosons $\to \psi^I$ $I=1,2,\cdots$ $O(32)$

$\psi^I, \bar\psi^I$ $O_8 \times O_8$

2. Viraso ~~$\Gamma(\ldots - 1 - \frac{s}{\ldots}$~~

Shapiro-type ampl.



Siegel. cov. formul.

Sometimes cov. gauge better than light cone.

Anomaly in string: open st → closed → cov. dev. ??

BRST: for str.

1). Free G_i → free Q_0 – $L_0 = \frac{1}{2}\Phi K_0 \Phi$, $[Q_0, K] = 0$

(2) $Q = Q_0 + gQ_1 + \cdots$ $Q^2 = 0 \to Q_0^2 = 0, \{Q_0, Q_1] = 0 \ldots$

$\to Q_1 \Rightarrow L_1$ (Vertex op.)

Bosonic str. $\hat{P}(\sigma) = \frac{1}{\sqrt{2}}\left(i\frac{\delta}{\delta X} \pm X'(\sigma)\right)$ $\tilde{C} = \frac{1}{\sqrt{2}}\left(C \pm \frac{1}{\delta \bar{C}}\right)$

$G(\sigma) = \frac{1}{2}\hat{P}^2 \to Q_0 = \hat{C}\left(\frac{1}{2}\hat{P}^2 + i\tilde{C}\frac{\delta}{\delta \tilde{C}}\right)$ on $\Phi[X, C, \bar{C})$

$K = [\mathcal{O}, Q\} \to [Q, K\} = 0$

where open: $\mathcal{O} = i\frac{\partial}{\partial c} \to K_0 = cH \frac{\partial}{\partial c}\hat{H}$.

closed $\mathcal{O} = \tilde{c}\frac{1}{2}[c\frac{\partial}{\delta c}] \to K_0 = \tilde{c}(cH - \frac{\partial}{\partial c}\tilde{H}) - \frac{1}{2}[\frac{\partial}{\partial \sigma}](N_L - N_R)$

$H = \left(\frac{1}{2}\hat{P}^2 + i\tilde{C}\frac{\delta}{\delta \tilde{C}}\right)$ $c = \int C d\sigma$, $\bar{c} = \int d\sigma \bar{C}$

⇒

1. Stueckelberg form of massive vectors
2. Faddeev-Popov
3. Not all modes (physical) appear at $C \neq \tilde{C} = 0$.
4. What is gauge inv?

$\delta\Phi \sim \int X' \frac{\delta}{\delta X}\Lambda_r[X]$

Susy. propertime τ for particles $X(\tau)$, $\theta(\tau)$

$\delta\theta = \epsilon$ $\delta x = i\epsilon\gamma\theta$

$$L = \dot{Z}e^A{}_M(z)p_A + \dot{y}\cdot f_i(p) = (\dot{x} + i\dot{\theta}\gamma\theta)p + [g p^2 + \psi p \pi]$$

(g, ψ) = gauge fields f Lag. multipl.

(p, π) = conj. momenta

BRST generators $G_i = p^2, p\pi$, $\{\pi, \pi\} = -2p$, $Q = cp^2 - c p \pi + (c p c)\frac{\partial}{\partial c}$

Conformal sym + susy algebra:

$D_\alpha = \frac{\delta}{\delta\theta^\alpha} + \gamma p \theta + \frac{1}{2}\gamma\gamma^{\eta}\theta\theta\theta$ γ = 3-indices

$P = p + i\gamma_\theta \theta \theta$

$\Omega = \theta$

M. Kaku Cov. quantiz.

1st quant. → interaction by hand

2nd " → ~~non~~ no double count.

how to incorporate Virasoro.

$$\mathcal{L}_0 = i\Phi^\dagger\dot{\Phi} - \Phi^\dagger(L_0-1)\Phi \qquad L_0: \text{transverse modes only}$$

~~But~~ Instead: $\quad \sum c_n L_n \Phi(x)$

$$\cancel{\rightarrow \mathbb{H} L_n^{-p} = E}$$

$$G(x_1 x_2) = \int \mathcal{D}x\, e^{i\int\sqrt{\ }\, d\tau d\sigma} = \int \mathcal{D}\Phi\, e^{i\int \Phi^\dagger \mathbb{H}\Phi}\, \Phi(x_1)\Phi(x_2)\, \tilde{\Delta}$$

$$\left(F_{\mu\nu} \sim A_\mu \underset{\text{proj.}}{P_{\mu\nu}} A_\nu\right)$$

$$\therefore = \int \mathcal{D}x\mathcal{D}p\mathcal{D}\lambda\mathcal{D}\mu\, e^{i\int d\sigma d\tau (p\dot{x} + \lambda(p^2+x'^2) + \mu p\cdot x)}$$

$$\text{||||||} : \quad e^{ip\dot{x}\Delta\tau} \Rightarrow e^{ip_i(x_i - x_{i+1})} \rightarrow \langle x_i p_i\rangle\langle\ 1\ \rangle \cdots$$

$$\Rightarrow \langle x|p\rangle\, \underset{\substack{\downarrow \\ \delta.\ \text{fns}}}{e^{i\int \lambda(\ ) + \mu(\ )}}\, \mathcal{D}p_i \mathcal{D}p_i$$

$$\Phi(x): \quad |x\rangle \equiv \prod_n |x_n\rangle = \exp(\cdots)|0\rangle$$

$$\delta\langle\phi|x\rangle = \epsilon_n \int(-\partial_x{}^2 + x^2 + 2ix'\partial_x)\, e^{in\sigma} d\tau\ \langle p|x\rangle$$

$$\rightarrow \quad \delta\phi = \epsilon_n L_n(\partial x, x)\phi(x)$$

$$\mathcal{L} \sim p\dot{q} + \lambda_n C_n \qquad \delta\lambda_n = \dot{\epsilon} + f_{nmp}\lambda_m\epsilon_m$$

$$\delta\lambda = \dot{\epsilon} - q' \quad \delta p = \dot{q} + \epsilon' \qquad \text{ghosts}$$

<u>gauge broken, Lorentz inv.</u> action ~~is~~ obtained.

$\mathbb{H}|\langle x|y\rangle$ postulate as

$$\mathcal{L} \sim -\tfrac{1}{4}F_{\mu\nu}{}^2 + \rightarrow \text{gravity linearized}$$

Brower-Thorn off shell version

Sustr. susy constraints = 8 1st class & 8 second class.

$\bar{\theta}\theta = 0 \overset{but}{\Rightarrow} \bar{\theta}\gamma^\mu\theta \neq 0$

Cov. case change to $\theta \not{\pi} \theta$

ky $P_a = 1 + \cancel{\pi\not{\pi}}/2\pi_+ \cdot \pi_-$

Also Hori & Kimura

M. Bowick High T

$$\rho(n) = n^{-a} \exp(bm)$$

Typ. I $a = 9/2$ $b = \pi\sqrt{8}\sqrt{\alpha'}$

Typ II $a = 10$ $b = \pi\sqrt{8}\sqrt{\alpha'}$

Het. $a = 10$ $b = (2+\sqrt{2})\,\pi\sqrt{\alpha'}$

$$\cancel{B}.\ \ln Z \to \left(\frac{TT_0}{(T_0 - T)}\right)^{1/2-a} \Gamma\left(\frac{y}{2} - a, \frac{8(T_0-T)}{T \times T_0}\right)$$

Typ I Typ II, het.

$p, C_V, \mathcal{E} \to \infty$ as $T \to T_0$ $p, \cancel{\phi}\, \mathcal{E} < \infty$, C_V

Fluctuations : large for hetero. too (Frautchi / Carlitz)

$$S \sim a \ln E_s + bE_s$$

$$T = E_s/(bE_s - a)$$

$T > T_c$? equil bet massive & massless ?

$$bT_{min} = \frac{20bE - 9a \pm \sqrt{81a^2 + 40abE}}{20(bE - a)}$$

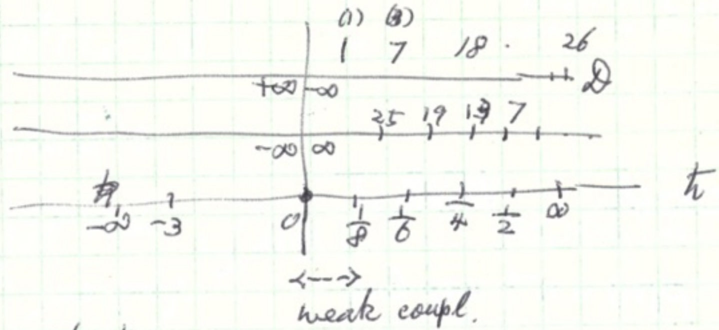
$$\to E_p < F - \frac{aT_{max}}{bT_{max} - 1} \qquad \underline{V\phi < E_n}$$

<u>Gervais</u>

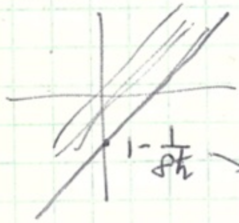
Liouville $S = \frac{1}{16\pi\hbar}\int\left[\frac{\dot{\varphi}_\tau^{\,2}}{2} - \frac{\varphi_\sigma^{\,2}}{2} - e^{\varphi}\right] d\tau\, d\sigma$

$\hbar$ param. L_n; $C = 1 + 3/\hbar$

$x_0 \Rightarrow$ ghost



$\hbar = \frac{N}{2(N+1)^2}$



no tachyons.

$1 - \frac{1}{8\hbar} \to$ zero Liouville state.

Locality OK for

25, 19, 13, 7, 1, 0

3, 5, 7

Strong coup $D = 7, \cancel{13}\, 13, 19$

$\downarrow$ Liouville on goes down