

Title: Lecture 2: SW solution of gauge theory with matter

Date: Feb 23, 2010 11:15 AM

URL: <http://pirsa.org/10020074>

Abstract:

$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{ij}^A P_{ij}$$

$$Q^A \quad A=1,2, \quad \bar{Q}^A$$

$$M > 0$$

$$\{Q, \bar{Q}\} = \gamma$$

$$\{Q, Q\} = 0$$

$$\{\bar{Q}, \bar{Q}\} = 0$$

$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{ij}^A P_{ij}$$

$$\{Q, Q\} = 0$$

$$\{\bar{Q}, \bar{Q}\} = 0$$

$$Q^A \quad A=1,2, \quad \bar{Q}_i^A$$

$$M > 0$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$\{Q^\Lambda, \bar{Q}^{\dot{\Lambda}}\} = \epsilon^{\Lambda\dot{\Lambda}} \gamma_{\mu}^{\Lambda\dot{\Lambda}} P_\mu$$

$$Q^\Lambda_{\lambda=1,2}, \bar{Q}_{\dot{\lambda}}^{\dot{\Lambda}}$$

$$M > 0$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$\{Q, Q\} = 0$$

$$\{\bar{Q}, \bar{Q}\} = 0$$

$$(j) \otimes \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)^2$$

$$\{Q^\Lambda, \bar{Q}^{\dot{\Lambda}}\} = \epsilon^{\Lambda\dot{\Lambda}} \gamma_{\mu}^{\Lambda\dot{\Lambda}} P_\mu$$

$$Q^\Lambda_{\quad \Lambda=1,2}, \bar{Q}_{\dot{\Lambda}}$$

$$M > 0$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$\{Q, Q\} = 0$$

$$\{Q, \bar{Q}\} = 0$$

$$(j) \otimes \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)^2$$

$$\{Q^\Lambda, \bar{Q}^{\dot{\Lambda}}\} = \epsilon^{\Lambda\dot{\Lambda}} \gamma_{\mu}^{\Lambda\dot{\Lambda}} P_\mu$$

$$\{Q, Q\} = 0$$

$$\{\bar{Q}, \bar{Q}\} = 0$$

$$Q^\Lambda_{\quad \mu}, \bar{Q}^{\dot{\Lambda}}_{\quad \dot{\mu}}$$

$$M > 0$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$(j) \otimes \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)^2$$

$$M = 0$$

$$\{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{ij}^A P_{ij}$$

$$\{Q, Q\} = 0$$

$$\{\bar{Q}, \bar{Q}\} = 0$$

$$Q^A \quad A=1,2, \quad \bar{Q}_i^A$$

$$M > 0$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$(j) \otimes \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)^2$$

$$M = 0$$

$$\{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$(j) \otimes \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)$$

$$j=0 \quad z(0) + \left(\frac{1}{2}\right)$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \overline{\mathbb{R}})$$

$$j=\frac{1}{2} \quad (1) + 2\left(\frac{1}{2}\right) + (0)$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \overline{\mathbb{R}})$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2 \left(\frac{1}{2}\right) + \begin{matrix} (0) \\ 0 \end{matrix}$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \overline{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2 \begin{matrix} \left(\frac{1}{2}\right) \\ \\ 0 \end{matrix} + \begin{matrix} (0) \\ \\ 0 \end{matrix} \quad A_n, \Phi$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \overline{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j = \frac{1}{2} \quad \begin{pmatrix} 1 \\ \pm 1 \\ 0 \end{pmatrix} + 2 \begin{pmatrix} 1 \\ \frac{1}{2} \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \end{pmatrix} \quad A_n, \Phi$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2 \begin{matrix} (\frac{1}{2}) \\ 0 \end{matrix} + (0) \quad A_n, \Phi$$

$$\begin{aligned} & \left(\mathbb{D}_n \Phi \right)^2 + \left[\Phi, \Phi^\dagger \right]^2 + |\mathbb{D}q|^2 + |\mathbb{D}\tilde{q}|^2 + |\Phi q|^2 \\ & \quad + |\overline{\Phi \tilde{q}}|^2 + \dots \end{aligned}$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2 \begin{matrix} (\frac{1}{2}) \\ 0 \end{matrix} + (0) \quad A_n, \Phi$$

$$F_{nv}^2 + (\mathbb{D}_n \Phi)^2 + [\Phi, \Phi^\dagger]^2 + |\mathbb{D}q|^2 + |\mathbb{D}\tilde{q}|^2 + |\Phi q|^2 + |\overline{\Phi \tilde{q}}|^2 + \dots$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2 \begin{matrix} \left(\frac{1}{2}\right) \\ 0 \end{matrix} + (0) \quad A_n, \Phi$$

$$F_{nv}^2 + (D_n \Phi)^2 + [\Phi, \Phi^\dagger]^2 + |Dq|^2 + |D\tilde{q}|^2 + |\Phi q|^2 + |\bar{\Phi} \tilde{q}|^2 + \dots$$

COULOMB BRANCH $\Phi = \begin{pmatrix} a_1 \\ a_2 \\ \dots \end{pmatrix}$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2 \begin{matrix} \left(\frac{1}{2}\right) \\ 0 \end{matrix} + (0) \quad A_n, \Phi$$

$$F_{nv}^2 + (\mathbb{D}_n \Phi)^2 + [\Phi, \Phi^r]^2 + |\mathbb{D}q|^2 + |\mathbb{D}\tilde{q}|^2 + |\Phi q|^2 + |\bar{\Phi}\tilde{q}|^2 + \dots$$

COULOMB BRANCH $\Phi = (a, a, a, \dots)$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2 \begin{matrix} (\frac{1}{2}) \\ 0 \end{matrix} + (0) \quad A_n, \Phi$$

$$F_{nv}^2 + (D_n \Phi)^2 + [\Phi, \Phi^\dagger]^2 + |Dq|^2 + |D\tilde{q}|^2 + |\Phi q|^2$$

COULOMB BRANCH $\Phi = (a, a, \dots)$ + $|\bar{\Phi} \tilde{q}|^2 + \dots$

$U(1)^2$ ABELIAN GAUGE THEORY

$$\{Q^\lambda, \bar{Q}^{\lambda'}\} = \epsilon^{\lambda\lambda'} \gamma_{\mu}^{\lambda} P_\mu$$

$$\{Q, Q\} = 0$$

$$\{Q, \bar{Q}\} = 0$$

$$Q^\lambda \quad \lambda=1,2 \quad \bar{Q}^{\lambda'}$$

$$M > 0$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$M = 0$$

$$(j) \otimes \left(2 \binom{1}{0} + \left(\frac{1}{2}\right) \right)^{\otimes 2}$$

$$(j) \otimes \left(2 \binom{0}{0} + \left(\frac{1}{2}\right) \right)$$

$$\{Q^\Lambda, \bar{Q}^{\dot{\Lambda}}\} = \epsilon^{\Lambda\dot{\Lambda}} \gamma_{\mu}^{\Lambda\dot{\Lambda}} P_\mu$$

$$Q^\Lambda_{\lambda=1,2}, \bar{Q}^{\dot{\Lambda}}_{\dot{\lambda}}$$

$$M > 0$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$M = 0$$

$$\{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, Q\} = \text{GAUGE TRANSF. PARAMETER } \phi$$

$$\{\bar{Q}, \bar{Q}\} = 0$$

$$(j) \otimes \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)^2$$

$$(j) \otimes \left(2(0) + \left(\frac{1}{2} \right) \right)$$

$$\{Q^\lambda, \bar{Q}^{\lambda'}\} = \epsilon^{\lambda\lambda'} \gamma_{\lambda\lambda'}^\mu P_\mu$$

$$Q^\lambda_{\lambda=1,2}, \bar{Q}^{\lambda'}$$

$$M > 0 \quad \{Q, \bar{Q}\} = \gamma^0 M$$

$$M = 0 \quad \{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, Q\} = Z = q_0 \cdot a$$

$$\{Q, \bar{Q}\} =$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2}\right) \right)^2$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2}\right) \right)$$

$$\{Q^\lambda, \bar{Q}^{\lambda'}\} = \epsilon^{\lambda\lambda'} \gamma_{\lambda\lambda'}^\mu P_\mu$$

$$Q^\lambda \quad \lambda=1,2, \quad \bar{Q}^{\lambda'}$$

$$M > 0 \quad \{Q, \bar{Q}\} = \gamma^0 M$$

$$M = 0 \quad \{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, Q\} = Z = q_e \cdot a$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$(j) \otimes \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)^2$$

$$(j) \otimes \left(2(0) + \left(\frac{1}{2} \right) \right)$$

$$\{Q^\Lambda, \bar{Q}^{\Lambda'}\} = \epsilon^{\Lambda\Lambda'} \gamma_{\mu}^{\Lambda} P_{\mu}$$

$$Q^{\Lambda} \quad \Lambda=1,2, \quad \bar{Q}^{\Lambda'}$$

$$M > 0$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$M = 0$$

$$\{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, Q\} = Z = q_e \cdot a$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$(j) \otimes \left(2 \binom{1}{0} + \left(\frac{1}{2}\right) \right)^2$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2}\right) \right)$$

$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{\mu}^{\alpha\beta} P_{\mu}$$

$$Q^A, \bar{Q}^A, \quad A=1,2$$

$$M > |Z| \quad \{Q, \bar{Q}\} = M$$

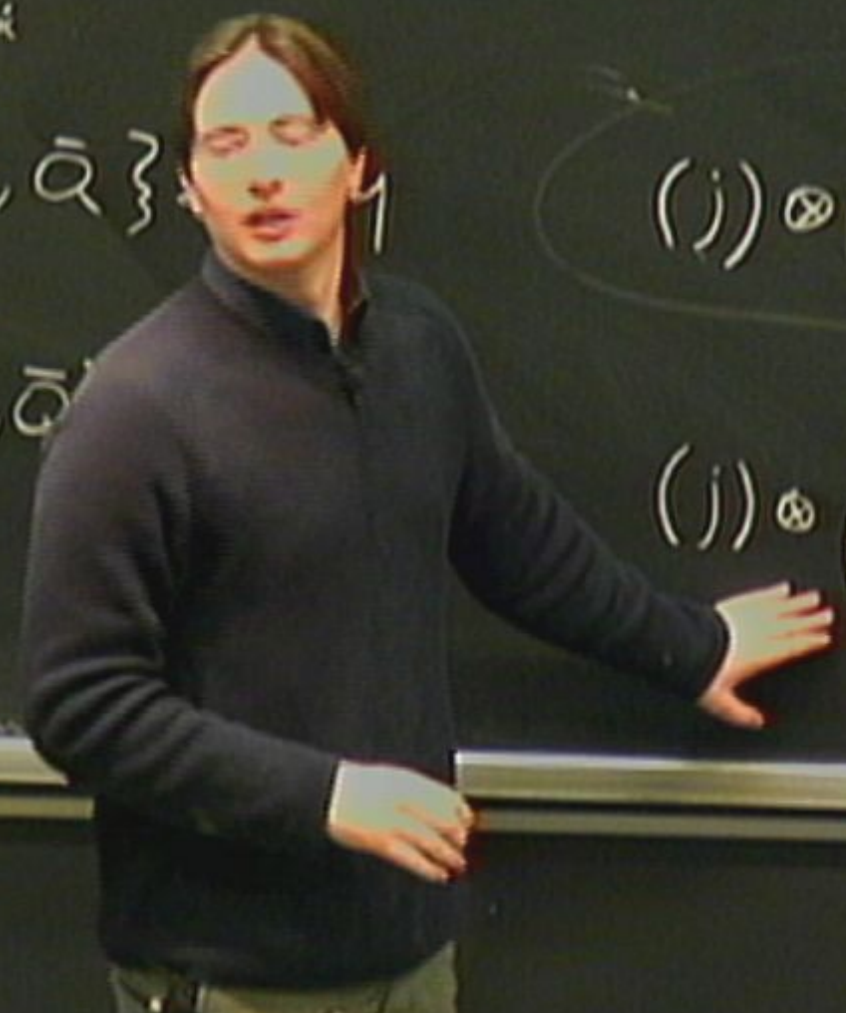
$$M = |Z| \quad \{Q, \bar{Q}\} = M$$

$$\{Q, Q\} = Z = q_e \cdot a$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)^{\otimes 2}$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)$$



$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{i,j}^A P_i$$

$$Q^A_{\lambda=1,2}, \bar{Q}^A_i$$

$$M > |Z| \quad \{Q, \bar{Q}\} = \gamma^0 M$$

$$M = |Z| \quad \{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, Q\} = Z = q_i \cdot a_i$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$(j) \otimes (2)$$

$$(j) \otimes (2)$$

$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{\alpha\beta} P_{\alpha}$$

$$Q^A, \bar{Q}^A, \quad A=1,2$$

$$M > |Z| \quad \{Q, \bar{Q}\} = \gamma^0 M$$

$$M = |Z| \quad \{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, Q\} = Z = q e \cdot a$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right)^{\otimes 2} \right)$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2 \begin{matrix} (\frac{1}{2}) \\ 0 \end{matrix} + (0) \quad A_n, \Phi$$

$$F_{nv}^2 + (D_n \Phi)^2 + [\Phi, \Phi^\dagger]^2 + |Dq|^2 + |D\tilde{q}|^2 + |\Phi q|^2$$

COULOMB BRANCH $\Phi = (a_1, a_2, \dots)$ + $|\Phi \tilde{q}|^2 + \dots$

$U(1)^2$ ABELIAN GAUGE THEORY

$$F_{ij} = \epsilon_{ijk} \mathcal{D}_k \phi$$

$$\in^{AB} \gamma_{\mu}^{\nu} P_{\mu}$$

$$\{Q, Q\} = Z = q_e \cdot a + q_m \cdot a_D$$

$$\{\bar{Q}, \bar{Q}\} = \bar{Z}$$

$$a_D = \tau a$$

$$\{\bar{Q}\} = \dots$$

$$(j) \otimes \left(2 \binom{0}{1} + \binom{1}{2} \right)^{\otimes 2}$$

$$\exists (\gamma^0, \gamma^1) \in$$

$$(j) \otimes \left(2 \binom{0}{1} + \binom{1}{2} \right)$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2\left(\frac{1}{2}\right) + (0) \quad A_n, \Phi$$

$$\frac{1}{2} \left(F_{\mu\nu}^2 + (D_\mu \Phi)^2 + [\Phi, \Phi^\dagger]^2 \right) + |D_\mu q|^2 + |D_\mu \tilde{q}|^2 + |\Phi q|^2 + |\Phi \tilde{q}|^2 + \dots$$

COULOMB BRANCH $\Phi = (a, a, a, \dots)$

$U(1)^2$ ABELIAN GAUGE THEORY

$$\{Q, Q\} = Z = q_e \cdot a + q_m \cdot a_D$$

$$\{\bar{Q}, \bar{Q}\} = \bar{Z}$$

$$a_D = \gamma a \quad \gamma = \frac{8\pi i}{g^2} + \frac{\theta}{\pi}$$

$$(j) \otimes \left(2 \left(\frac{Q}{2} \right) + \left(\frac{1}{2} \right) \right)$$

$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{i,j} P_{ij}$$

$$Q^A \quad A=1,2, \quad \bar{Q}^A$$

$$M > |Z| \quad \{Q, \bar{Q}\} = \gamma^0 M$$

$$M = |Z| \quad \{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, \bar{Q}\} = Z = q_+ a + q_- a_0$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$a_0 = \gamma a \quad \gamma = \frac{8\pi i}{g^2} + \frac{\theta}{\pi}$$

$$(j) \otimes \left(2 \binom{0}{1} + \binom{1}{2} \right)^2$$

$$(j) \otimes \left(2 \binom{0}{1} + \binom{1}{2} \right)$$

$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{ij}^A P_{ij}$$

$$Q^A \quad A=1,2, \quad \bar{Q}^A$$

$$M > |Z|$$

$$\{Q, \bar{Q}\} = \gamma \cdot M$$

$$\{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, \bar{Q}\} = Z = q_e \cdot a + q_m \cdot a_0$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$a_0 = \gamma a \quad \gamma = \frac{e\pi i}{g^2} + \frac{Q}{2\pi}$$

$$(j) \otimes \left(2 \binom{0}{1} + \binom{1}{2} \right)^2$$

$$(j) \otimes \left(2 \binom{0}{1} + \binom{1}{2} \right)$$

$$\{Q^\Lambda, \bar{Q}^{\Lambda'}\} = \epsilon^{\Lambda\Lambda'} \gamma_{\mu}^{\Lambda} P_{\mu}$$

$$Q^{\Lambda} \quad \Lambda=1,2, \quad \bar{Q}_{\Lambda'}$$

$$M > |Z| \quad \{Q, \bar{Q}\} = \gamma^0 M$$

$$M = |Z| \quad \{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, Q\} = Z = q_e \cdot a + q_{\tau} \cdot a_0$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$a_0 = \tau a \quad \tau = \frac{a_0}{a}$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)^{\otimes 2}$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)$$

$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{ij}^A P_{ij}$$

$$Q^A \quad A=1,2, \quad \bar{Q}^A$$

$$M > |Z| \quad \{Q, \bar{Q}\} = \gamma \cdot M$$

$$M = |Z| \quad \{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, \bar{Q}\} = Z = q_+ \cdot a + q_- \cdot a_0$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$a_0 = \tau a \quad \tau$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)^2$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2\left(\frac{1}{2}\right) + (0) \quad A_n, \Phi$$

$$\frac{1}{g^2} \left(F_{\mu\nu}^2 + (D_\mu \Phi)^2 + [\Phi, \Phi^\dagger]^2 \right) + |D_\mu q|^2 + |D_\mu \tilde{q}|^2 + |\Phi q|^2$$

COULOMB BRANCH $\Phi = (a, a, \dots)$ + $|\bar{\Phi} \tilde{q}|^2 + \dots$

$U(1)^2$ ABELIAN GAUGE THEORY

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2\left(\frac{1}{2}\right) + (0) \quad \begin{matrix} M \in \text{LIE ALGEBRA} \\ \text{OF FLAVOR} \\ A_n, \Phi \end{matrix}$$

$$\frac{1}{g^2} \left(F_{\mu\nu}^2 + (D_\mu \Phi)^2 + [\Phi, \Phi^\dagger]^2 \right) + |D_\mu q|^2 + |D_\mu \tilde{q}|^2 + |\Phi q|^2$$

COULOMB BRANCH $\Phi = (a, a, \dots)$ $+ |\Phi \tilde{q}|^2 + \dots$

$U(1)^2$ ABELIAN GAUGE THEORY

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2\left(\frac{1}{2}\right) + (0) \quad \begin{matrix} M \in \text{LIE ALGEBRA} \\ \text{OF FLAVOR} \\ A_n, \Phi \end{matrix}$$

$$\frac{1}{g^2} \left(F_{nv}^2 + (D_n \Phi)^2 + [\Phi, \Phi^\dagger]^2 \right) + |Dq|^2 + |D\tilde{q}|^2 + |\Phi q|^2$$

COULOMB BRANCH $\Phi = (a, a, \dots)$ $+ |\bar{\Phi} \tilde{q}|^2 + |Mq|^2$

$U(1)^2$ ABELIAN GAUGE THEORY

$$\{Q^\lambda, \bar{Q}^{\lambda'}\} = \epsilon^{\lambda\lambda'} \gamma_{\lambda\lambda'} P_\mu$$

$$Q^\lambda_{\lambda=1,2}, \bar{Q}^{\lambda'}$$

$$M > |Z| \quad \{Q, \bar{Q}\} = \gamma^0 M$$

$$M = |Z| \quad \{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, Q\} = Z = q_e \cdot a + q_m \cdot a_D + q_f \cdot m$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$a_D = \tau a \quad \tau = \frac{m}{\mu}$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right)^2 \right)$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$M \in \text{LIE ALGEBRA OF FLAVOR}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2\left(\frac{1}{2}\right) + (0) \quad A_n, \Phi$$

$$\frac{1}{g^2} \left(F_{\mu\nu}^2 + (D_\mu \Phi)^2 + [\Phi, \Phi^\dagger]^2 \right) + |Dq|^2 + |D\tilde{q}|^2 + |\Phi q|^2$$

COULOMB BRANCH $\Phi = (a, a, \dots)$ $+ |\bar{\Phi} \tilde{q}|^2 + |Mq|^2$

$U(1)^2$ ABELIAN GAUGE THEORY $U(1)^2$ FLAVOR

$$\{Q^\lambda, \bar{Q}^{\lambda'}\} = \epsilon^{\lambda\lambda'} \gamma_{\lambda\lambda'} P_\mu$$

$$Q^\lambda \quad \lambda=1,2, \quad \bar{Q}^{\lambda'}$$

$$M > |z| \quad \{Q, \bar{Q}\} = \gamma^0 M$$

$$M = |z| \quad \{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, Q\} = Z = q_e \cdot a + q_m \cdot a_D + q_f \cdot m$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$a_D = \tau a \quad \tau = \frac{m}{\mu}$$

$$(j) \otimes \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)^2$$

$$(j) \otimes \left(2(0) + \left(\frac{1}{2} \right) \right)$$

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$M \in$ LIE ALGEBRA OF FLAVOR

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2\left(\frac{1}{2}\right) + (0)$$

$$A_n, \Phi$$

$$M = \begin{pmatrix} \dots \\ \dots \\ \dots \end{pmatrix}$$

$$\frac{1}{2} \left(F_{\mu\nu}^2 + (D_\mu \Phi)^2 + [\Phi, \Phi^\dagger]^2 \right) + |Dq|^2 + |D\tilde{q}|^2 + |\Phi q|^2$$

COULOMB BRANCH $\Phi = \begin{pmatrix} a_1 \\ a_2 \\ \dots \end{pmatrix} + |\Phi \tilde{q}|^2 + |Mq|^2$

ABELIAN GAUGE THEORY $U(1)^r$ FLAVOR

$$j=0 \quad 2(0) + \left(\frac{1}{2}\right) \otimes (\mathbb{R} \oplus \bar{\mathbb{R}}) \quad q \quad \tilde{q}$$

$$j=\frac{1}{2} \quad \begin{matrix} (1) \\ \pm 1 \\ 0 \end{matrix} + 2\left(\frac{1}{2}\right) + (0) \quad \begin{matrix} M \in \text{LIE ALGEBRA} \\ \text{OF FLAVOR} \\ A_n, \Phi \\ M = \begin{pmatrix} \dots \\ \dots \\ \dots \end{pmatrix} \end{matrix}$$

$$\frac{1}{2} \left(F_{\mu\nu}^2 + (D_\mu \Phi)^2 + [\Phi, \Phi^\dagger]^2 \right) + |Dq|^2 + |D\tilde{q}|^2 + |\Phi q|^2$$

COULOMB BRANCH $\Phi = \begin{pmatrix} a_1 \\ a_2 \\ \dots \\ a_n \end{pmatrix} + |\Phi \tilde{q}|^2 + |M q|^2$

$U(1)^2$ ABELIAN GAUGE THEORY $U(1)^{2n}$ FLAVOR

$$\{Q^\Lambda, \bar{Q}^{\Lambda'}\} = \epsilon^{\Lambda\Lambda'} \gamma_{i,j} P_{ij}$$

$$Q^\Lambda_{\quad i}, \bar{Q}^{\Lambda'}_{\quad i}$$

$$M > |Z|$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$M = |Z|$$

$$\{Q, \bar{Q}\} =$$

$$\{Q, Q\} = Z = q_e \cdot a + q_m \cdot a_D + q_f \cdot m$$

$$\{Q, \bar{Q}\} = \bar{Z}$$

$$a_D = \tau a \quad \tau = \frac{m}{\mu}$$

$$\left(\frac{1}{2} \right) \otimes \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)^2$$

$$,, \left(2 \left(\frac{1}{2} \right) + \left(\frac{1}{2} \right) \right)$$

$$\{Q^A, \bar{Q}^B\} = \epsilon^{AB} \gamma_{\mu}^A P_{\mu}$$

$$Q^A \quad A=1,2, \quad \bar{Q}^A$$

$$M > |Z|$$

$$\{Q, \bar{Q}\} = \gamma^0 M$$

$$M = |Z|$$

$$\{Q, \bar{Q}\} = (\gamma^0 + \gamma^1) E$$

$$\{Q, \bar{Q}\} = Z = q_e \cdot a + q_m \cdot a_D + q_f \cdot m$$

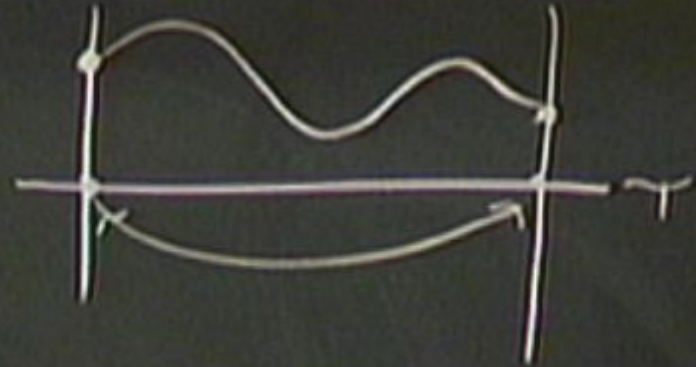
$$\{Q, \bar{Q}\} = Z$$

$$a_D = \tau_{ij} a$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)^2$$

$$(j) \otimes \left(2 \binom{0}{1} + \left(\frac{1}{2} \right) \right)$$

$$F_{ij} = \epsilon_{ijk} D_k \phi$$



$\gamma_{IJ}(a)$

$$\text{Im} \gamma_{IJ} F^I{}_{\nu} F^{J\nu} + \text{Re} \gamma_{IJ} F^I \wedge F^J$$

$$\tau_{IJ}(a) \quad a^I, F_{\mu\nu}^I \quad \text{Im} \tau_{IJ} F_{\mu\nu}^I F^{\mu\nu J} + \text{Re} \tau_{IJ} F^I \wedge F^J$$

$$\tau_{IJ} = \partial_{a^I} \partial_{a^J} f(a^*)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} \sum_q z_q^2 \ln z_q$$

$$\Upsilon_{IJ}(a) \quad a^I, F_{\mu\nu}^I \quad \text{Im} \Upsilon_{IJ} \quad F_{\mu\nu}^I F^{J\mu\nu} + \text{Re} \Upsilon_{IJ} \quad F^{I\lambda} F^J$$

$$\Upsilon_{IJ} = \partial_{a^I} \partial_{a^J} f(a^*)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} \sum_q z_q^2 \ln z_q \quad \Omega(q) = (-1)^{2j} (2j+1)$$

$$\tau_{IJ}(a) \quad a^I, F_{\mu\nu}^I \quad \text{Im} \tau_{IJ} F_{\mu\nu}^I F^{J\mu\nu} + \text{Re} \tau_{IJ} F^I \wedge F^J$$

$$\tau_{IJ} = \partial_{a^I} \partial_{a^J} f(a^*)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} Z_q^2 \ln Z_q \quad \Omega(q) = (-, 1)$$

$$W\text{-BOSONS: } \tau_{IJ} \dots + \frac{i}{\pi} q_I q_J \ln q_I a^I$$

$$\tau_{IJ}(a) \quad a^I, F_{\mu\nu}^I \quad \text{Im} \tau_{IJ} F_{\mu\nu}^I F^{J\mu\nu} + \text{Re} \tau_{IJ} F^I \wedge F^J$$

$$\tau_{IJ} = \partial_{a^I} \partial_{a^J} f(a^*)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} \sum_q z_q^2 \ln z_q \quad \Omega(q) = (-1)^{2j} (2j+1)$$

$$W\text{-BOSONS: } \tau_{IJ} = \dots + \frac{i}{\pi} q_I q_J \ln q_I a^I + \dots$$

$$\tau_{IJ}(a) \quad a^I, F_{\mu\nu}^I \quad \text{Im} \tau_{IJ} F_{\mu\nu}^I F^{J\mu\nu} + \text{Re} \tau_{IJ} F^I \wedge F^J$$

$$\tau_{IJ} = \partial_{a^I} \partial_{a^J} f(a^*)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} \sum_q z_q^2 \ln z_q \quad \Omega(q) = \binom{(-1)^{2j}}{(2j+1)}$$

$$W\text{-BOSONS: } \tau_{IJ} \dots + \frac{i}{\pi} q_I q_J \ln q_I a^I + \dots$$

$$\tau_{IJ}(a) \quad a^I, F_{\mu\nu}^I \quad \text{Im} \tau_{IJ} F_{\mu\nu}^I F^{J\mu\nu} + \text{Re} \tau_{IJ} F^I \wedge F^J$$

$$\tau_{IJ} = \partial_{a^I} \partial_{a^J} f(a^*)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} \sum_q z_q^2 \ln z_q \quad \Omega(q) = \binom{(-1)^{2j}}{(2j+1)}$$

$$W\text{-BOSONS: } \tau_{IJ} = \dots + \frac{i}{\pi} q_I q_J \ln q_I a^I + \dots$$

$$\tau_{IJ}(a) \quad a^I, F_{\mu\nu}^I \quad \text{Im} \tau_{IJ} F_{\mu\nu}^I F^{\mu\nu J} + \text{Re} \tau_{IJ} F^{\mu\nu I} F^{\mu\nu J}$$

$$\tau_{IJ} = \partial_{a^I} \partial_{a^J} f(a^*)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} \sum_q Z_q^2 \ln Z_q \quad \Omega(q) = ((-1)^{2j}) (2)$$

$$W\text{-BOSONS: } \tau_{IJ} = \dots + \frac{i}{\pi} q_I q_J \ln q_I a^I + \dots$$

$$\tau_{IJ}(a) \quad a^I, F_{\mu\nu}^I \quad \text{Im} \tau_{IJ} F_{\mu\nu}^I F^{\mu\nu J} + \text{Re} \tau_{IJ} F^I \wedge F^J$$

$$\tau_{IJ} = \partial_{a^I} \partial_{a^J} f(a)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} \sum_q Z_q^2 \ln Z_q \quad \Omega(q) = \binom{(-1)^{2j}}{(2j+1)}$$

$$W\text{-BOSONS: } \tau_{IJ} = \dots + \frac{i}{\pi} q_I q_J \ln q_I a^I + \dots$$

$$T_{IJ}(a) \quad a^I, F_{\mu\nu}^I \quad \text{Im} T_{IJ} \quad F_{\mu\nu}^I F^{J\mu\nu} + \text{Re} T_{IJ} \quad F^{J\mu\nu} F^{\mu\nu}$$

$$T_{IJ} = \partial_{a^I} \partial_{a^J} f(a, m)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} \sum_q \ln Z \quad \Omega(q) = \left((-1)^{2j} \right) (2j+1)$$

$$W\text{-BOSONS: } T_{IJ} = \dots + \left(\frac{i}{\pi} \right) q_I q_J \ln Z \quad a^I \quad \dots$$

$$Z = a_0 \cdot a + q_0 \cdot a_0 + q_0 \cdot m$$

$$T_{IJ}(a) = \text{Im} T_{IJ} F_{\mu\nu}^I F^{\mu\nu J} + \text{Re} T_{IJ} F^I \wedge F^J$$

$$T_{IJ} = \partial_{a^I} \partial_{a^J} f(a, m)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} \sum q_i^2 \ln Z_i \quad \Omega(q) = \left((-1)^{2j} \right) (2j+1)$$

$$W\text{-BOSONS: } T_{IJ} = \dots + \frac{i}{\pi} q_i q_j \ln q_i a^I + \dots$$

$$Z = q_e \cdot a + q_{\mu} \cdot a_{\mu} + q_{\mu} \cdot m$$

$$\Upsilon_{IJ}(a) \quad a^I, F^I_{\nu} \quad \text{Im} \Upsilon_{IJ} \quad F^I_{\nu} F^J{}^{\nu} + \text{Re} \Upsilon_{IJ} \quad F^I \wedge F^J$$

$$\Upsilon_{IJ} = \partial_{a^I} \partial_{a^J} f(a, m)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} Z_q^2 \ln Z_q \quad \Omega(q) = ((-1)^{2j})_{(2,1,1)}$$

W-BOSONS: $\Upsilon_{IJ} = \dots + \frac{i}{\pi} q_I q_J \ln q_I a^I + \dots$

$$Z = q_e \cdot a + q_p \cdot a_D + q_f \cdot m \quad a_{D,I} \rightarrow \frac{\partial f}{\partial a^I} \quad \Upsilon_{IJ} = \frac{\partial a_{I,1}}{\partial a^J}$$

$$T_{IJ}(a) = \text{Im} T_{IJ} F_{\mu\nu}^I F^{\mu\nu J} + \text{Re} T_{IJ} F^I \wedge F^J$$

$$T_{IJ} = \partial_{a^I} \partial_{a^J} f(a, m)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} Z_q^2 \ln Z_q \quad \Omega(q) = ((-1)^{2j})_{(2, +1)}$$

W-BOSONS: $T_{IJ} = \dots + \frac{i}{\pi} q_I q_J \ln q_e a^I + \dots$

$$Z = q_e \cdot a + q_p \cdot a_0 + q_f \cdot m \quad a_{0,I} \rightarrow \frac{\partial f}{\partial a^I} \quad T_{IJ} = \frac{\partial a_{I,2}}{\partial a^J}$$

$$T_h \phi^n = U^{(n)}$$

$$T_{IJ}(a) \quad a^I, F^I_{\nu} \quad \text{Im} T_{IJ} F^I_{\nu} F^{J\nu} + \text{Re} T_{IJ} F^I \wedge F^J$$

$$T_{IJ} = \partial_{a^I} \partial_{a^J} f(a, m)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} Z_q^2 \ln Z_q \quad \Omega(q) = ((-1)^{2j})_{(2,1,1)}$$

$$W\text{-BOSONS: } T_{IJ} = \dots + \frac{i}{\pi} q_I q_J \ln q_I a^I + \dots$$

$$Z = q_e \cdot a + q_p \cdot a_0 + q_f \cdot m \quad a_{0,I} \rightarrow \frac{\partial f}{\partial a^I} \quad T_{IJ} = \frac{\partial a_{I,1}}{\partial a^J}$$

$$T_h \phi^n = U^{(n)} \quad a(u) \quad a_0(u)$$

$$T_{IJ}(a) \quad \text{Im} T_{IJ} \quad F^I \quad F^{J+V} + \rho \epsilon T_{IJ} F^I \wedge F^J$$

$$T_{IJ} = \partial_{a^I} \partial_{a^J} f(a, m)$$

$$f(a) = \Omega(q) \cdot -\frac{i}{2\pi} Z_q^2 \ln Z_q \quad \Omega(q) = \left((-1)^{2j} \right) (2j+1)$$

W-BOSONS: $T_{IJ} \dots + \left(\frac{i}{\pi} \right) q_I q_J \ln q_I a^I \dots$

$$Z = q_0 \cdot a + q_1 \cdot a_0 + q_2 \cdot m \quad a_{0,I} \quad \frac{\partial f}{\partial a^I} \quad T_{IJ} = \frac{\partial a_{I,1}}{\partial a^J}$$

$$T_h \phi^n = U^{(n)} \quad a(u) \quad a_0(u) ?$$

PURE $SU(2)$ $N=2$ GAUGE THEORY

PURE $SU(2)$ $N=2$ GAUGE THEORY

$$\phi \sim \begin{pmatrix} a & \\ & -a \end{pmatrix}$$

$$\text{Tr} \phi^2 = v \sim 2a^2$$

PURE $SU(2)$ $N=2$ GAUGE THEORY

$$\phi \sim \begin{pmatrix} a & \\ & -a \end{pmatrix}$$

$$\text{Tr} \phi^2 = v \sim 2a^2$$

$$\gamma \sim \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4}$$

PURE $SU(2)$ $N=2$ GAUGE THEORY

$$\phi \sim \begin{pmatrix} a & \\ & -a \end{pmatrix}$$

$$\text{Tr} \phi^2 = v \sim 2a^2$$

$$\gamma \sim \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4}$$

$$a \sim \sqrt{\frac{v}{2}}$$

$$a_0 \sim \sqrt{\frac{v}{2}} \frac{i}{2\pi} \ln \frac{v^2}{\Lambda^4}$$

PURE $SU(2)$ $N=2$ GAUGE THEORY

$$\phi \sim \begin{pmatrix} a \\ -a \end{pmatrix}$$

$$\text{Tr} \phi^2 = v \approx 2a^2$$

$$\gamma \sim \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4}$$

$$a = \sqrt{\frac{v}{2}} + ?$$

$$a_0 = \sqrt{\frac{v}{2}} \frac{i}{2\pi} \ln \frac{v^2}{\Lambda^4} + ?$$

PURE SU(2) N=2 GAUGE THEORY

$$\phi \sim \begin{pmatrix} a \\ -a \end{pmatrix}$$

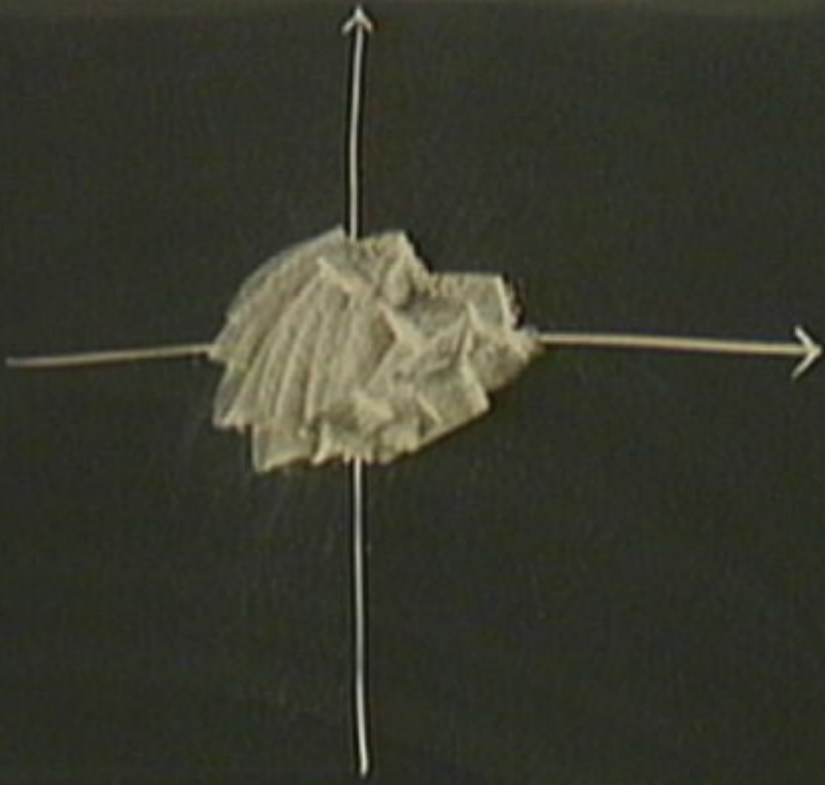
$$\text{Tr} \phi^2 = U \approx 2a^2$$

$$\gamma \approx \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} + \dots$$

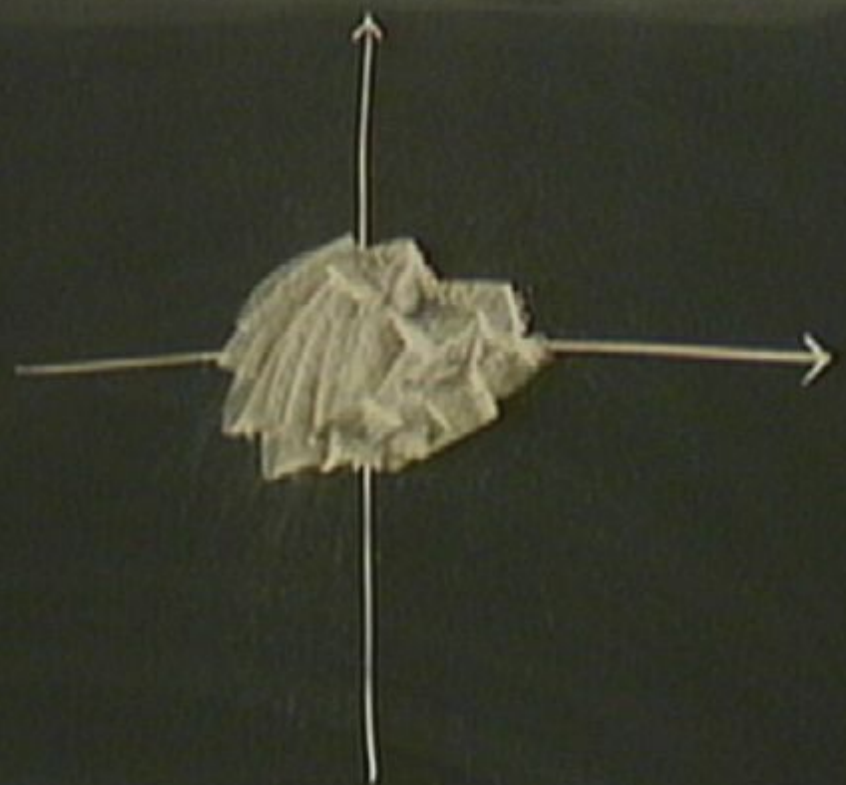
$$a = \sqrt{\frac{U}{2}} + ?$$

$$a_0 = \sqrt{\frac{U}{2}} \frac{i}{2\pi} \ln \frac{U^2}{\Lambda^4} + ?$$

70

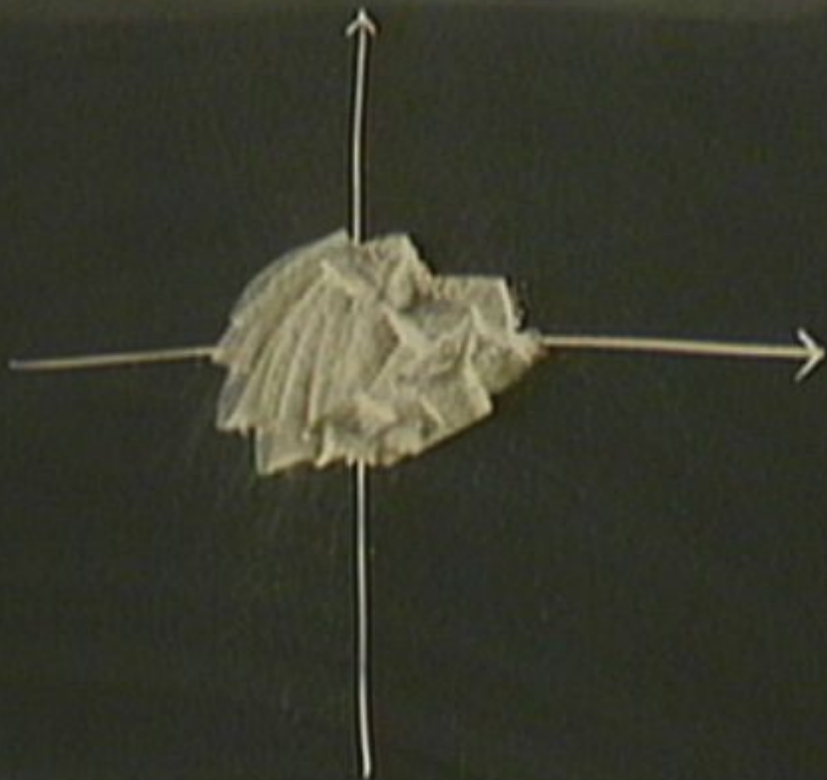


LU



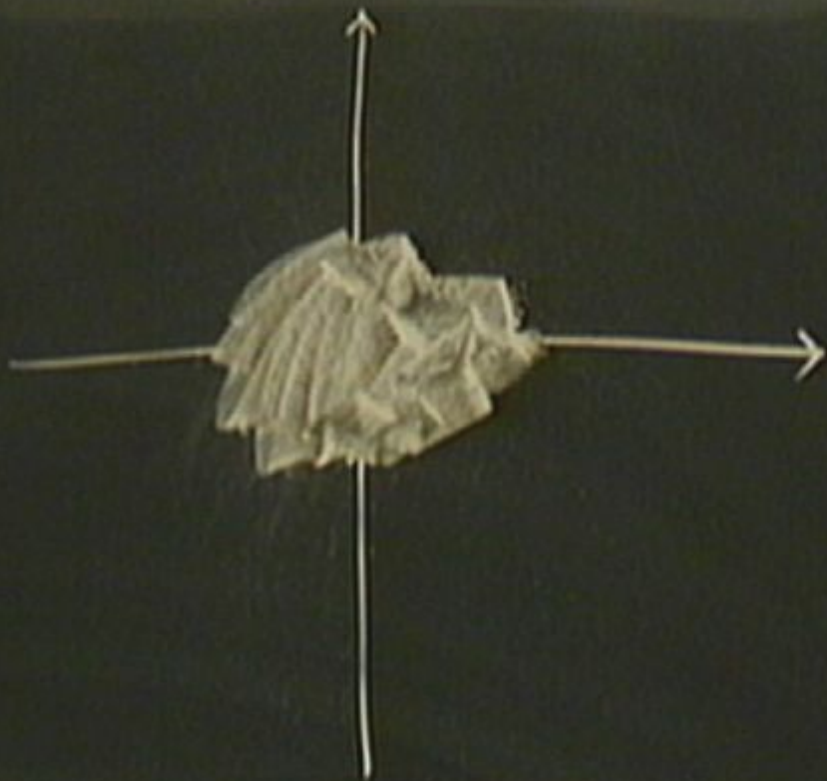
$$W = (0, 2) \\ q_-, q_+$$

\mathbb{Z}



$$W = (0, 2)$$
$$q_-, q_+$$
$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

\sqcup



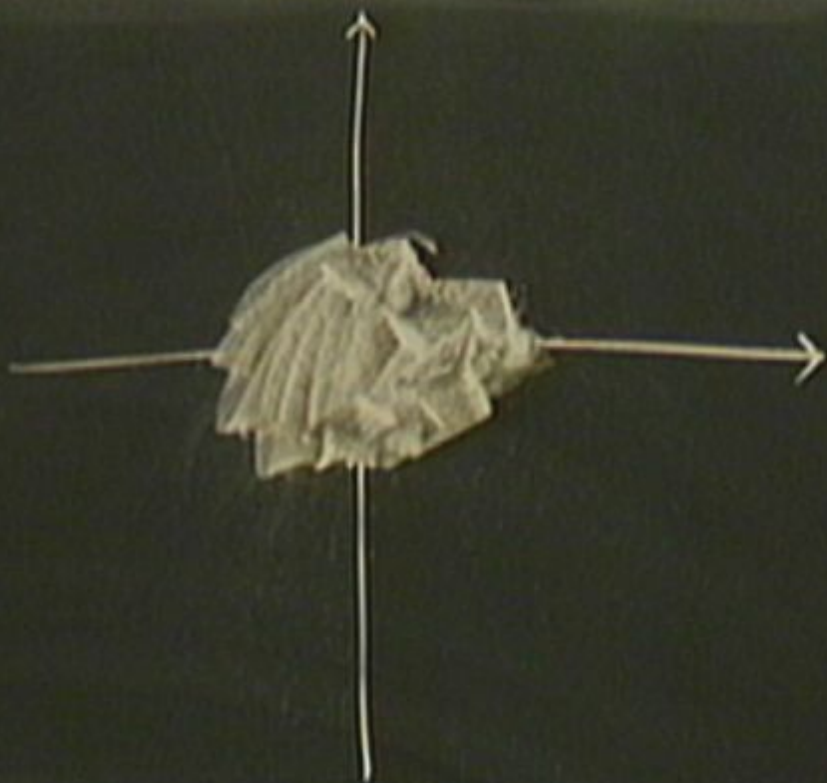
$$W = (0, \frac{a}{2})$$

$$q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2na|$$

\mathbb{Z}

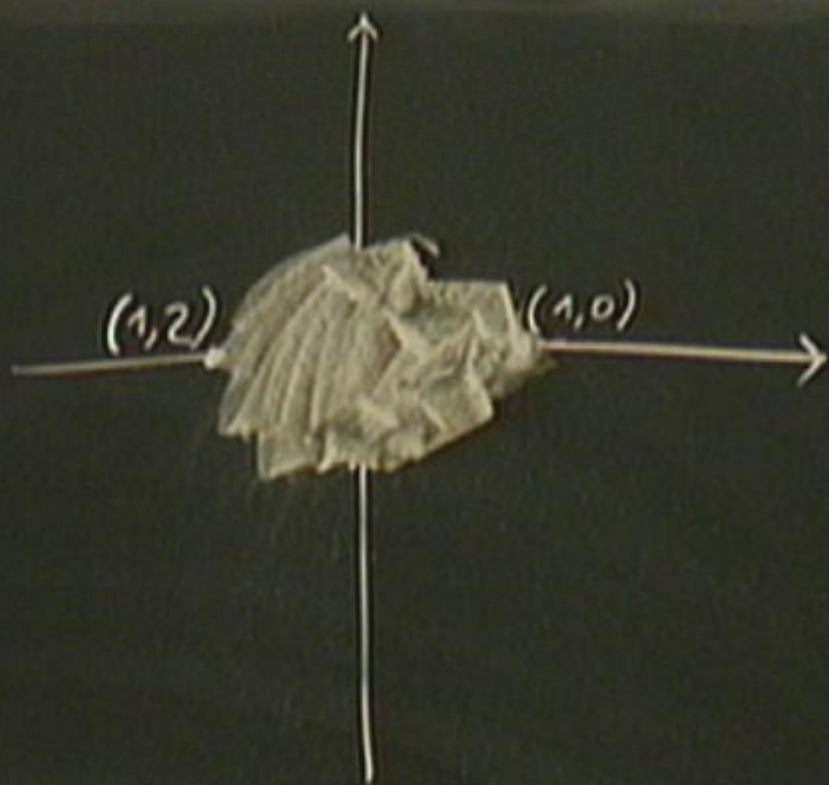


$$W = (0, 2) \\ q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2na|$$

\sqcup



$$W = (0, 2) \\ q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2na|$$

$$E \rightarrow B$$

$$B \rightarrow -E$$

$$F \rightarrow *F$$

$$E \rightarrow B \quad B \rightarrow -E$$

$$F \rightarrow *F$$

$$T \rightarrow -\overset{\uparrow}{\cancel{T}}$$

$$E \rightarrow B \quad B \rightarrow -E \quad F \rightarrow *F$$

$$\gamma_D = -\frac{1}{T}$$

$$f_D(a_D)$$

$$a = -\frac{\partial F_0}{\partial a_D}$$



$$E \rightarrow B \quad B \rightarrow -E$$

$$F \rightarrow *F$$

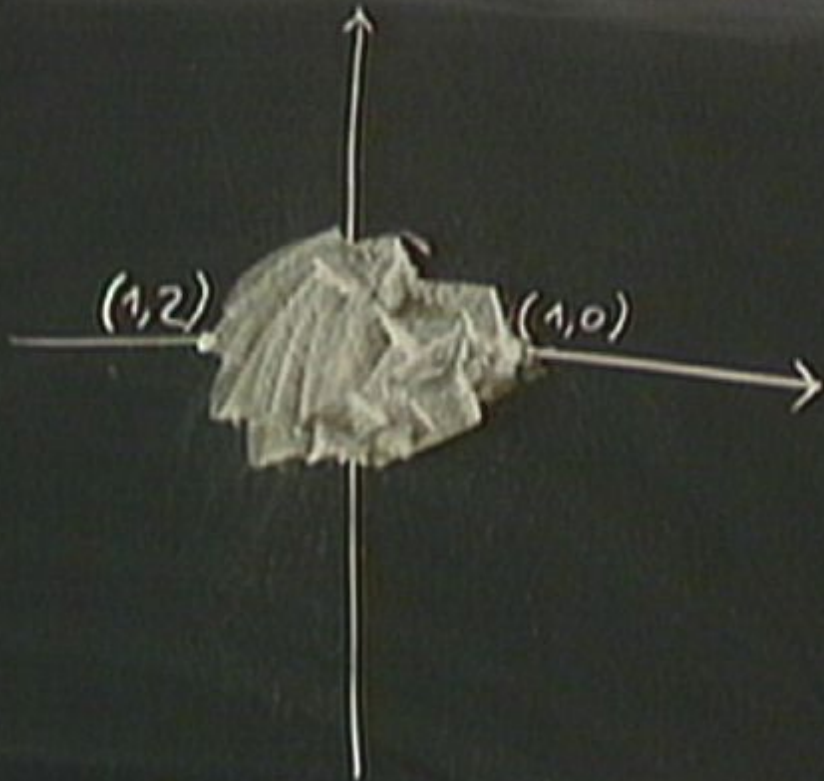
$$\tau_D = -\frac{1}{T}$$

$$f_D(a_D)$$

$$a = -\frac{\partial f_0}{\partial a_D}$$

$$\tau_0 = -\frac{1}{T} = -\frac{\partial a}{\partial a_D}$$

U



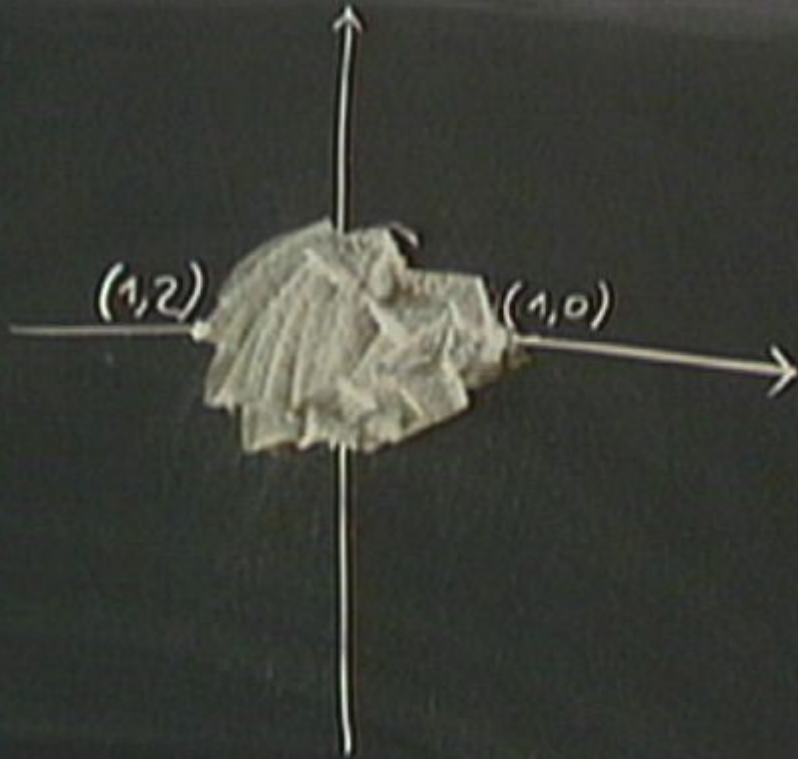
$$W = (0, 2) \\ q_n, q_{e^i}$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2na|$$

$$a_0 \rightarrow 0$$

U



$$W = (0, \frac{1}{2})$$
$$q_n, q_n^{-1}$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

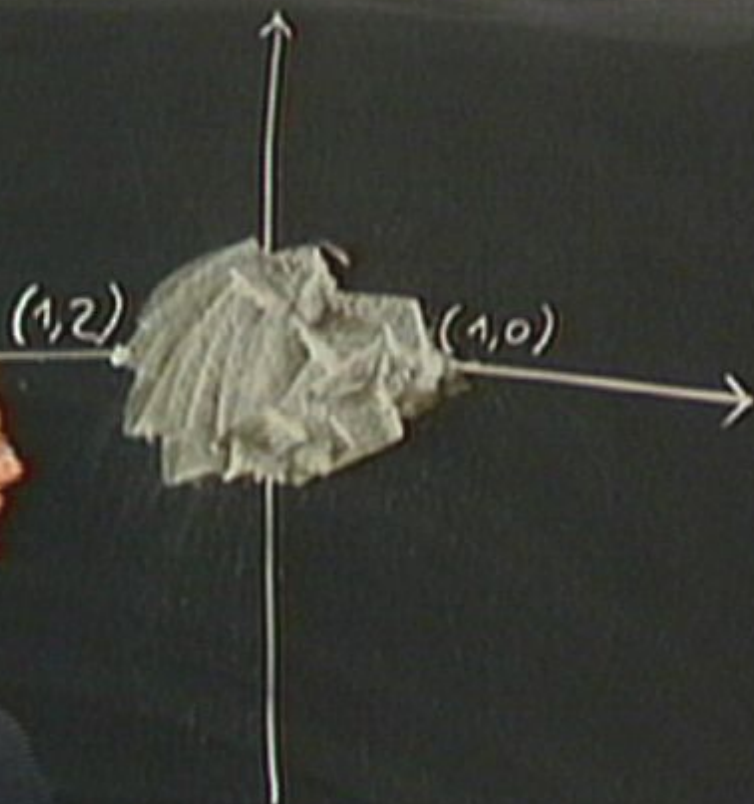
$$M_n = |a_0 + 2na|$$

$$a_0 \neq 0 \quad \tau_D \sim -\frac{i}{2\pi} \log$$

$W = \text{BOSONS: } \tau_{IJ} \dots + \left(\frac{1}{\pi}\right) q_I q_J \ln q_K a^2 \dots$
 $Z = q_e \cdot a + q_p \cdot a_0 + q_f \cdot m \dots a_{0,I} \frac{\partial F}{\partial a^2} \quad \tau_{IJ} = \frac{\partial a_{I,2}}{\partial a_J}$
 $\tau_{IJ} \phi^n = U^{(I)} \quad a(U) \quad a_0(U) ?$

$E \rightarrow \beta \quad \beta = \dots \quad F = *F$
 $\tau_D = -\frac{1}{T} \quad f_D(a_D) \quad a = -\frac{\partial F_0}{\partial a_D} \quad \tau_0 = -\frac{1}{T} = -\frac{\partial a}{\partial a_D}$

LU



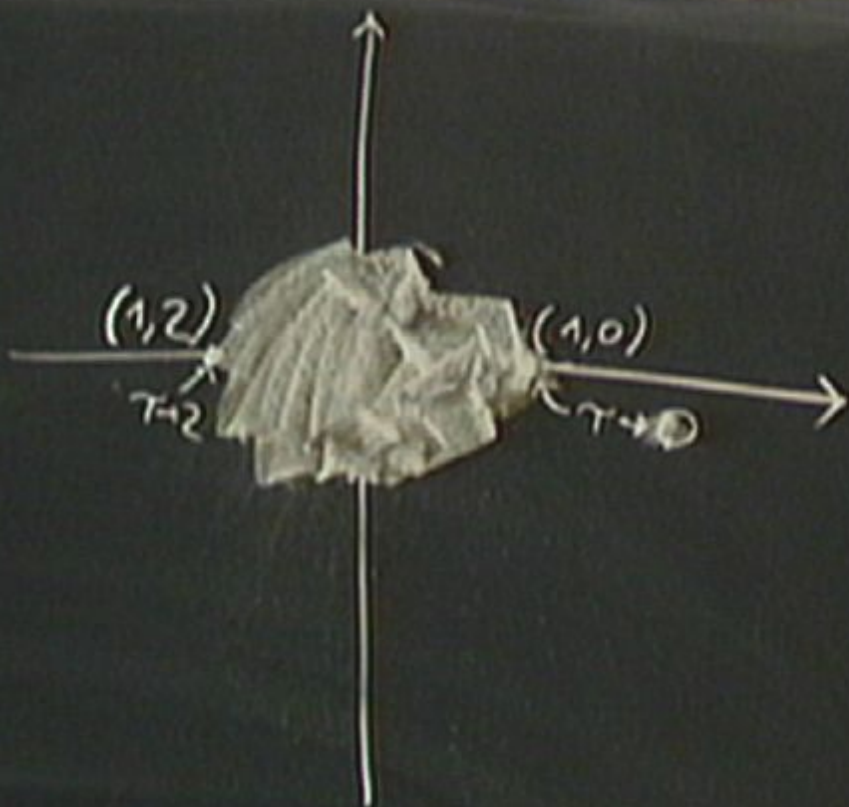
$$W = (0, 2) \\ q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2na|$$

$$a_0 \rightarrow 0 \quad \tau_D \sim -\frac{i}{2\pi} \log a_D \\ a \sim -\frac{i}{2\pi} a_0 \log a_D$$

U



$$W = (0, \pm 2)$$
$$q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

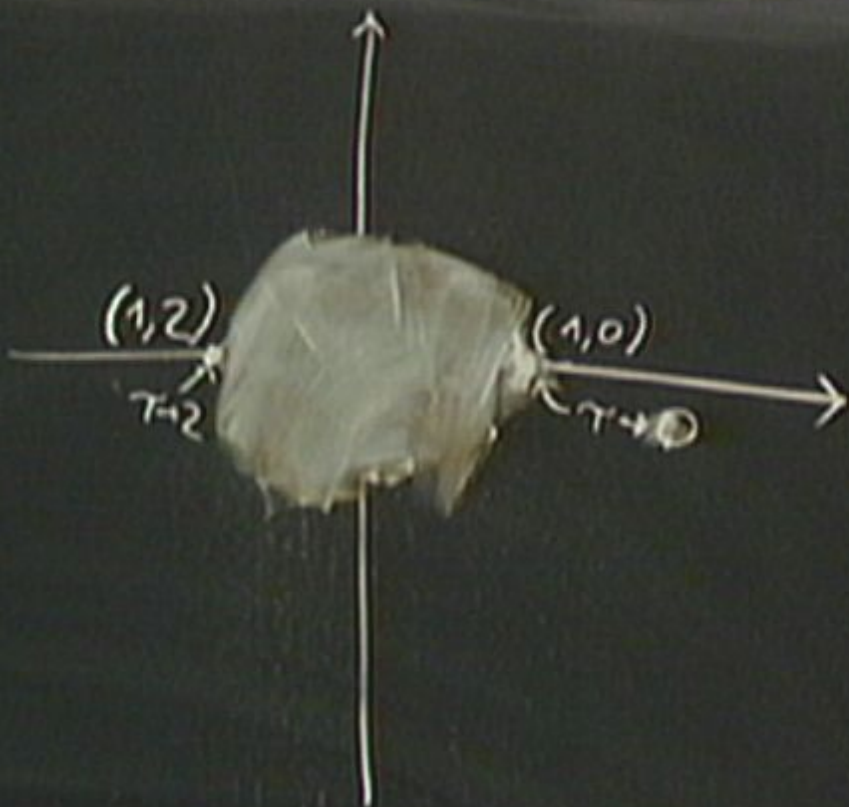
$$M_n = |a_0 + 2na|$$

$$a_0 \rightarrow 0 \quad \frac{1}{\tau} = \tau_0 \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_0 + 2a \rightarrow 0 \quad -\frac{1}{\tau-2} \sim -\frac{i}{2\pi} \log a_0 + 2a$$

U



$$W = (0, 2) \\ q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

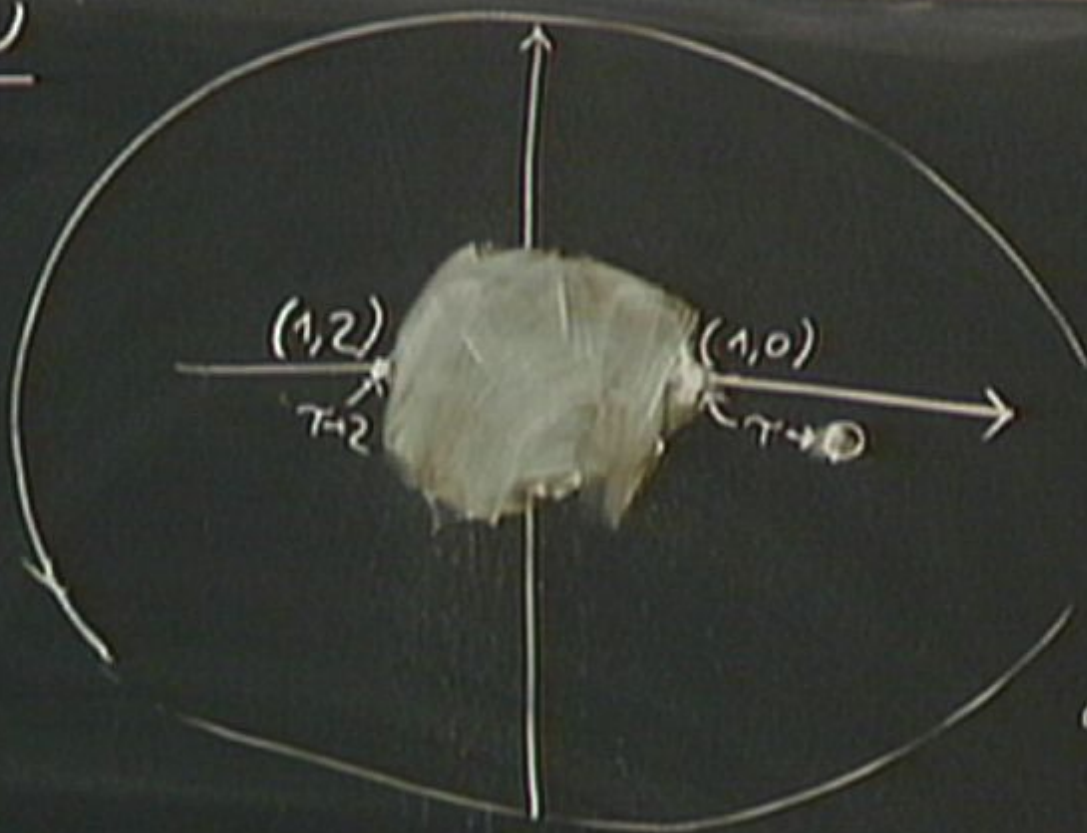
$$M_n = |a_0 + 2na|$$

$$a_0 \rightarrow 0 \quad \frac{1}{\tau} = \tau_0 \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_0 + 2a \rightarrow 0 \quad -\frac{1}{\tau-2} \sim -\frac{i}{2\pi} \log a_0 + 2a$$

U



$$W = (0, 2) \\ q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2na|$$

$$a_0 \rightarrow 0 \quad \frac{1}{\tau} = \tau_0 \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_0 + 2a \rightarrow 0 \quad -\frac{1}{\tau - 2} \sim -\frac{i}{2\pi} \log a_0 + 2a$$

PURE SU(2) N=2 GAUGE THEORY

$$\phi \sim \begin{pmatrix} a \\ -a \end{pmatrix}$$

$$\text{Tr} \phi^2 = v \sim 2a^2$$

$$\tau = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} + \dots$$

$$a = \sqrt{\frac{v}{2}} + ?$$

$$a_0 = \sqrt{\frac{v}{2}} \frac{i}{2\pi} \ln \frac{v^2}{\Lambda^4} + ?$$

$$U \rightarrow e^{2\pi i} U$$

$$\tau \rightarrow \tau + 4$$

$$a_0 \rightarrow a_0 + 4a$$

PURE SU(2) N=2 GAUGE THEORY

$$\phi \sim \begin{pmatrix} a \\ -a \end{pmatrix}$$

$$\text{Tr} \phi^2 = v \approx 2a^2$$

$$\tau = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} + \dots$$

$$a = \sqrt{\frac{v}{2}} + ?$$

$$a_0 = \sqrt{\frac{v}{2}} \frac{i}{2\pi} \ln \frac{v^2}{\Lambda^4} + ?$$

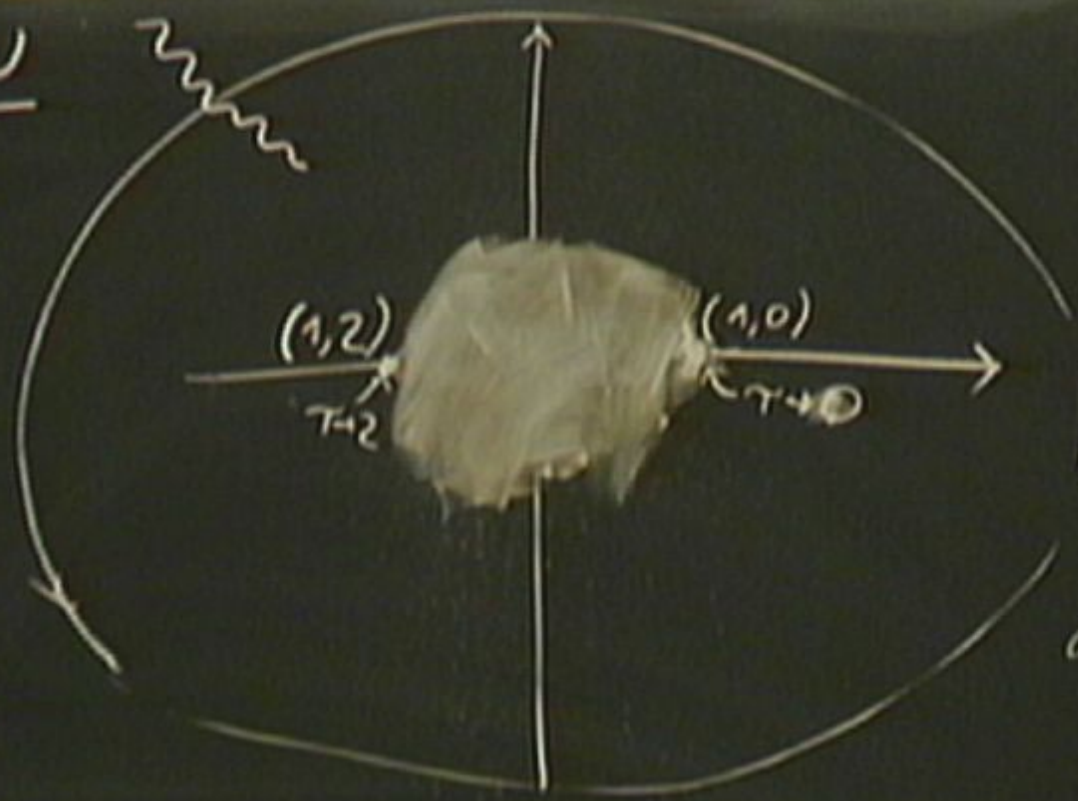
$$U \rightarrow e^{2\pi i} U$$

$$\tau \rightarrow \tau + 4$$

$$a_0 \rightarrow a_0 + 4a$$

$$q_e \rightarrow q_e - 4q_m$$

\sqcup



$$W = (0, 2) \\ q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

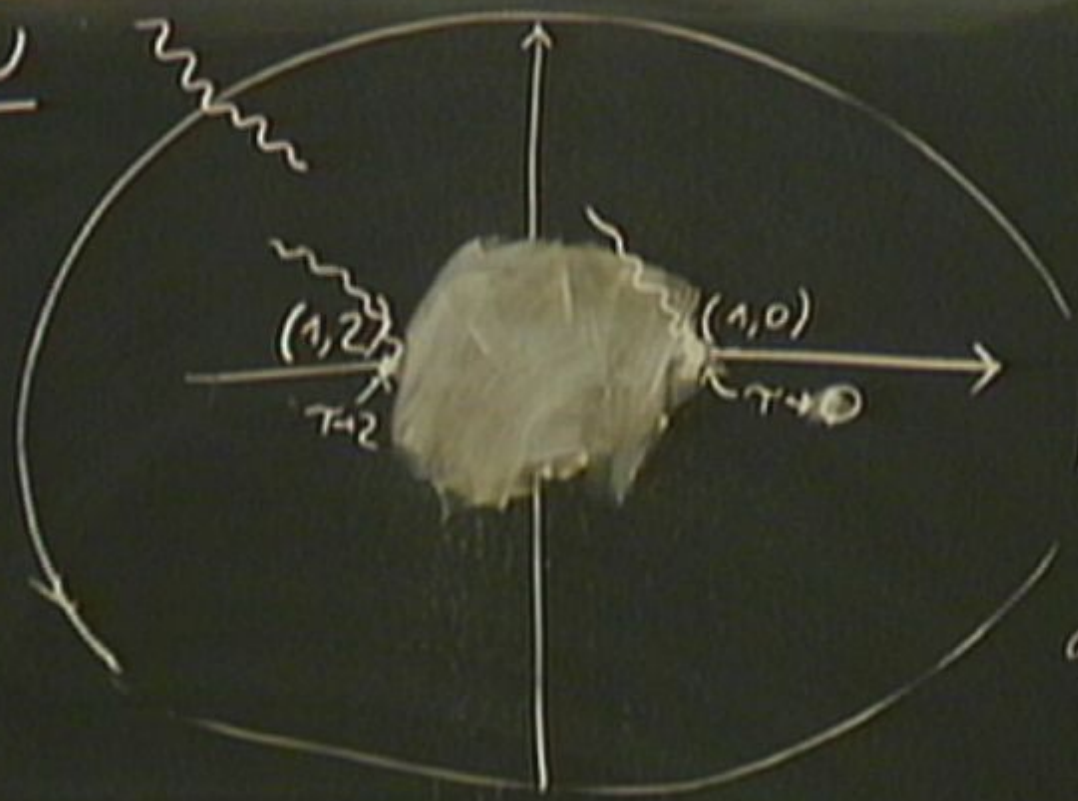
$$M_n = |a_0 + 2n a|$$

$$a_0 + 0 \cdot \frac{1}{\tau} = \tau_0 \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_0 + 2a + 0 \cdot \frac{1}{\tau-2} \sim -\frac{i}{2\pi} \log(a_0 + 2a)$$

U



$$W = (0, 2) \\ q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

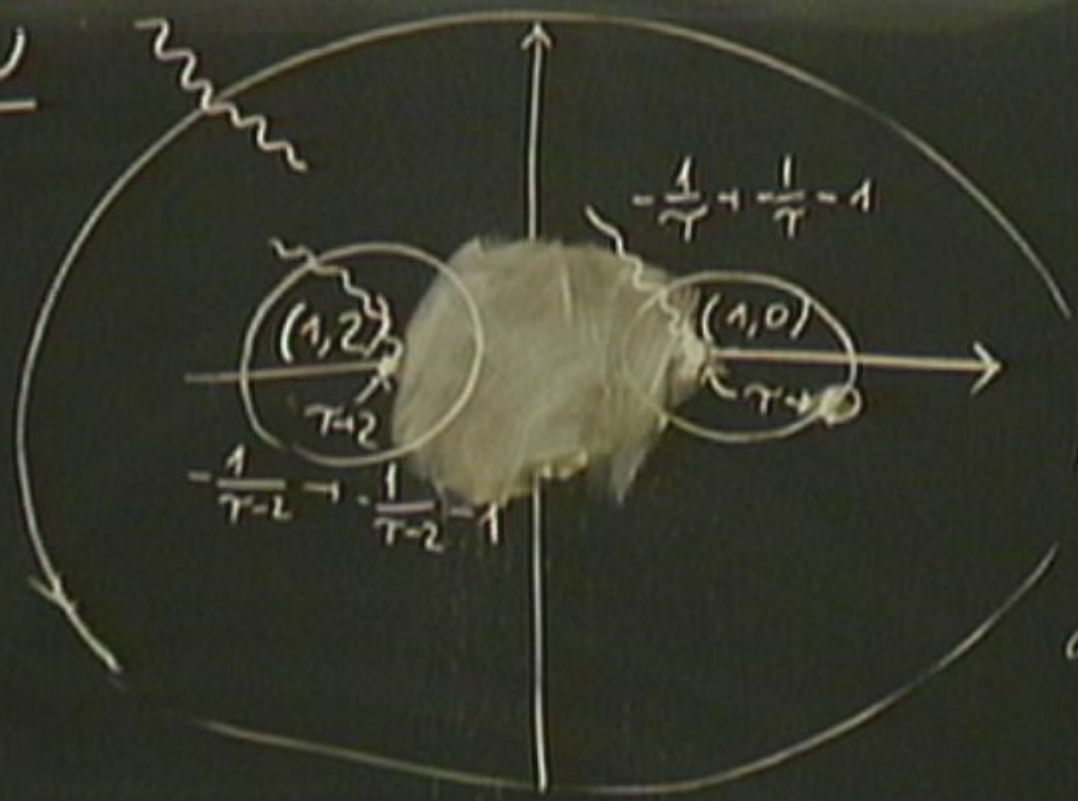
$$M_n = |a_0 + 2n a|$$

$$a_0 + 0 \cdot \frac{1}{\tau} = \tau_0 \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_0 + 2a + 0 \cdot \frac{1}{\tau-2} \sim -\frac{i}{2\pi} \log(a_0 + 2a)$$

U



$$W = (0, \infty)$$

$$q_-, q_+^*$$

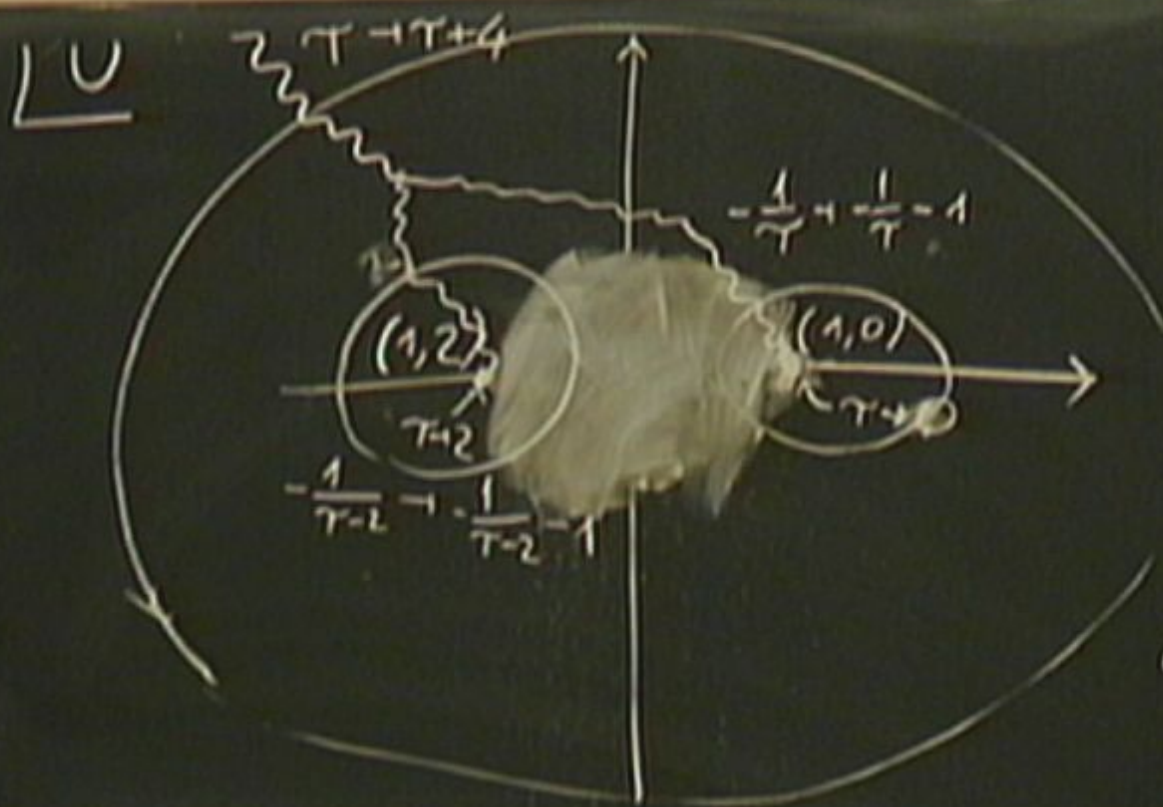
$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2n a|$$

$$a_0 + 0 \quad \frac{1}{\tau} = \tau_0 \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_0 + 2a + 0 \quad -\frac{1}{\tau-2} \sim -\frac{i}{2\pi} \log a_0 + 2a$$



$$W = (0, \frac{1}{2})$$

$$q_-, q_+^*$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2n a|$$

$$a_0 \rightarrow 0 \quad \frac{1}{\tau} = \tau_0 \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_0 + 2a \rightarrow 0 \quad -\frac{1}{\tau-2} \sim -\frac{i}{2\pi} \log(a_0 + 2a)$$

PURE SU(2) N=2 GAUGE THEORY

$$\phi \sim \begin{pmatrix} a \\ -a \end{pmatrix}$$

$$\text{Tr} \phi^2 = v \approx 2a^2$$

$$\dots g_i^T g_i, g_i^T g_i, g_i^T g_i \\ = 1$$

$$\tau = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} + \dots$$

$$a = \sqrt{\frac{v}{2}} + ?$$

$$a_0 = \sqrt{\frac{v}{2}} \frac{i}{2\pi} \ln \frac{v^2}{\Lambda^4} + ?$$

$$U \rightarrow e^{2\pi i} U$$

$$\tau \rightarrow \tau + 4$$

$$a_0 \rightarrow a_0 + 4a$$

$$q_e \rightarrow q_e - 4q_m$$

$$E \rightarrow B \quad B \rightarrow -E$$

$$F \rightarrow *F$$

$$\tau_D \rightarrow -\frac{1}{\tau}$$

$$f_D(a_D)$$

$$a = -\frac{\partial f_0}{\partial a_D}$$

$$\tau_0 = \frac{1}{\tau} = -\frac{\partial a}{\partial a_D}$$

$$\tau(u)$$

$$a(u), a_0(u)$$

\mathbb{U}



$$W = (0, \frac{1}{2})$$

$$q_n, q_n^\dagger$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2n a|$$

$$a_0 \neq 0 \quad \frac{1}{\tau} = \tau_0 \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_0 + 2n a \neq 0 \quad -\frac{1}{\tau-2} \sim -\frac{i}{2\pi} \log a_0 + 2n$$

$$E \rightarrow B \quad B \rightarrow -E \quad F \rightarrow *F$$

$$\tau_D = -\frac{1}{\tau} \quad f_D(a_D) \quad a = -\frac{\partial f_D}{\partial a_D} \quad \tau_D = \frac{1}{\tau} = -\frac{\partial a}{\partial a_D}$$

$$\tau(u) \quad \Gamma(u) \in SL(2, \mathbb{Z})$$
$$a(u), a_0(u)$$

$$E \rightarrow B \quad B \rightarrow -E \quad F \rightarrow *F$$

$$\tau_D = -\frac{1}{\tau} \quad f_D(a_D) \quad a = -\frac{\partial f_0}{\partial a_D} \quad \tau_D = \frac{1}{\tau} = -\frac{\partial a}{\partial a_D}$$

$$\tau(u) \quad \Gamma(4) \in SL(2, \mathbb{Z}) \quad \begin{pmatrix} a & b \\ c & d \end{pmatrix} \quad b \equiv 0 \pmod{4}$$

$$a(u), a_0(u)$$

$$T^4 = \begin{pmatrix} 1 & 4 \\ 0 & 1 \end{pmatrix} \quad \begin{pmatrix} 1 & \\ 0 & 1 \end{pmatrix} = STS$$

$$u \rightarrow H_{\Gamma(4)}$$

$$E \rightarrow B \quad B \rightarrow -E \quad F \rightarrow *F$$

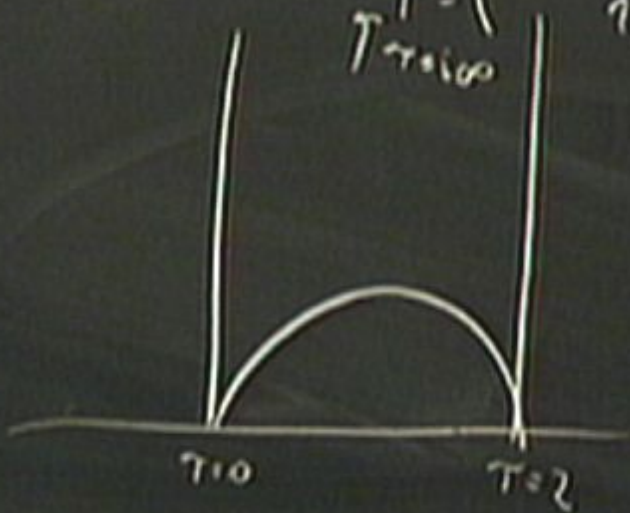
$$\tau_D = -\frac{1}{\tau} \quad f_D(a_D) \quad a = -\frac{\partial F_0}{\partial a_D} \quad \tau_D = -\frac{1}{\tau} = -\frac{\partial a}{\partial a_D}$$

$$\tau(u) \quad \Gamma(4) \in SL(2, \mathbb{Z}) \quad \begin{pmatrix} a & b \\ c & d \end{pmatrix} \quad b \equiv 0 \pmod{4}$$

$$a(u), a_0(u)$$

$$u \rightarrow H_{\Gamma(4)}$$

$$\tau^4 = \begin{pmatrix} 1 & 4 \\ 0 & 1 \end{pmatrix} \quad \begin{pmatrix} 1 & \\ 0 & 1 \end{pmatrix} = S$$



$$E \rightarrow B \quad B \rightarrow -E$$

$$F \rightarrow *F$$

$$\tau_D = -\frac{1}{\tau}$$

$$f_D(a_D)$$

$$a = -\frac{\partial f_0}{\partial a_D}$$

$$\tau_D = \frac{1}{\tau} = -\frac{\partial a}{\partial a_D}$$

$$\tau(u) \quad \Gamma(4) \in SL(2, \mathbb{Z})$$

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix}$$

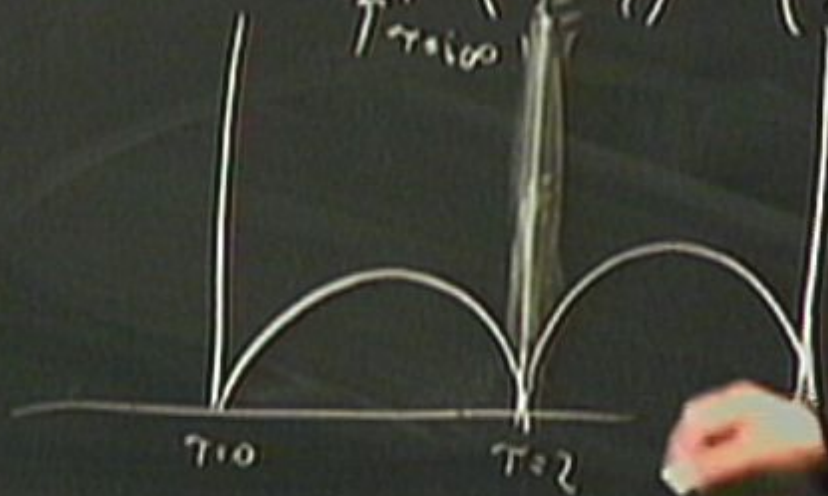
$$b \equiv 0 \pmod{4}$$

$$a(u), a_0(u)$$

$$\tau^4 = \begin{pmatrix} 1 & 4 \\ 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} 1 & \\ 0 & 1 \end{pmatrix} = S$$

$$u \rightarrow H_{\Gamma(4)}$$



$$E \rightarrow B \quad B \rightarrow -E \quad F \rightarrow *F$$

$$\tau_D = -\frac{1}{\tau} \quad f_D(a_D) \quad a = -\frac{\partial f_0}{\partial a_D} \quad \tau_0 = \frac{1}{\tau} = -\frac{\partial a}{\partial a_D}$$

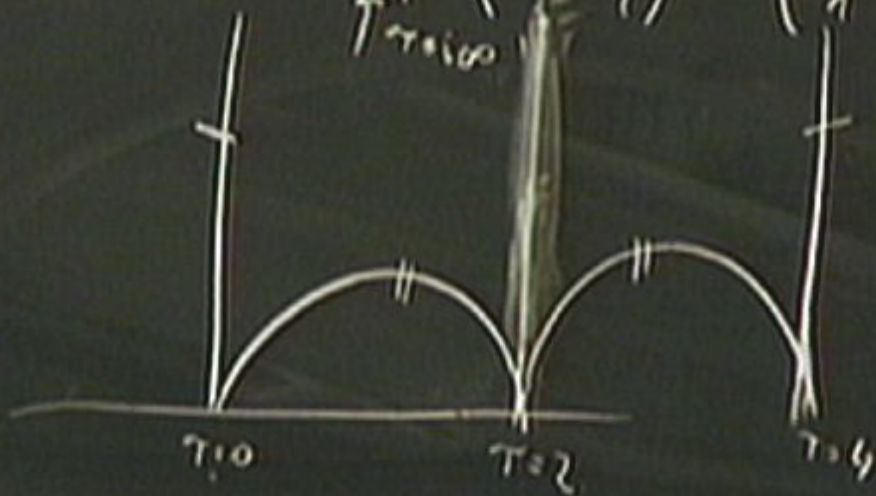
$$\tau(u) \quad \Gamma(4) \in SL(2, \mathbb{Z}) \quad \begin{pmatrix} a & b \\ c & d \end{pmatrix} \quad b \equiv 0 \pmod{4}$$

$$a(u), a_0(u)$$

$$\tau^4 = \begin{pmatrix} 1 & 4 \\ 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} 1 & \\ 0 & 1 \end{pmatrix} = STS$$

$$u \rightarrow H_{\Gamma(4)}$$



\mathbb{U}



$$W = (0, 2) \\ q_-, q_+$$

$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2n a_1|$$

$$a_0 + 0 \cdot \frac{1}{\tau} = \tau_0 \sim -\frac{i}{2\pi} \log$$

$$a \sim -\frac{i}{2\pi} a_0 \log a$$

$$a_0 + 2a + 0 \cdot \frac{1}{\tau-2} \sim$$

$v \rightarrow E_T$

$\frac{1}{2}v$



$$v \rightarrow E_T$$

~~$\omega = \frac{1}{2} \epsilon_{ij} \omega_{ij}$~~



$$\int_{\gamma_1} \omega = \frac{\partial \phi}{\partial u}$$
$$\int_{\gamma_2} \omega = \frac{\partial \phi}{\partial v}$$

$v \rightarrow E_T$

ω, ψ



$$\int_{\mathcal{R}_3} \omega = \frac{\partial a}{\partial v}$$

$$\int_{\mathcal{R}_i} \omega = \frac{\partial a_0}{\partial v}$$

$$v \rightarrow E_T$$

~~h, v~~



$$\int_{r_0} \omega = \frac{\partial a}{\partial v}$$

$$\int_{x_i} \omega = \frac{\partial a_0}{\partial v}$$

$$y^2 = \Lambda^2 z^3 + 2v z^2 + \Lambda^2$$



$$v \rightarrow E_T$$

~~h.v~~



$$\int_{r_1}^{r_2} \omega = \frac{\partial a}{\partial v}$$

$$\int_{r_1}^{r_2} \omega = \frac{\partial a_0}{\partial v}$$

$$y^2 = \Lambda^2 z^3 + 2v z^2 + \Lambda^2 z$$

$$\omega = \frac{dz}{y}$$

$v \rightarrow E_T$

~~λ, ν~~



$$\int_{r_0}^{\infty} \omega = \frac{\partial a}{\partial v}$$

$$\int_{r_0}^{\infty} \omega = \frac{\partial a_0}{\partial v}$$

$$y^2 = \lambda^2 z^3 + 2\nu z^2 + \lambda^2 z$$

$$\omega = \frac{dz}{y}$$

$$U \rightarrow E_T$$

λ, ν



$$\int_{\gamma_0} \omega = \frac{\partial a}{\partial U}$$

$$y^2 = \Lambda^2 z^3 + 2U z^2 + \Lambda^2 z$$

$$\int_{\gamma_i} \omega = \frac{\partial a_0}{\partial U}$$

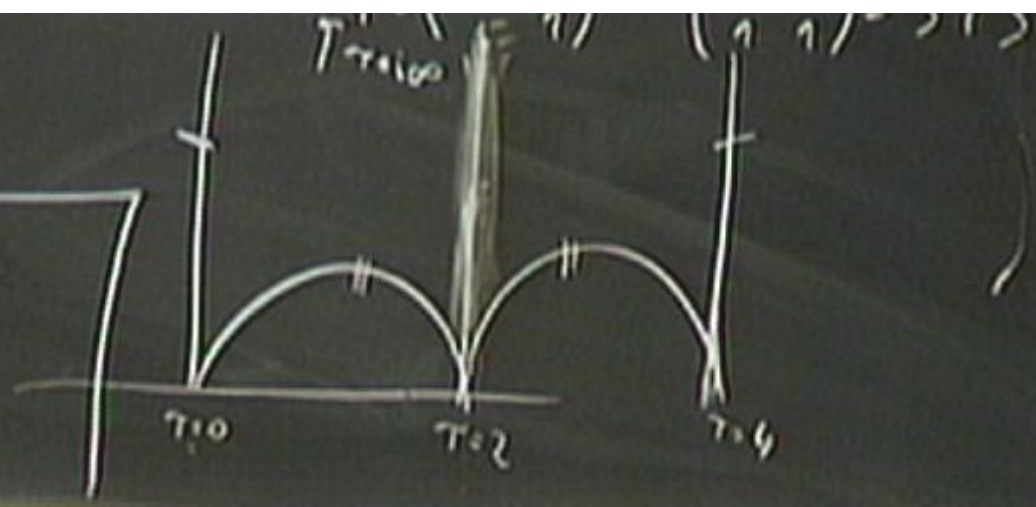
$$\omega = \frac{dz}{y}$$

$$U \gg \Lambda^2, |z| \sim 1$$

$$y \sim \sqrt{2U} z$$

$$\frac{1}{2\pi i} \int_{|z|=1} \frac{dz}{y} \sim \frac{1}{\sqrt{2U}} \sim \frac{\partial a}{\partial U}$$

$$U \rightarrow H_K(u)$$



$$\frac{\partial a_0}{\partial u}$$

$$\omega = \frac{dz}{y}$$

$$z, |z| \sim 1$$

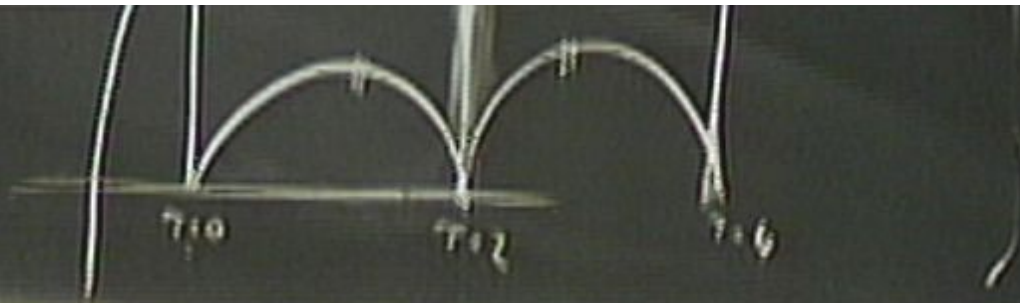
$$y \sim \sqrt{2u} z$$

$$\frac{1}{2\pi i} \int \frac{dz}{y} \approx \frac{1}{i\sqrt{2u}} \approx \frac{\partial a}{\partial u}$$

$$z \sim \frac{\Lambda^2}{2u}$$

$$|z| \gg 1 \Rightarrow \omega \sim \frac{2u}{\Lambda^2}$$

x



$\int_{\tau_0}^{\tau_1} \omega$
 $\frac{\partial a}{\partial u}$
 $\int_{\tau_0}^{\tau_1} \omega$
 $\frac{\partial a}{\partial v}$

$$y^2 = \lambda^2 z^3 + 2\nu z^2 + \lambda^2 z$$

$$\omega = \frac{dz}{y}$$

$\cup \gg \lambda$

$$\frac{1}{2\pi i} \int_{|z|=1} \frac{dz}{y} \sim \frac{1}{i\sqrt{2\nu}} \sim \frac{\partial a}{\partial \nu}$$

$|z| \ll 1 \quad z$

$$\omega \sim \frac{2\nu}{\lambda^2}$$

x



$$\int_{x_1}^{x_2} \omega \frac{\partial a}{\partial u}$$

$$\int_{x_2}^{x_3} \omega \frac{\partial a_0}{\partial u}$$

$$y^2 = \lambda^2 z^3 + \nu z^2 + \lambda^2 z$$

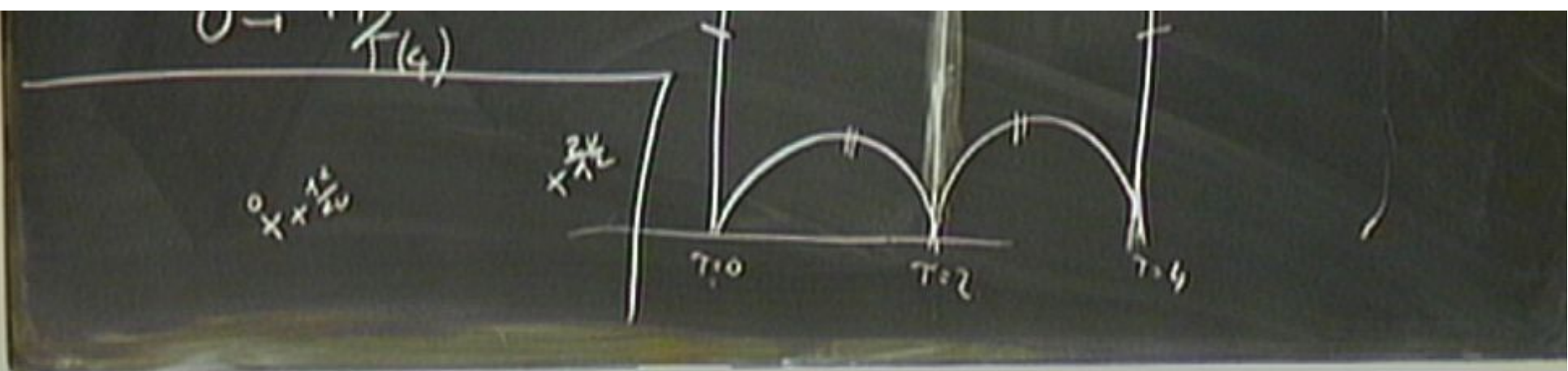
$$\omega = \frac{dz}{y}$$

$$U \gg \lambda$$

$$\frac{1}{2\pi i} \int_{|z|=1} \frac{dz}{y} \approx \frac{1}{i\sqrt{2U}} \approx \frac{\partial a}{\partial U}$$

$$|z| \ll 1 \quad z$$

$$y^2 \approx \frac{2U}{\lambda^2}$$



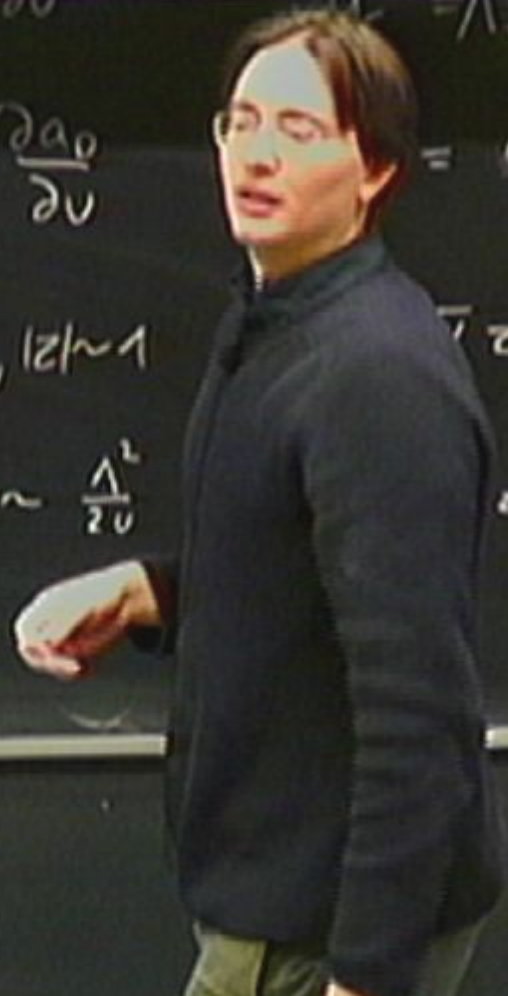
$$\int_{\partial_i} \omega = \frac{\partial a_0}{\partial u} = \frac{dz}{y}$$

$$U \gg \Lambda^2, |z| \sim 1$$

$$|z| \ll 1, z \sim \frac{\Lambda^2}{2U}$$

$$\frac{1}{2\pi i} \int_{|z|=1} \frac{dz}{y} \sim \frac{1}{i\sqrt{2U}} \sim \frac{\partial a}{\partial u}$$

$$z \sim \frac{2U}{\Lambda^2}$$



$0 \rightarrow K(u)$

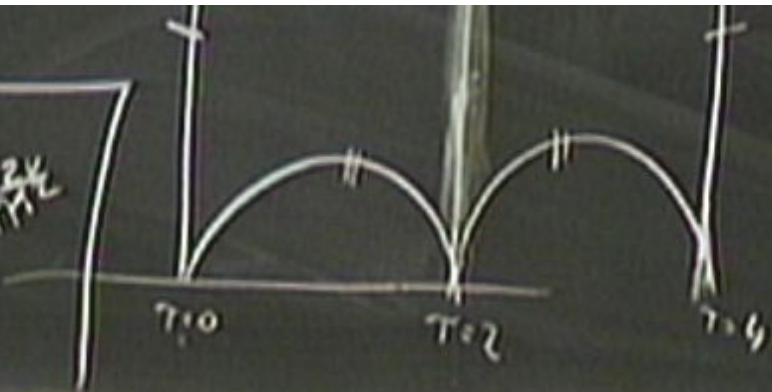


$\frac{2u}{x} + \frac{i}{2u}$

$\tau=0$

$\tau=2$

$\tau=4$



$$y = -\lambda z^2 + 2u z + \lambda z$$

$$\omega = \frac{dz}{y}$$

$$\frac{\partial a}{\partial u}$$

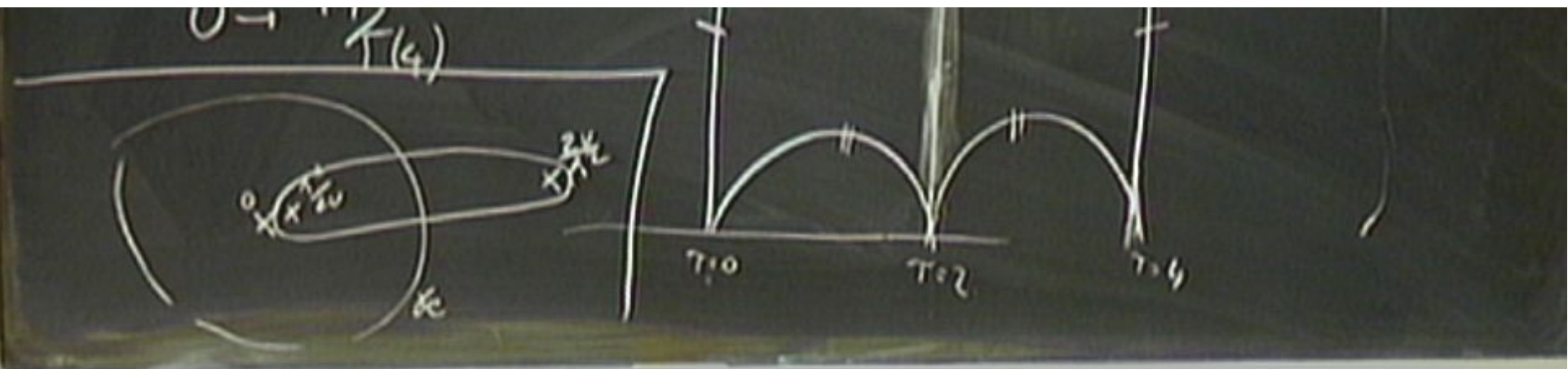
$$|z| \sim 1$$

$$y \sim \sqrt{2u} z$$

$$\frac{1}{2\pi i} \int_{|z|=1} \frac{dz}{y} \approx \frac{1}{i\sqrt{2u}} \approx \frac{\partial a}{\partial u}$$

$$\sim \frac{\lambda^2}{2u}$$

$$|z| \gg 1 \Rightarrow \omega \sim \frac{2u}{\lambda z}$$

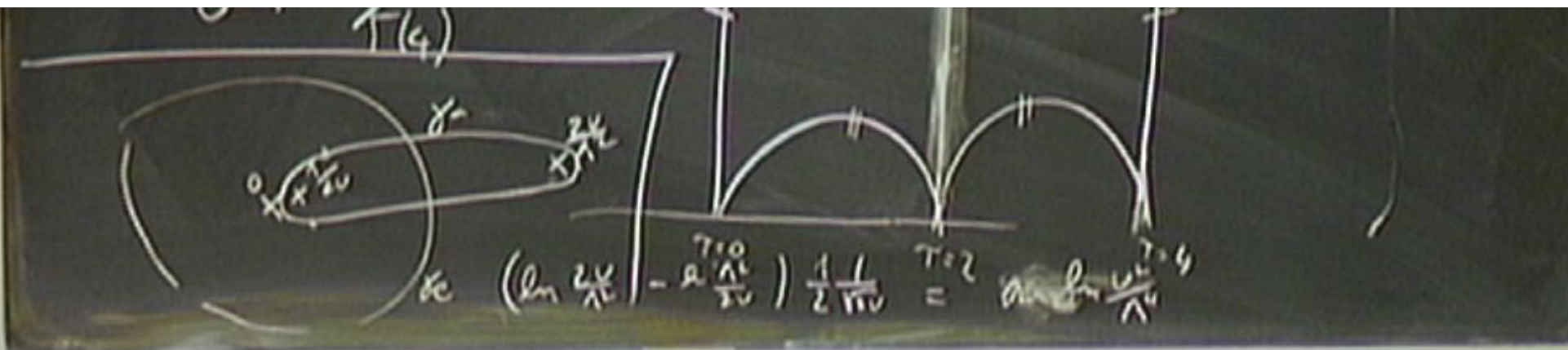


$$y = \Lambda z^2 + 2U z + \Lambda z$$

$$\int_{\gamma_i} \omega = \frac{\partial a_0}{\partial U} \quad \omega = \frac{dz}{y}$$

$$U \gg \Lambda^2, |z| \sim 1 \quad y \sim \sqrt{2U} z \quad \frac{1}{4\pi i} \int_{|z|=1} \frac{dz}{y} \sim \frac{1}{i\sqrt{2U}} \sim \frac{\partial a}{\partial U}$$

$$|z| \ll 1 \quad z \sim \frac{\Lambda^2}{2U} \quad |z| \gg 1 \quad z \sim \frac{2U}{\Lambda^2}$$



$$y' = \Lambda z^3 + 2\nu z^2 + \Lambda z$$

$$\omega = \frac{\partial a_0}{\partial \nu}$$

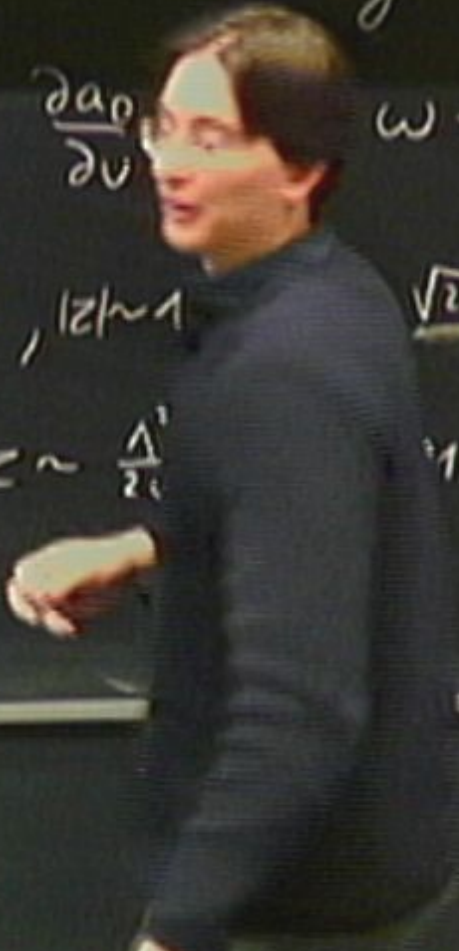
$$\omega = \frac{dz}{y}$$

$$U \gg \Lambda^2, |z| \sim 1$$

$$\frac{1}{2\pi i} \int_{|z|=1} \frac{dz}{y} \approx \frac{1}{i\sqrt{2U}} \approx \frac{\partial a}{\partial \nu}$$

$$|z| \ll 1, z \sim \frac{\Lambda}{z_1}$$

$$1 \approx \frac{2\nu}{\Lambda^2}$$



$$U \rightarrow E_T$$

diff



$$\int_{r_0} \omega = \frac{\partial a}{\partial U}$$

$$y^2 = \Lambda^2 z^3 + 2U z^2 + \Lambda^2 z$$

$$\int_{x_i} \omega = \frac{\partial a_0}{\partial U}$$

$$\omega = \frac{dz}{y}$$

$$U \gg \Lambda^2, |z| \sim 1$$

$$y \sim \sqrt{2U} z$$

$$\frac{1}{2\pi i} \int_{|z|=1} \frac{dz}{y} \sim \frac{1}{i\sqrt{2}}$$

$$|z| \ll 1 \quad z \sim \frac{\Lambda^2}{2U}$$

$$|z| \gg 1 \quad z \sim \frac{2U}{\Lambda^2}$$

$v \rightarrow E_T$

$$\int_{r_n} \omega = \frac{\partial a}{\partial v}$$

$$\int_{r_i} \omega = \frac{\partial a_0}{\partial v}$$

$v \gg \Lambda^2, |z| \sim 1$

$|z| \ll 1 \quad z \sim \frac{\Lambda^2}{2v}$



$$y^2 = \Lambda^2 z^3 + 2v z^2 + \Lambda^2 z$$

$$\omega = \frac{dz}{y}$$

$y \sim \sqrt{2v} z$

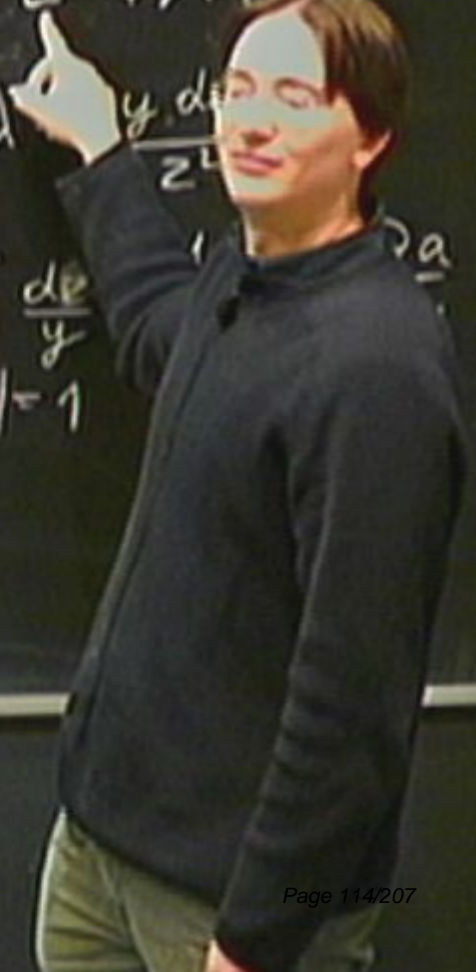
$|z| \gg 1 \quad \omega \sim \frac{2v}{\Lambda^2}$

$$a = \int_{r_i} \lambda$$

$$a_0 = \int_{r_n} \lambda$$

$$\frac{1}{2\pi i} \int \frac{dz}{y}$$

$|z|=1$



$U \rightarrow E_T$

$$\int_{\gamma_n} \omega = \frac{\partial a}{\partial U}$$

$$\int_{\gamma_i} \omega = \frac{\partial a_0}{\partial U}$$



$$a = \int_{\gamma_c} \lambda$$

$$a_0 = \int_{\gamma_n} \lambda$$

$$y^2 = \Lambda^2 z^3 + 2U z^2 + \Lambda^2 z$$

$$\omega = \frac{dz}{y}$$

$$\lambda = \frac{y \cdot dz}{z^2}$$

$$U \gg \Lambda^2, |z| \sim 1$$

$$y \sim \sqrt{2U} z$$

$$\frac{1}{2\pi i} \int_{|z|=1} \frac{dz}{y} \sim \frac{1}{i\sqrt{2U}} \sim \frac{\partial a}{\partial U}$$

$$|z| \ll 1 \quad z \sim \frac{\Lambda^2}{2U}$$

$$|z| \gg 1 \quad z \sim \frac{2U}{\Lambda^2}$$

$SU(2) \quad N_f = 1$

Υ

$$SU(2) \quad N_f = 1$$

$$\Upsilon = \frac{i}{\pi} \ln \frac{a^4}{14} - i$$

$$SU(2) \quad N_f = 1$$

$$T = \frac{i}{2\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a_0 = \frac{a^4}{\Lambda^4} - \frac{i}{2\pi}$$

$$SU(2) \quad N_f = 1$$

$$\Upsilon = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a_0 \sim \frac{i}{\pi} a \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} (a+m) \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} (a-m) \ln \frac{a-m}{\Lambda}$$

$$m \gg \Lambda^2$$

$$a \sim t m$$

$$U \sim m^2$$

$$L U$$

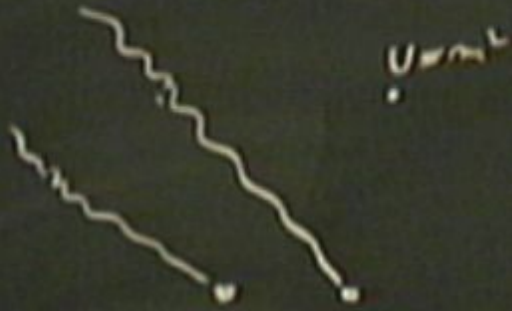
$$U \sim m^2$$

$$m \gg \Lambda^2$$

$$a \sim t m$$

$$U \sim m^2$$

$$L U$$



$$m^2 \gg \Lambda^2$$

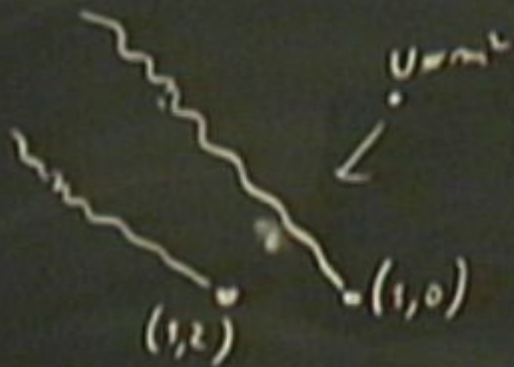
$$a \sim \pm m$$

$$v \sim m^2$$

$$m^2 \ll 0$$

$\perp v$

$\perp v$



$$(1,1)$$

$$(1,0)$$

$$(1,2)$$

$$m \gg \Lambda^2$$

$$a \sim t m$$

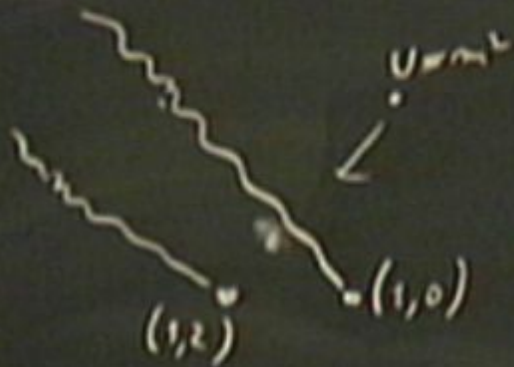
$$v \sim m^2$$

$$m^2 \ll 0$$

$$(1, n)$$

$\perp v$

$\perp v$



$$(1,1)$$

$$(1,0)$$

$$(1,2)$$

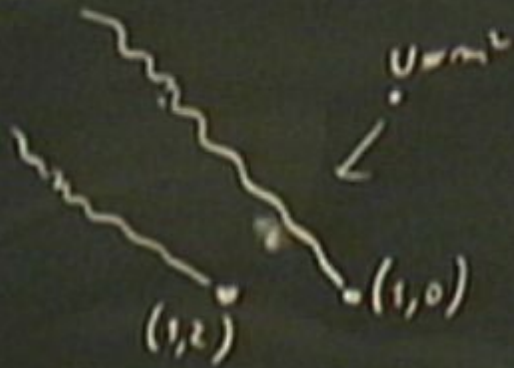
$$m \gg \Lambda^2$$

$$a \sim \pm m$$

$$v \sim m^2$$

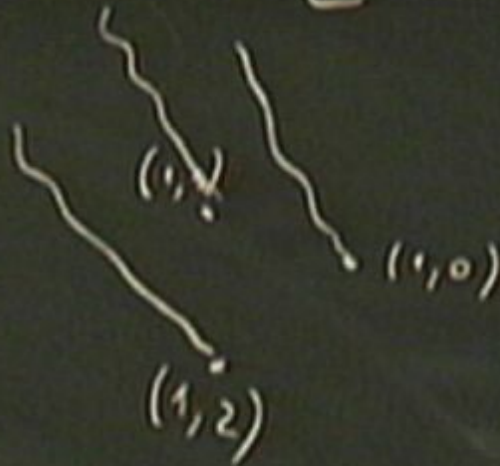
$$(1, n)$$

$\perp v$



$$m^2 \ll 0$$

$\perp v$



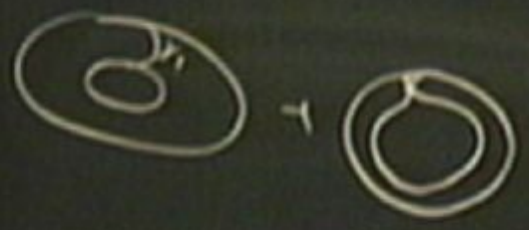
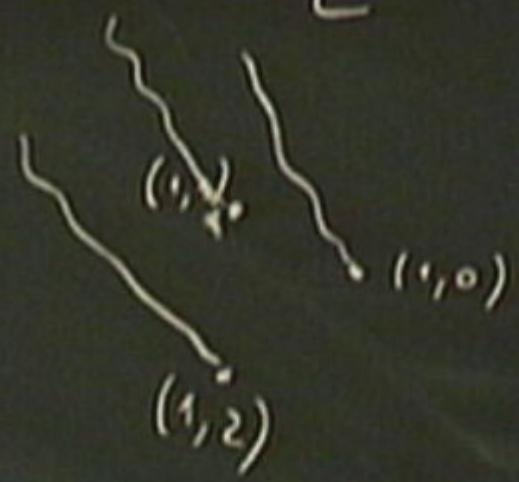
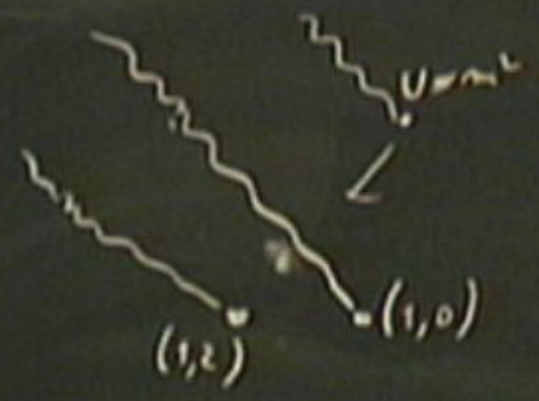
$$m^2 \gg \Lambda^2$$

$$a \sim \pm m$$

$$V \sim m^2$$

$$m^2 = 0$$

$$(n, m)$$



$$\gamma \rightarrow \gamma + \gamma, \langle \gamma, \gamma, \gamma \rangle$$

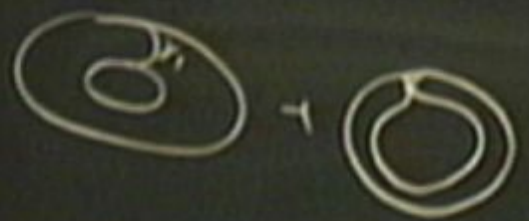
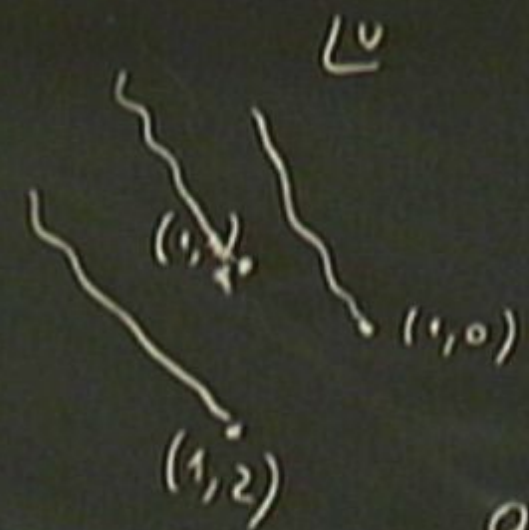
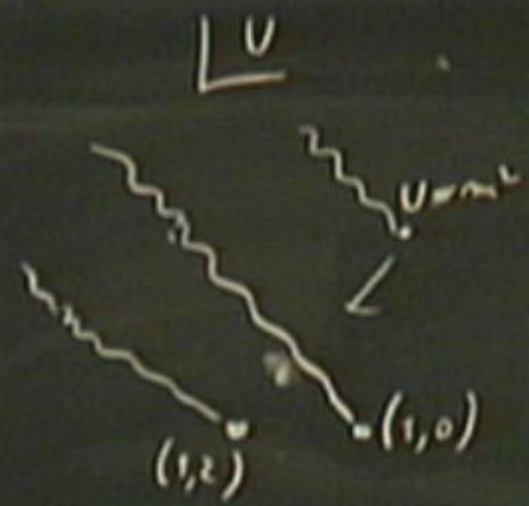


$$m^2 \gg \Lambda^2$$

$$a \sim \pm m$$

$$U \sim m^2$$

$$(1, n)$$



$$\gamma \rightarrow \gamma + \gamma, \langle \gamma, \gamma \rangle$$

$$q \rightarrow q + q, \langle q, q \rangle$$

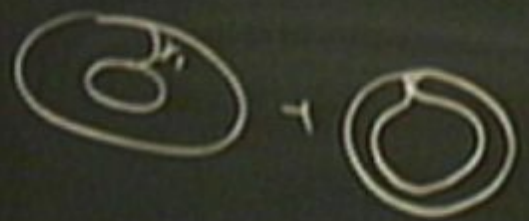
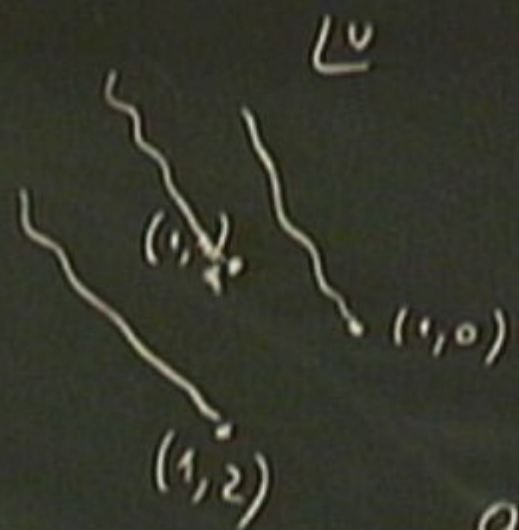
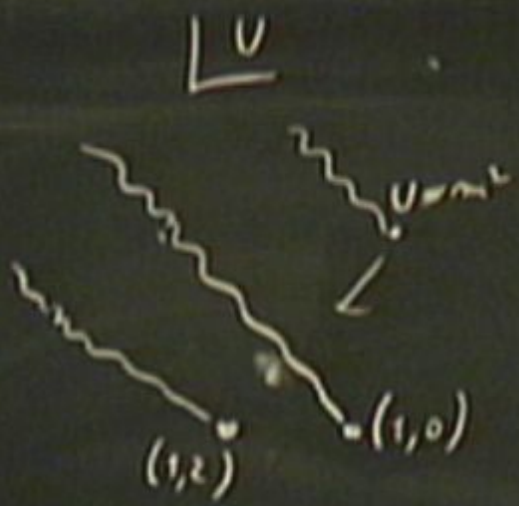
$$\langle q, q \rangle = q_1 q_2 - q_2 q_1$$

$$m \gg \Lambda^2$$

$$a \sim \pm m$$

$$v \sim m^2$$

$$(1, n)$$



$$\gamma \rightarrow \gamma + \gamma, \langle \gamma, \gamma \rangle$$

$$\frac{\partial}{\partial c} = \int \omega$$

$$q \rightarrow q + q, \langle q, q \rangle$$

$$\langle q, q \rangle = q_1 q_2 - q_2 q_1$$

$$m^2 \gg \Lambda^2$$

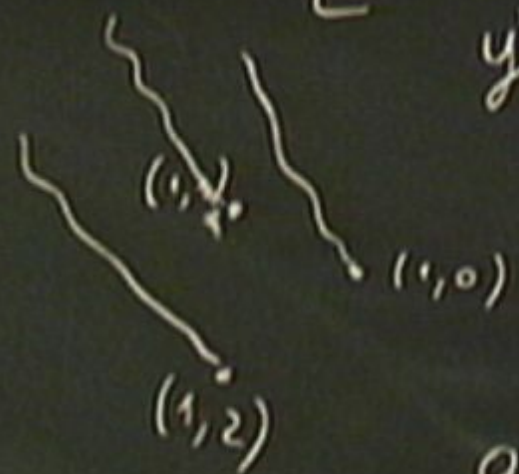
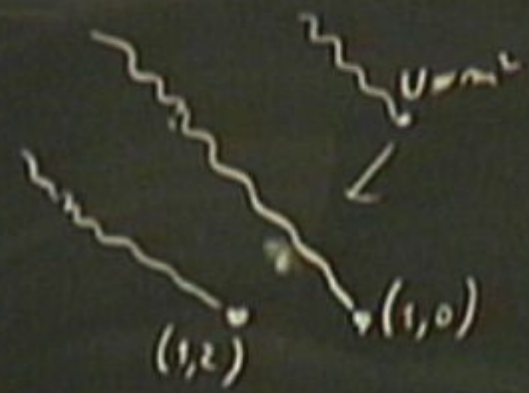
$$a \sim +m$$

$$v \sim m^2$$

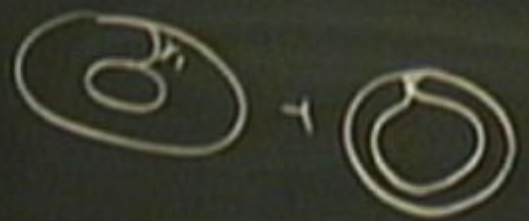
$$m^2 = 0$$

$$(1, n)$$

$$\perp v$$

$$\perp v$$


$$y^L = \Lambda^2 z^3 + 2v z^2 + 2\Lambda z + \Lambda^2$$



$$\gamma \rightarrow \gamma + \gamma, \langle \gamma, \gamma \rangle$$

$$\frac{\partial^2 \mathcal{L}}{\partial \alpha^2} = \int \mathcal{L} \gamma$$

$$q \rightarrow q + q, \langle q, q \rangle$$

$$m \gg \Lambda^2$$

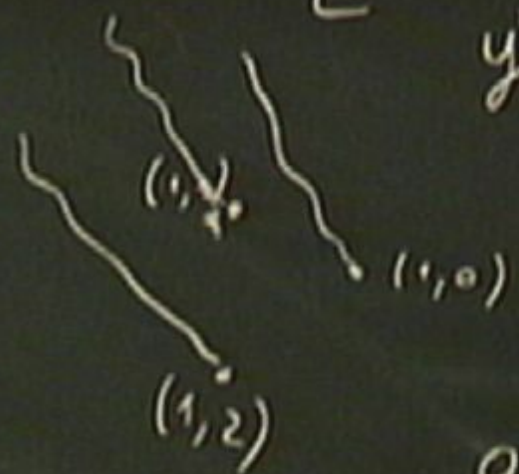
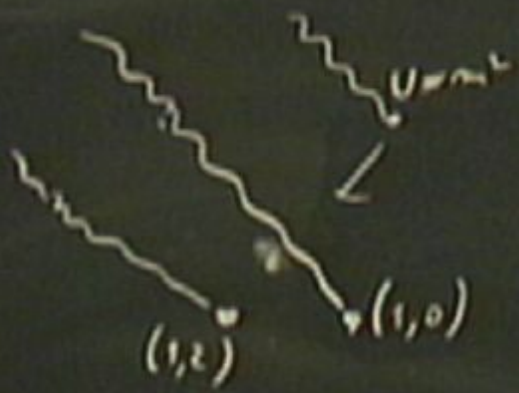
$$a \sim \pm m$$

$$U \sim m^2$$

$$m^2 = 0$$

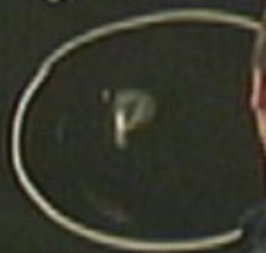
$$(1, m)$$

$$\perp U$$

$$\perp U$$


$$y^2 = \Lambda^2 z^3 + 2Uz^2 + 2\Lambda z + \Lambda^2$$

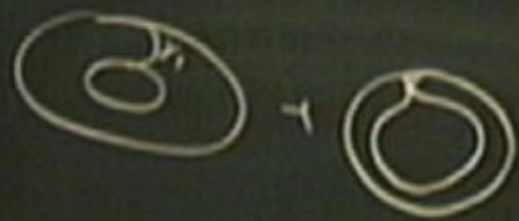
$$U \gg \Lambda^2 \quad m \gg \Lambda$$



$$q \rightarrow q + 0$$

$$q + b + 0$$

$$\langle q \rangle$$



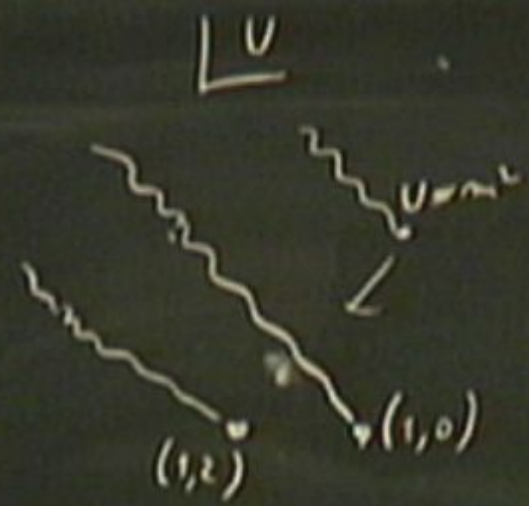
$$y \rightarrow y + y, \langle y, y \rangle$$

$$\frac{\partial^2}{\partial x^2 \partial y^2} = \int \dots$$

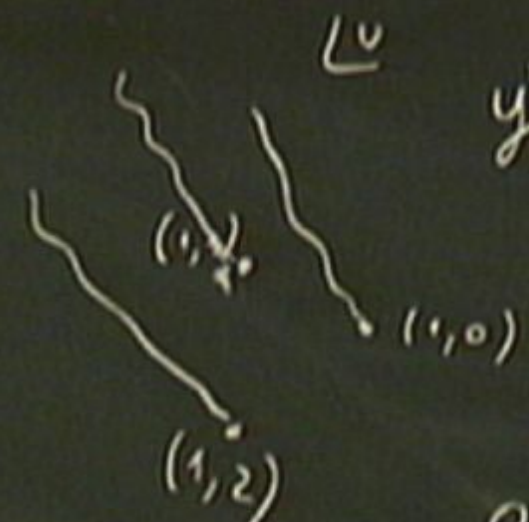
$$m \gg \Lambda^2$$

$$a \sim +m$$

$$U \sim m^2$$



$$m^2 = 0$$



$$(1, m) \frac{dz}{y}$$

$$y^2 = \Lambda^2 z^3 + 2Uz^2 + 2\Lambda z + \Lambda^2$$

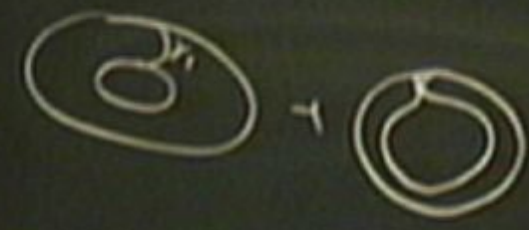
$$U \gg \Lambda^2 \quad m \gg \Lambda \quad \times$$



$$|z|=1$$

$$q \rightarrow q + q_1 \langle q, q_1 \rangle$$

$$\langle q, q_1 \rangle = q_1 q_2 - q_2 q_1$$



$$\gamma \rightarrow \gamma + \gamma_i \langle \gamma, \gamma_i \rangle$$

$$\frac{\partial \log \zeta}{\partial c} = \int \frac{1}{\zeta} \frac{\partial \zeta}{\partial c}$$

$$m \gg \Lambda^2$$

$$a \sim +m$$

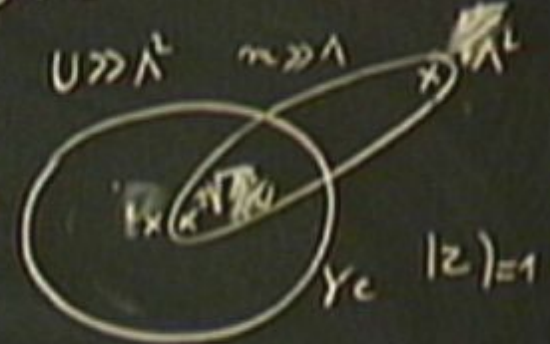
$$U \sim m^2$$

$$m^2 = 0$$

$$(1, m) \frac{dz}{y}$$

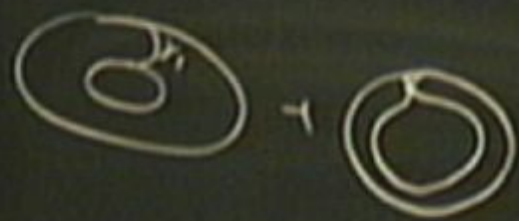
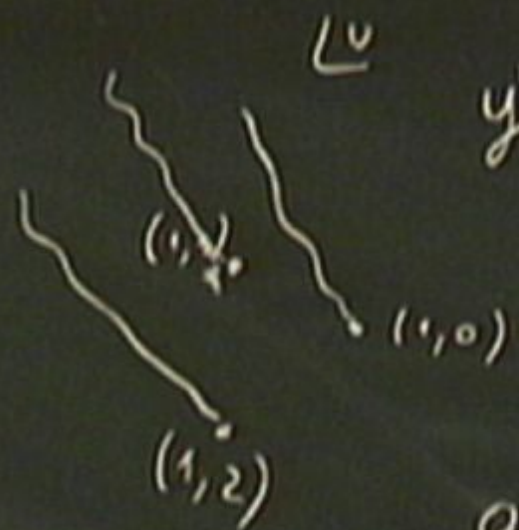
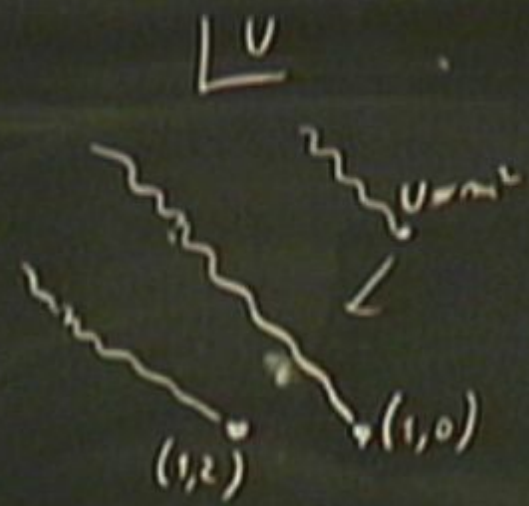
$$y^2 = \Lambda^2 z^3 + 2Uz^2 + 2\Lambda z + \Lambda^2$$

$$U \gg \Lambda^2 \quad m \gg 1$$



$$q \rightarrow q + q_1 \langle q, q_1 \rangle$$

$$\langle q, q_1 \rangle = q_c q_1^2 - q_c q_1$$



$$y \rightarrow y + y_1 \langle y, y_1 \rangle$$

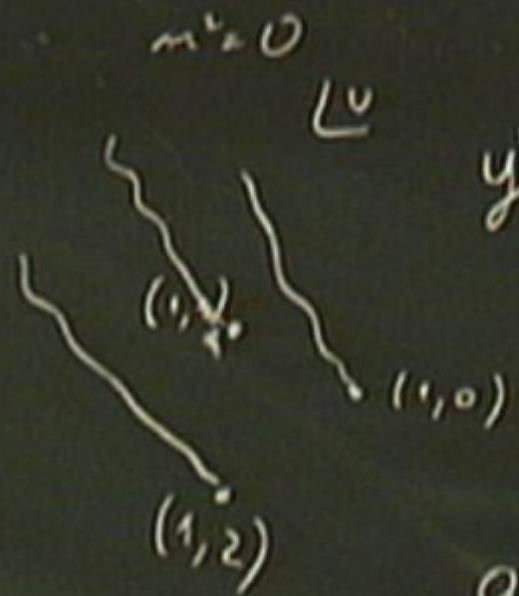
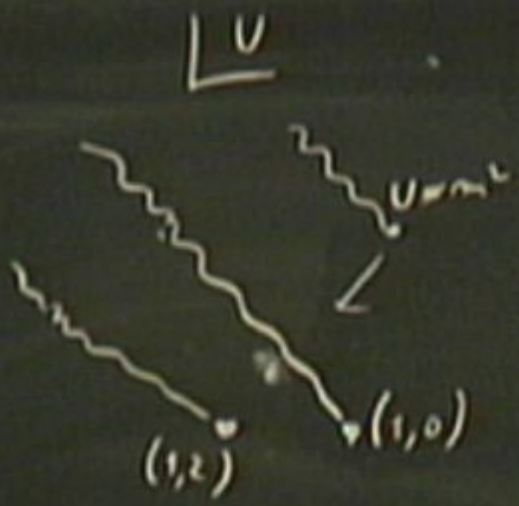
$$\frac{\partial \mathcal{L}}{\partial x} = \int \mathcal{L} \frac{\partial x}{\partial y}$$

$SU(2) \quad N_f = 1$

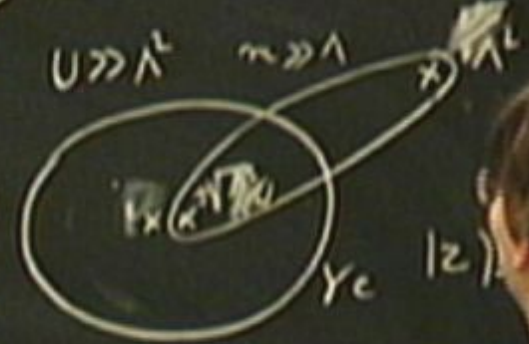
$$\Upsilon = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a_0 \sim \frac{i}{\pi} a \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} (a+m) \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} (a-m) \ln \frac{a-m}{\Lambda}$$

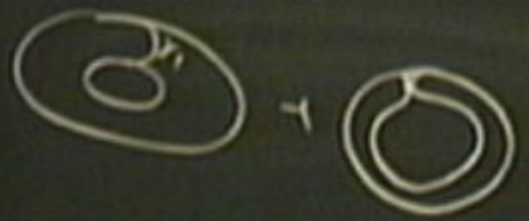
$m \gg \Lambda^2$ $a \sim +m$ $U \sim m^2$



$(1, m) \frac{dz}{y}$
 $y^2 = \Lambda^2 z^3 + 2Uz^2 + 2\Lambda z + \Lambda^2$



$U \gg \Lambda^2 \quad m \gg 1$
 $q \rightarrow q + q_1 \langle q, q_1 \rangle$
 $\langle q, q_1 \rangle = q_1 q^2$



$\gamma \rightarrow \gamma + \gamma_1 \langle \gamma, \gamma_1 \rangle$
 $\frac{\partial \mathcal{L}}{\partial c} = \int \omega$
 $\frac{\partial \mathcal{L}}{\partial c} = \int \omega$

$$SU(2) \quad N_f = 1$$

$$Y = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a_0 \sim \frac{i}{\pi} a \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} (a+m) \ln \frac{(a+m)}{\Lambda} - \frac{i}{2\pi} (a-m) \ln \frac{a-m}{\Lambda}$$

$$SU(2) \quad N_f = 4$$

$$y^2 = P_3(z, U, m_a)$$

m_a CARTAN OF $SO(8)$

$$SU(2) \quad N_f = 1$$

$$T = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a_0 \sim \frac{i}{\pi} a \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} (a+m) \ln \frac{(a+m)}{\Lambda} - \frac{i}{2\pi} (a-m) \ln \frac{a-m}{\Lambda}$$

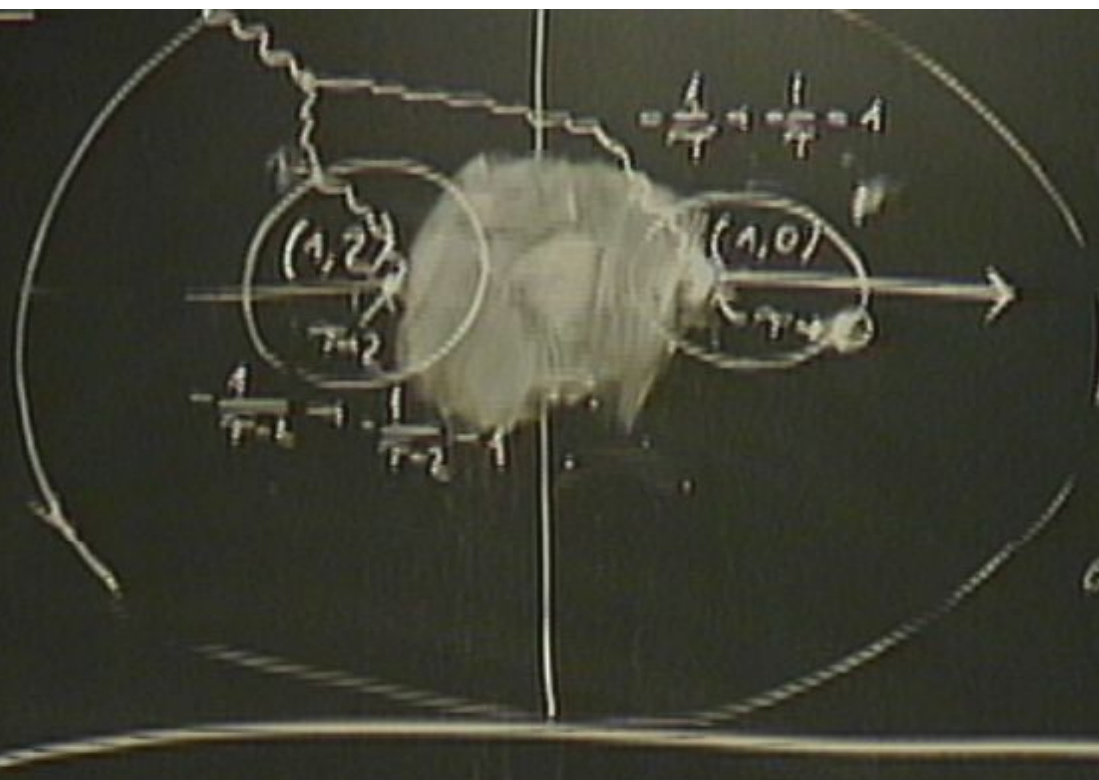
$$SU(2) \quad N_f = 4$$

$$y^2 = P_3(z, U, m_a)$$

m_a CARTAN OF $SO(8)$

$$\sum m_i^2 \quad \sum m_i^4 \quad \sum m_i^6$$

$$\prod m_i$$



$$q_n, q_0'$$

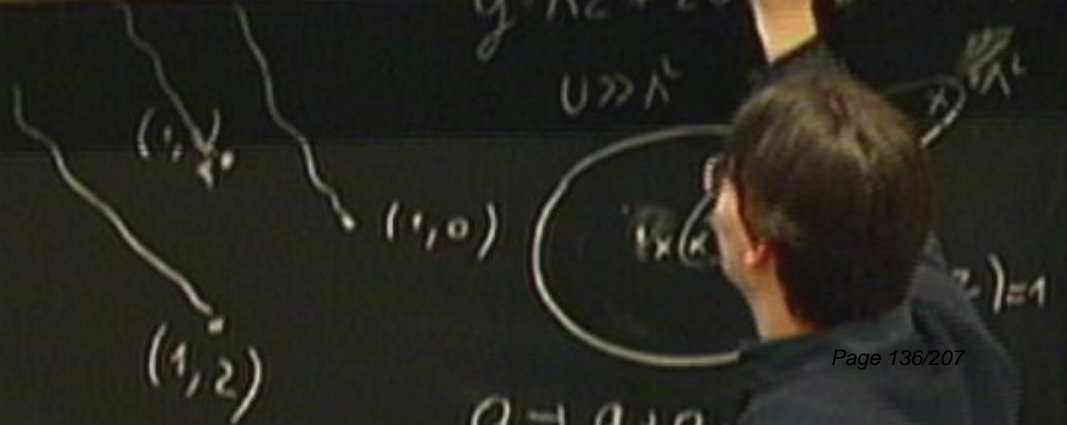
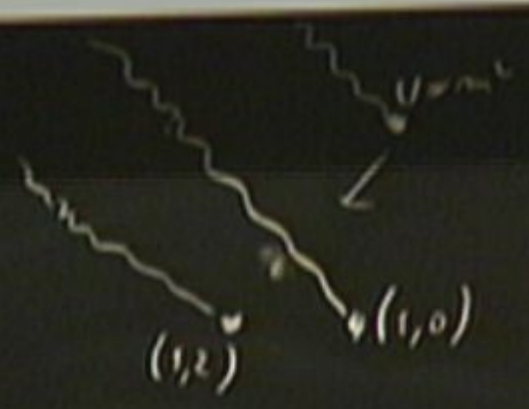
$$\pm(1, \pm 2n) \quad n \in \mathbb{Z}$$

$$M_n = |a_0 + 2n a|$$

$$a_0 + 0 \frac{1}{T} \sim T_0 \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_0 + 2n a \sim -\frac{1}{T-2} \sim -\frac{i}{2\pi} \log(a_0 + 2n a)$$



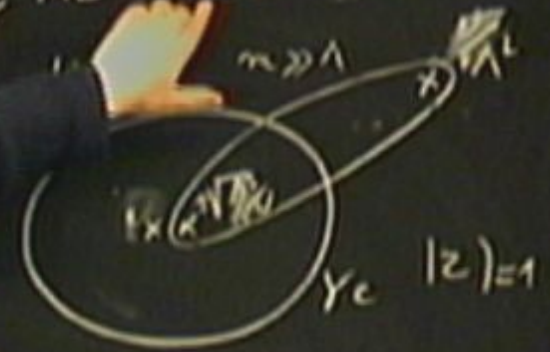
$$2\pi = 2\pi_0 + 2\pi$$

$$m^2 = 0$$

$$(n, m) \quad \omega = \frac{d\epsilon}{dy}$$

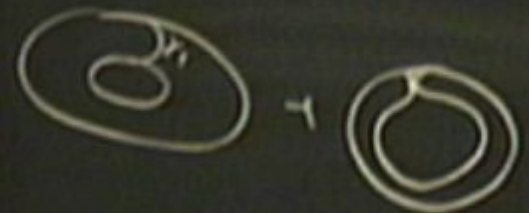
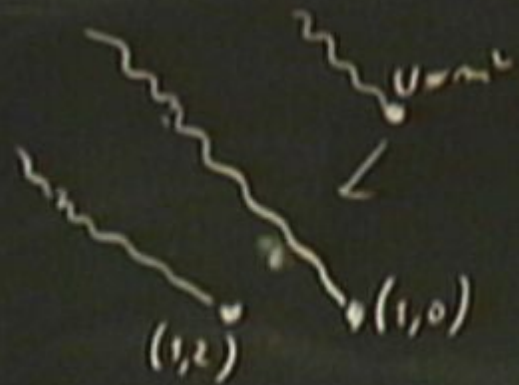
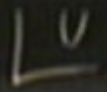
$$y^2 = \Lambda^2 z^2 + 2\nu z + 2\Lambda z + \Lambda^2$$

$$m \gg 1$$



$$q \rightarrow q + q_1 < q, q_1 >$$

$$< q, q_1 > = q_1 q_2 - q_2 q_1$$



$$y \rightarrow y + y_1 < y, y_1 >$$

$$\frac{\partial \epsilon}{\partial c} = \frac{\partial \epsilon}{\partial c} + \frac{\partial \epsilon}{\partial c}$$

$$\lambda = y \frac{dz}{z^2}$$

$$m^2 \gg \Lambda^2$$

$$a \sim \pm m$$

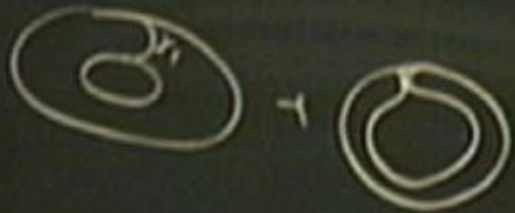
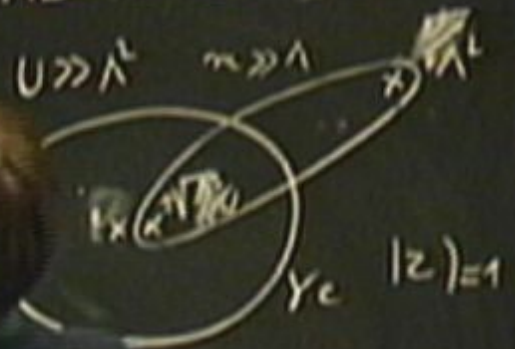
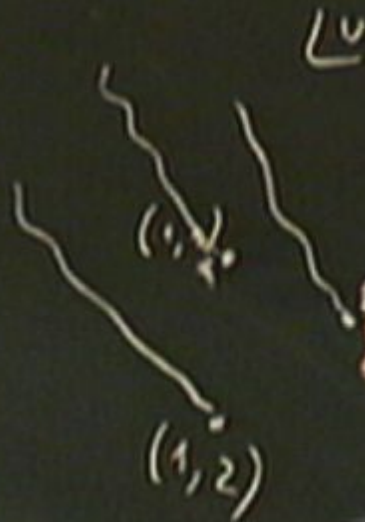
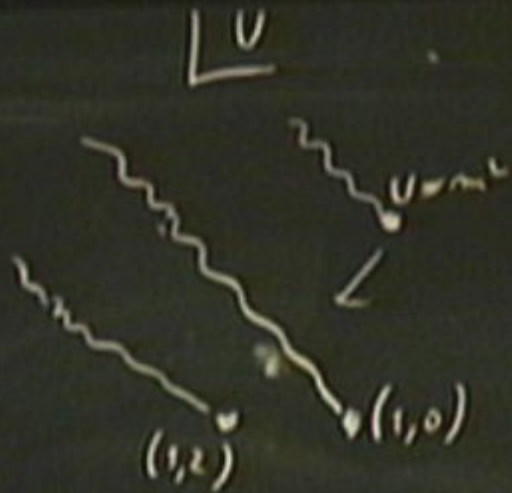
$$U \sim m^2$$

$$m^2 = 0$$

$$(1, m) \quad W = \frac{dz}{y}$$

$$y^2 = \Lambda^2 z^3 + 2Uz^2 + 2\Lambda z + \Lambda^2$$

$$U \gg \Lambda^2 \quad m \gg 1$$



$$\gamma \rightarrow \gamma + \gamma, \langle \gamma, \gamma \rangle$$

$$\int_{\gamma} \frac{dx}{y} = \frac{0}{2\pi i} = \frac{0}{2\pi i}$$

$$\langle q, q \rangle$$

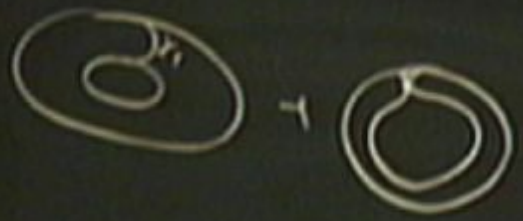
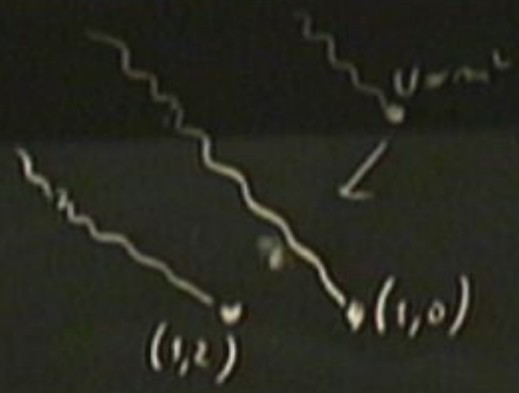
$$q_1 q_2 - q_3 q_4$$

$$a_{D+2a} \sim -\frac{1}{\gamma-2} \sim -\frac{i}{2\pi} \ln a_{D+2a}$$

$$\lambda = y \frac{dz}{z^2} \quad \lambda_0 = y_0 \frac{de}{z^2} = \frac{1}{i} \frac{z z^L}{y} \frac{dz^r}{z^2} = \frac{de}{y} = \omega$$

$$y = \Lambda z^3 + 2v z^2 + d + \Lambda z + \Lambda$$

$U \gg \Lambda^2 \quad m \gg \Lambda$



$$\gamma \rightarrow \gamma + \gamma \rightarrow \langle \gamma, \gamma \rangle$$

$$\int_{\gamma} \omega = \int_{\gamma} \frac{de}{y}$$

$$\int_{\gamma} \omega = \int_{\gamma} \frac{de}{y}$$

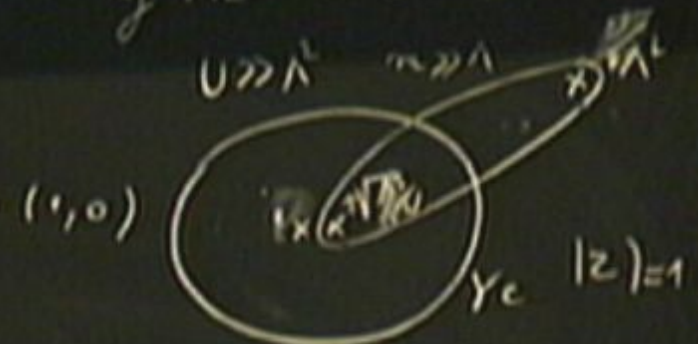
$$a_{D+2a} \neq 0 \quad -\frac{1}{\gamma-2} \sim -\frac{c}{2\pi} \ln a_{D+2a}$$

$$\lambda = y \frac{dz}{z^2} \quad \lambda_0 = y_0 \frac{dz}{z^2} = \frac{1}{c} \frac{2z^L}{y} \frac{dz^c}{z^2} = \frac{dz}{y} = \omega$$

$$\lambda^L = \frac{dz^L}{z^L} \left(\frac{\Lambda^L}{z} + 2 \right)$$

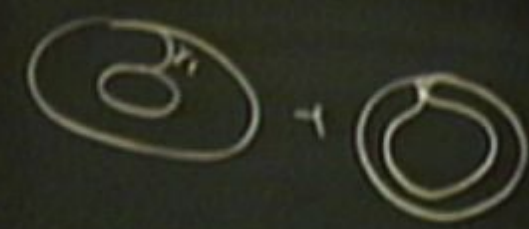
$$y^L = \Lambda^L z^2 + 2u z^2 + 2 + \Lambda z + \Lambda^L$$

$$u \gg \Lambda^L \quad m \gg 1$$



$$q + q + q_1 \langle q, q_1 \rangle$$

$$\langle q, q_1 \rangle = q_1 q_1^* - q_1 q_1^1$$



specific

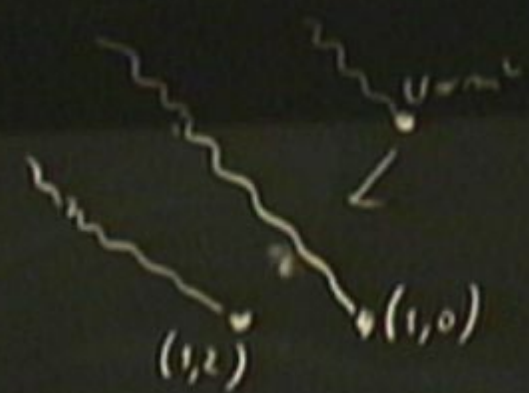
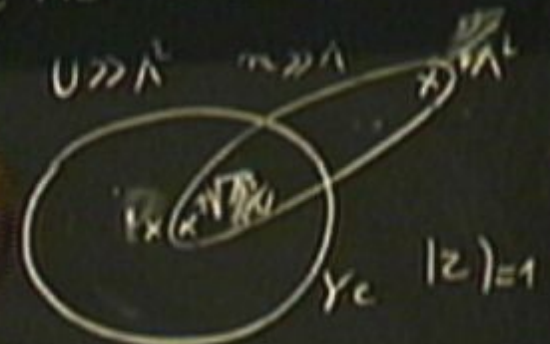
$$a_{D+2a} \sim -\frac{1}{\gamma-2} \sim -\frac{c}{2\pi} \ln a_{D+2a}$$

$$\lambda = y \frac{dz}{z^2} \quad \lambda_0 = y_0 \frac{dz}{z^2} = \frac{1}{c} \frac{2z^L}{y} \frac{dz^r}{z^2} = \frac{dc}{y} = \omega$$

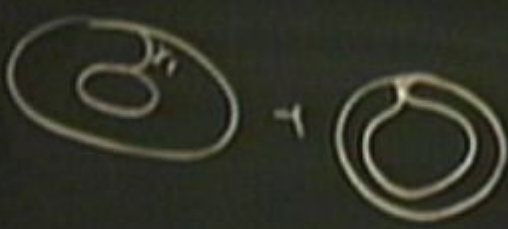
$$\lambda^L = \frac{dz^L}{z^L} \left(\frac{\Lambda^L}{z} + 2U + \frac{2\Delta^L}{z} + \frac{\Lambda^L}{z^L} \right)$$

$$y^L = \Lambda^L z^3 + 2U z^2 + 2\Lambda^L z + \Lambda^L$$

$$U \gg \Lambda^L \quad m \gg \Lambda^L$$



(1,2)



$$y \rightarrow x + y, \langle x, y \rangle$$

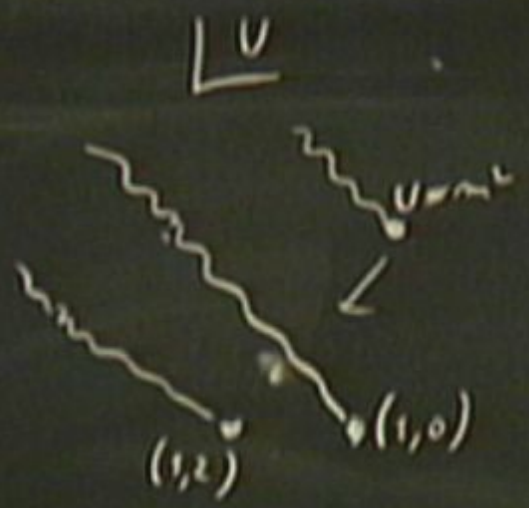
$$\frac{\partial}{\partial c} = \frac{\partial}{\partial \Lambda^L}$$

$$\rightarrow q + q_1 \langle q, q_1 \rangle$$

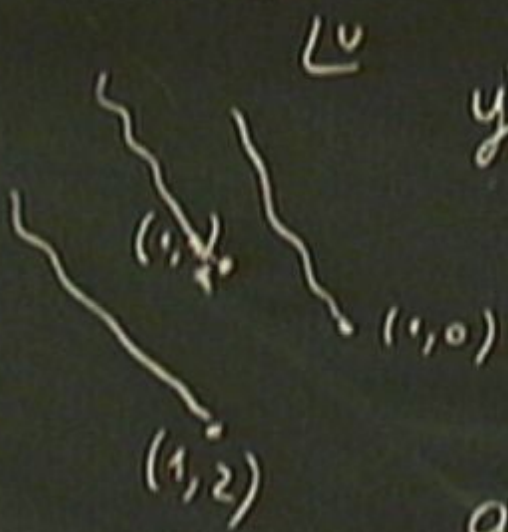
$$\langle q, q_1 \rangle = q_1 q_2 - q - q_1$$

$$\lambda = \frac{c}{2L} \left(\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} \right)$$

$$m^2 \gg \Lambda^2 \quad a \sim \pm m \quad v \sim m^2$$



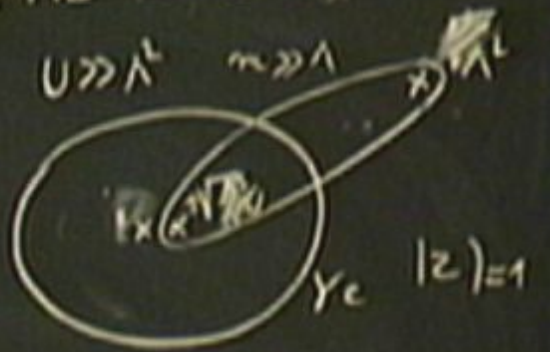
$$m^2 = 0$$



$$(1, m) \quad \omega = \frac{d^2 z}{y}$$

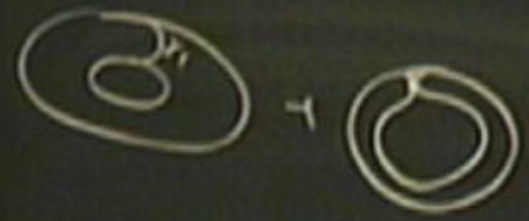
$$y^2 = \Lambda^2 z^3 + 2vz^2 + 2\Lambda z + \Lambda^2$$

$$v \gg \Lambda^2 \quad m \gg 1$$



$$q \rightarrow q + q_1 \langle q, q_1 \rangle$$

$$\langle q, q_1 \rangle = q_1 q_2 - q_1 q_1$$



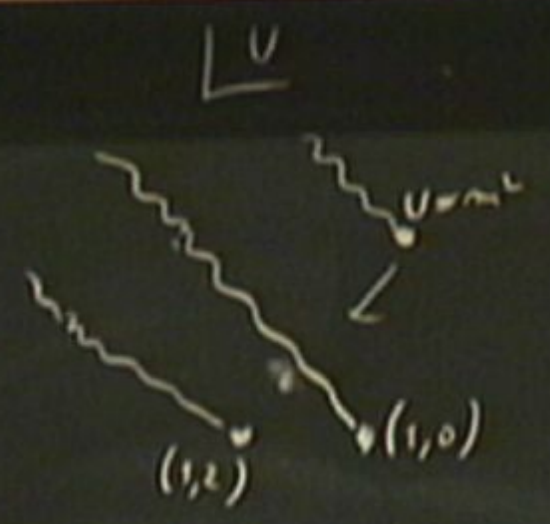
$$\langle \gamma, \gamma \rangle = \gamma + \gamma + \gamma$$

$$\int_{\gamma} \frac{dx}{y} = \frac{0}{2\pi i} \frac{1}{e}$$

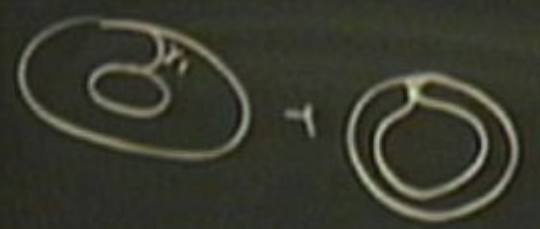
$$\gamma - 2 \sim -\frac{c}{2\pi} \ln a_0 + 2a$$

$$\lambda = y \frac{dz}{z^2} \quad \lambda_U = y_U \frac{dz}{z^2} = \frac{1}{c} \frac{z z^c}{y} \frac{dz^c}{z^2} = \frac{dz^c}{y} = \omega$$

$$\lambda^L = \frac{dz^L}{z^L} \left(\Lambda^L z + 2U + \frac{2\Lambda^L y}{z} + \frac{\Lambda^L z^L}{z^L} \right) \quad \lambda^L = \frac{dz^L}{z^L} (\Lambda^L z + 2U)$$



$$y' = \Lambda^L + 2U z' + 2\Lambda^L z$$



$$\langle \cdot, \cdot \rangle = \int_{\mathcal{C}} \omega \otimes \omega$$

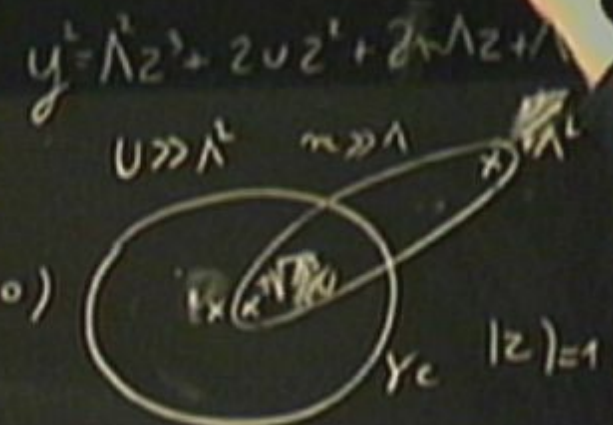
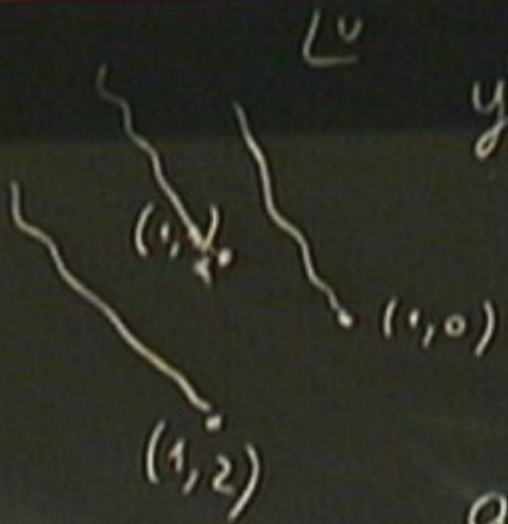
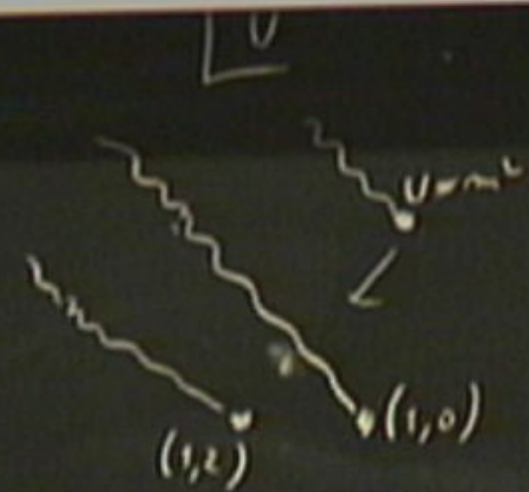
$$\frac{\partial}{\partial c} \frac{\partial}{\partial c} = \frac{\partial^2}{\partial c^2}$$

g →

$$\frac{1}{\gamma-2} \sim -\frac{1}{2\pi} \ln a_0 + 2a$$

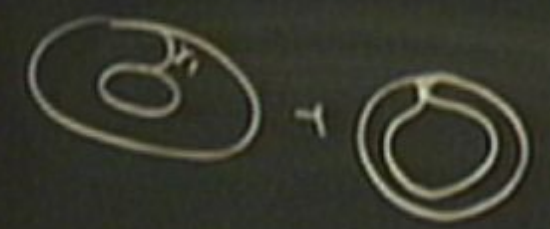
$$\lambda = y \frac{dz}{z^2} \quad \lambda_0 = y_0 \frac{dz}{z^2} = \frac{1}{c} \frac{z z^c}{y} \frac{dz}{z^2} = \frac{dz}{y} = \omega$$

$$\lambda^L = \frac{dz^L}{z^L} \left(\Lambda^L z + 2\nu + \frac{2\Lambda^L y}{z} + \frac{\Lambda^L}{z^2} \right) \quad \lambda^L = \frac{dz^L}{z^L} \left(\Lambda^L z + 2\nu + \frac{\Lambda^L}{z} \right)$$



$$q \rightarrow q + q_1 \langle q, q_1 \rangle$$

$$\langle q, q_1 \rangle = q_1 q_2 - q_2 q_1$$



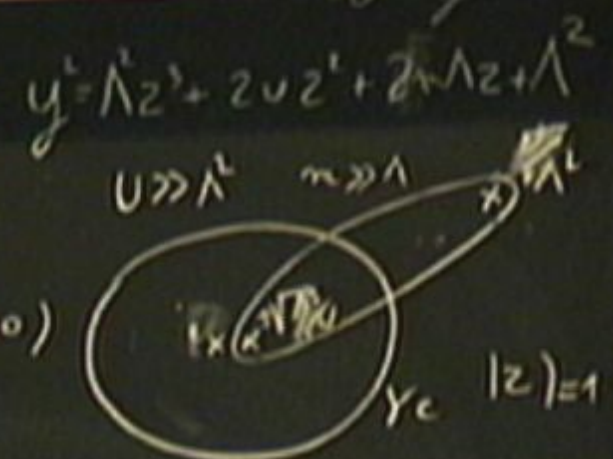
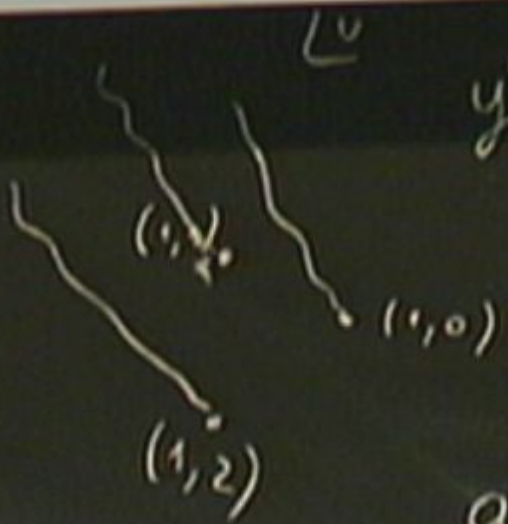
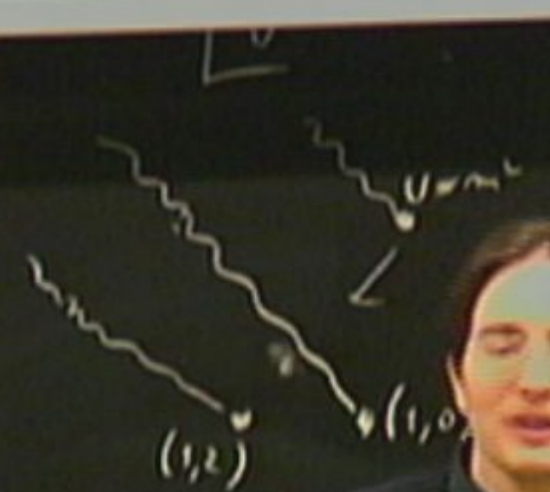
$$\gamma \rightarrow \gamma + \gamma_1 \langle \gamma, \gamma_1 \rangle$$

$$\frac{\partial \mathcal{H}}{\partial c} = \int \mathcal{H} \frac{\partial \mathcal{H}}{\partial c} = 0$$

$$v \ll c \quad \frac{1}{\gamma - 2} \sim -\frac{c}{2\pi} \ln a_0 + 2\pi$$

$$\lambda = y \frac{dz}{z^2} \quad \lambda_0 = y_0 \frac{dz}{z^2} = \frac{1}{c} \frac{2z^L}{y} \frac{dz^L}{z^2} = \frac{dc}{y} = \omega$$

$$z \rightarrow 0 \quad \lambda \sim \frac{\Lambda}{z^2} + \frac{\nu}{z} + \dots \quad \lambda^L = \frac{dz^L}{z^L} \left(\frac{\Lambda^L}{z} + 2\nu + \frac{2\Lambda\nu}{z} + \frac{\Lambda^L}{z^2} \right) \quad \lambda^L = \frac{dz^L}{z^L} \left(\Lambda^L z + 2\nu + \frac{\Lambda^L}{z} \right)$$



$$q \rightarrow q + q_1 \langle q, q_1 \rangle$$

$$\langle q, q_1 \rangle = q_1 q_1^* - q_0 - q_0^1$$

$$-\frac{1}{T-2} = \frac{1}{T-2} - 1$$

$$a_0 \rightarrow 0 \quad \frac{1}{T} \sim \frac{1}{T_0} \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_{D+2} \rightarrow 0 \quad -\frac{1}{T-2} \sim -\frac{i}{2\pi} \log a_{D+2}$$

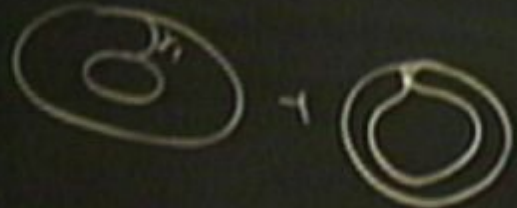
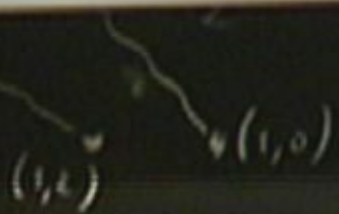
$$Z = q_0 a + q_1 a^0 + q_2 a^{-m}$$

$$\lambda = y \frac{dz}{z^2}$$

$$\lambda_{D+2} = y \frac{dz}{z^2} = \frac{1}{L} \frac{2z^L}{y} \frac{dz^L}{z^2} = \frac{dz^L}{y}$$

$$\lambda^L = \frac{dz^L}{z^L} \left(\frac{\Lambda^L}{L} z + 2V + \frac{2\Lambda^L y}{z} + \frac{\Lambda^L}{z^2} \right) \quad \lambda^L = \frac{dz^L}{z^L} \left(\Lambda^L z + 2V + \frac{\Lambda^L}{z} \right)$$

$$z=0 \quad \lambda \sim \frac{\Lambda}{z} + \frac{\Lambda}{z^2} + \dots$$



$$\gamma = \gamma_1 + \gamma_2 + \gamma_3 \quad \langle \gamma, \gamma \rangle = \langle \gamma_1, \gamma_1 \rangle + \langle \gamma_2, \gamma_2 \rangle + \langle \gamma_3, \gamma_3 \rangle$$

$$\int_{\gamma_1} \frac{dz}{z} = 2\pi i$$

$$q_1 + q_2 + q_3 < q_1, q_2 \rangle$$

$$\langle q_1, q_2 \rangle = q_1 q_2 - q_1 q_2$$

$$\frac{1}{T-2} \sim \frac{1}{T-2} - 1$$

$$a_0 \rightarrow 0 \quad \frac{1}{T} \sim -\frac{i}{2\pi} \log a_0$$

$$a \sim -\frac{i}{2\pi} a_0 \log a_0$$

$$a_{D+2a} \rightarrow 0 \quad -\frac{1}{T-2} \sim -\frac{i}{2\pi} \log a_{D+2a}$$

$$Z = q_1 a + q_2 a_0 + q_3 r^m$$

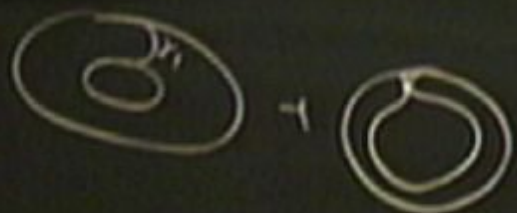
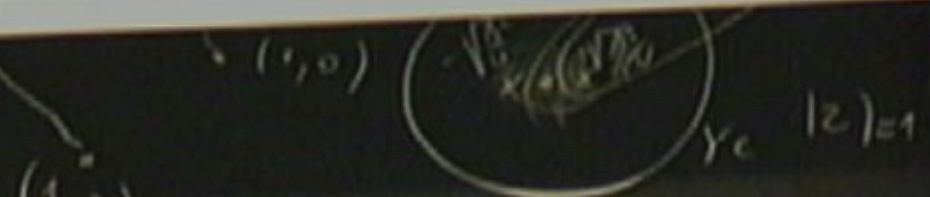
$$Z_y = \int \lambda$$

$$\lambda = y \frac{dz}{z^2}$$

$$\lambda_v = y_v \frac{dz}{z^2} = \frac{1}{i} \frac{z z^L}{y} \frac{dz^r}{z^2} = \frac{dz}{y} = \omega$$

$$z \rightarrow 0 \quad \lambda \sim \frac{\Lambda}{z^2} + \frac{\nu}{z} + \dots$$

$$\lambda^2 = \frac{dz^2}{z^4} \left(\frac{\Lambda^2}{z^2} + 2\nu + \frac{2\Lambda\nu}{z} + \frac{\Lambda^2}{z^2} \right) \quad \lambda^2 = \frac{dz^2}{z^4} \left(\Lambda^2 z + 2\nu + \frac{\Lambda^2}{z} \right)$$



$$\langle x, x \rangle = x + x + x \dots$$

$$\int_{\mathcal{C}} \frac{dz}{z} = 2\pi i$$

$$q + q + q_1 \langle q, q_2 \rangle$$

$$\langle q, q \rangle = q_1 q_2 - q_3 q_4$$

$SU(2) \quad N_f = 1$

$$T = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a_0 \sim \frac{i}{\pi} a \ln$$

$SU(2) \quad N_f = 1$

$$\omega =$$

$$y^2 = P_3(z, U, m_a)$$

m_a CARTAN OF $SO(8)$

$$\sum m_i^2 \quad \sum m_i^2 \quad \sum m_i^2$$

$$\pi m_a$$

$$SU(2) \quad N_f = 1$$

$$T = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a_0 \sim \frac{i}{\pi} a \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} (a+m) \ln \frac{(a+m)}{\Lambda} - \frac{i}{2\pi} (a-m) \ln \frac{(a-m)}{\Lambda}$$

$$SU(2) \quad N_f = 4$$

$$\omega = \frac{dz}{y}$$

$$y^2 = P_3(z, U, m_a)$$

m_a CARTAN OF $SO(8)$
 $\sum m_i^2$ $\sum m_i^4$ $\sum m_i^6$
 πm_a

$SU(2) \quad N_f = 1$

$$Y = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} (a+m) \ln \frac{(a+m)}{\Lambda} - \frac{i}{2\pi} (a-m) \ln \frac{(a-m)}{\Lambda}$$

$N_f = 4$

$$y^2 = P_3(z, U, m_a)$$

m_a CARTAN OF $SO(8)$

$$\sum m_i^2 \quad \sum m_i^4 \quad \sum m_i^6$$

$$\lambda \frac{m_a}{z - z_a}$$

$$SU(2) \quad N_f = 1$$

$$T = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a_0 \sim \frac{i}{\pi} a \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} (a+m) \ln \frac{(a+m)}{\Lambda} - \frac{i}{2\pi} (a-m) \ln \frac{(a-m)}{\Lambda}$$

$$SU(2) \quad N_f = 4$$

$$\omega = \frac{dz}{y}$$

$$y^2 = P_3(z, U, m_a)$$

m_a CARTAN OF $SO(8)$

$$\lambda \sim \frac{m_a}{z - z_n}$$

$$\lambda^8 + P_1 \lambda^6 + P_2 \lambda^4 + \dots$$

$$\sum_{m_n^1} \quad \sum_{m_n^2} \quad \sum_{m_n^3}$$

$$\pi m_a$$

$$SU(2) \quad N_f = 1$$

$$T = \frac{i}{\pi} \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} \ln \frac{a+m}{\Lambda} - \frac{i}{2\pi} \ln \frac{a-m}{\Lambda}$$

$$a_0 \sim \frac{i}{\pi} a \ln \frac{a^4}{\Lambda^4} - \frac{i}{2\pi} (a+m) \ln \frac{(a+m)}{\Lambda} - \frac{i}{2\pi} (a-m) \ln \frac{(a-m)}{\Lambda}$$

$$SU(2) \quad N_f = 4$$

$$\omega = \frac{dz}{y}$$

$$y^2 = P_3(z, U, m_a)$$

m_a CARTAN OF $SO(8)$

$$\lambda \sim \frac{m_a}{z - z_n}$$

$$\lambda^8 + P_1 \lambda^6 + P_2 \lambda^4 + \dots = 0$$

$$\sum m_i^2 \quad \sum m_i^4 \quad \sum m_i^6$$

$$\lambda^2 = \phi_2(z) = R(z) dz^2$$

$$a = \int \lambda$$
$$a_0 = \int \lambda$$

$$y^2 = z^3 + 20z^2 + \lambda z$$

y

\sqrt{y}

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$$

$(m_a, -m_a)$

$$\lambda \sim \pm \frac{m_a}{z - z_a}$$

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$$

$$\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix}$$

$$\lambda \sim \pm \frac{m_a}{z - z_a} dz$$

$$m_a^2$$

$$\lambda^2 \sim \frac{m_a^2}{(z - z_a)^2} dz^2$$

y

~~Handwritten scribbles and crossed-out equations on the chalkboard.~~

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$$

$$\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix}$$

$$\lambda \sim \pm \frac{m_a}{z - z_a} dz$$

$$m_a^2$$

$$\lambda^2 \sim \left(\frac{m_a^2}{(z - z_a)^2} + \dots \right) dz^2$$

y

w

IV

IV

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$

$\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix}$
 m_a^2

$$\lambda \sim \pm \frac{m_a}{z - z_a} dz$$

$$\lambda^2 \sim \oint \left[\frac{m_a^2}{(z - z_a)^2} dz + \frac{\gamma_a \gamma_a}{z - z_a} \right] dz^2$$

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$\lambda^2 \sim \prod_n \left[\frac{m_n^2}{(z-z_n)^2} + \frac{\kappa_n}{z-z_n} \right] dz^2$$

$$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$$

$$\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix}$$

$$\lambda \sim \pm \frac{m_a}{z-z_n} dz$$

$$m_n^2$$

$$\frac{dz}{z} \quad z \pm \frac{1}{2}$$

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$$

$$\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix}$$

$$\lambda \sim \pm \frac{m_c}{z - z_a} dz$$

$$m_a^2$$

$$\lambda^2 \sim \prod_a \left[\frac{m_a^2}{(z - z_a)^2} + \frac{\kappa_a}{z - z_a} \right] dz^2$$

$$\frac{dz^2}{z^4} \quad z + \frac{1}{z}$$

$$\frac{1}{z^2} \quad \frac{1}{z^2} \quad \frac{1}{z^2}$$

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$$

$$\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix} \lambda \sim \pm \frac{m_a}{z - z_a} dz$$

$$\lambda^2 \sim \oint \left[\frac{m_a^2}{(z - z_a)^2} + \frac{m_a}{z - z_a} \right] dz^2$$

$$\frac{dz^2}{z^4} \quad z + \frac{1}{z}$$

$$\lambda^2 = \frac{P_a}{\pi(z - z_a)^2} + \frac{U}{\pi(z - z_a)}$$

$$\frac{1}{z^2} \quad \frac{1}{z^3}$$

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$$

$$\left(\begin{matrix} m_a \\ -m_a \end{matrix} \right) \quad \lambda \sim \pm \frac{m_a}{z-z_a} dz$$

$$\lambda^2 \sim \oint \left[\frac{m_a^2}{(z-z_a)^2} + \frac{\gamma_a}{z-z_a} \right] dz^2$$

$$\lambda^2 = \frac{P_a}{\pi(z-z_a)^2} + \frac{U}{\pi(z-z_a)}$$

$$\frac{dz^2}{z^4} \quad z \sim \frac{1}{z}$$

$$\frac{1}{z^2} \quad \frac{1}{z^2} \quad \frac{1}{z^3}$$



$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$\lambda^2 \sim \oint \left[\frac{m_a^2}{(z-z_n)^2} + \frac{\gamma_n}{z-z_n} \right] dz^2$$

$$\lambda^2 = \frac{P_n}{\pi(z-z_n)^2} + \frac{U}{\pi(z-z_n)}$$

$$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$$

$$\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix} \quad \lambda \sim \pm \frac{m_a}{z-z_n} dz$$

$$m_n^2$$

$$\frac{dz^2}{z^2} \quad \nu = \frac{1}{2}$$



$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$\lambda^2 \sim \prod_a \left[\frac{m_a^2}{(z-z_a)^2} + \frac{\gamma_a}{z-z_a} \right] dz^2$$

$$\lambda^2 = \frac{P_0}{\prod (z-z_a)^2} + \frac{U}{\prod (z-z_a)}$$

$$z_a = 0, 1, q, \infty$$

$$SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$$

$$\left(\begin{matrix} m_a & \\ & -m_a \end{matrix} \right) \lambda \sim \pm \frac{m_c}{z-z_a} dz$$

$$\frac{dz^2}{z^4} \quad z + \frac{1}{z}$$

$$\frac{1}{z^2} \quad \frac{1}{z^3} \quad z \rightarrow \frac{Az+B}{Cz+D}$$



9 >> 1

0.0.0.0

0.0.0.0

2

9

$q \gg 1$

$\frac{1}{2} \frac{1}{2}$

$\frac{1}{2} \frac{1}{2}$

9

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$SU(2)_a \times SU(2)_b \times SU(2)_c$

$$\left(\begin{matrix} m_a \\ -m_a \end{matrix} \right) \lambda \sim \pm \frac{m_a}{z - z_a}$$

$$\lambda^2 \sim \left[\frac{m_a^2}{(z - z_a)^2} + \frac{\kappa_a}{z - z_a} \right] dz^2$$

$$\frac{dz^2}{z^4} \sim \frac{z + \frac{1}{2}}{z^4}$$

$$\lambda^2 = \frac{P_0}{\prod (z - z_a)^2} + \frac{U}{\prod (z - z_a)}$$

$$z_a = 0, 1, q, \infty$$



$9 \gg 1$

$\begin{matrix} 2 & 2 \\ \circ & \circ \end{matrix}$

$\frac{2}{2}$ $\frac{2}{2}$

9

$$9 \gg 1$$



$$\lambda^2 \approx \frac{1}{2}$$

$$q \gg 1$$



$$\lambda^2 \approx \frac{2U}{z^2} \quad \frac{1}{4\pi i} \int_{\gamma_c} \lambda \sim \sqrt{\frac{U}{2}} \sim a$$

$$q \gg 1$$



$$\lambda^2 \sim \frac{2U}{z^2} \quad \frac{1}{4\pi i} \int_{\gamma_c} \lambda \sim \sqrt{\frac{U}{2}} \sim a$$



$$q \gg 1$$



$$\lambda^2 \sim \frac{\gamma_c}{2V} \frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{U}{2}} \sim a$$



$$\lambda^2 \sim \frac{m_i^2}{2V}$$

q

$q \gg 1$



$$\lambda^2 \approx \frac{\gamma_0}{2V} \frac{1}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{V}{2}} \sim a$$



$$\lambda^2 \sim \frac{m_i^2}{z^2(1-z)} + \frac{m_i^2}{15(z-1)^2} + \frac{eV}{z(z+1)}$$

$q \gg 1$



$$\lambda^2 \sim \frac{2U}{\hbar^2} \quad \frac{1}{4\pi i} \int_{\gamma_c} \lambda \sim \sqrt{\frac{2U}{\hbar^2}} \sim a$$



$$\lambda^2 \sim \frac{m_1^2}{2^2(1-z)} + \frac{m_2^2}{15^2(z-1)^2} + \frac{2U}{\hbar^2(z-1)}$$

$$q \gg 1$$



$$\lambda^2 \approx \frac{2U}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{2U}{z}} \sim a$$



$$\lambda^2 \sim \frac{m_1^2}{z^2(1-z)} + \frac{m_2^2}{z^2(1-z)^2} + \frac{2U}{z(1-z)}$$

$$U = (m_1 \pm m_2)^2$$

$q \gg 1$



$$\lambda^2 \approx \frac{2U}{\hbar^2} \quad \frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{U}{2}} \sim a$$



$$\lambda^2 \sim \frac{m_1^2}{2^2(1-2)} + \frac{m_2^2}{1^2(2-1)^2} + \frac{2U}{2(2-1)}$$

$$U = (m_1 \pm m_2)^2$$

$$q \gg 1$$



$$\lambda^2 \approx \frac{2U}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{U}{z}} \sim a$$



$$\lambda^2 \sim \frac{m_1^2}{z^2(1-z)} + \frac{m_2^2}{z^2(z-1)^2} + \frac{2U}{z(z-1)}$$

$$U = (m_1 \pm m_2)^2$$

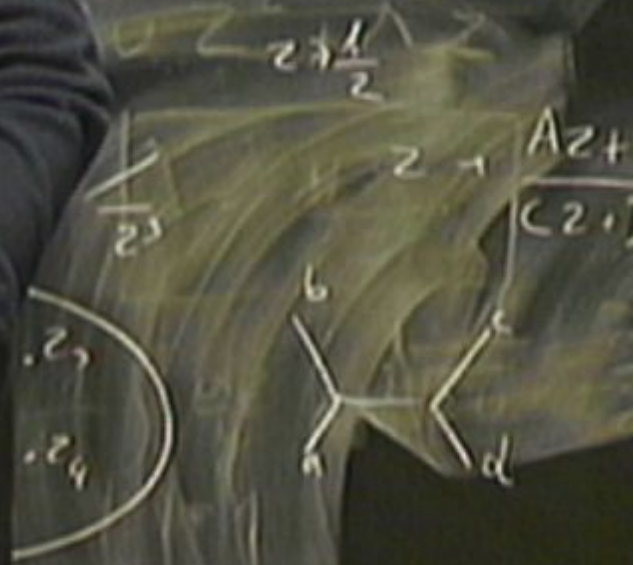
$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$SU(2)_a \times SU(2)_b \times SU(2)_c$
 $(m_a - m_b)$
 m_a^2
 $\lambda \sim \pm \frac{m_a}{z - z_a}$

$$\lambda^2 \sim \oint \left[\frac{m_a^2}{(z - z_a)^2} + \frac{m_a}{z - z_a} \right] dz$$

$$\lambda^2 = \frac{P_a}{\pi(z - z_a)^2} + \frac{U}{\pi(z - z_a)}$$

$$z_a = 0, 1, q, \infty$$



$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$$\lambda^2 \sim \prod_n \left[\frac{m_n^2}{(z-z_n)^2} + \frac{c_n}{z-z_n} \right] dz^2$$

$$\lambda^2 = \frac{P_0}{\prod (z-z_n)^2} + \frac{U}{\prod (z-z_n)}$$

$$z_n = 0, 1, q, \infty$$

max mb $\rightarrow SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$

$$\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix}$$

$$m_n^2$$

$$\lambda \sim \pm \frac{m_n}{z-z_n} dz$$

$$\frac{dz^2}{z^4} \quad z \pm \frac{1}{2}$$

$$\frac{1}{z} \quad \frac{1}{z^2} \quad \frac{1}{z^3}$$

$$\frac{Az+B}{Cz+D}$$



$$q \gg 1$$



$$\lambda^2 \sim \frac{2U}{z^2} \quad \frac{1}{4\pi i} \int \lambda \sim \frac{\sqrt{2U}}{2} \sim a$$



$$\lambda^2 \sim \frac{m_i^2}{z^2(1-z)} + \frac{m_i^2}{z^2(z-1)^2} + \frac{c}{z}$$

$$U = (m_a \pm m_b)^2$$



$$U = (m_c \pm \dots)^2$$

$$q \gg 1$$

\mathbb{R}



$$\lambda^2 \sim \frac{2V}{2^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{2V}{2}} \sim a$$



$$\lambda^2 \sim \frac{m_1^2}{2^2(1-2)} + \frac{m_2^2}{1^2(2-1)^2} + \frac{2V}{2(2-1)}$$

$$U = (m_a \pm m_b)^2$$



$$U = (m_c \pm m_d)^2$$

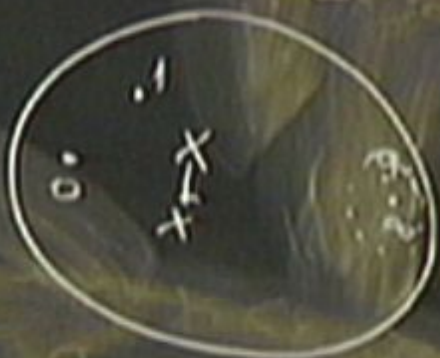
$$q \gg 1$$

\mathbb{R}



$$\lambda^2 \sim \frac{2V}{2z}$$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{2V}{z}} \sim a$$



$$\lambda^2 \sim \frac{m_1^2}{z^2(1-z)} + \frac{m_2^2}{z^2(1-z)^2} + \frac{2V}{z(1-z)}$$

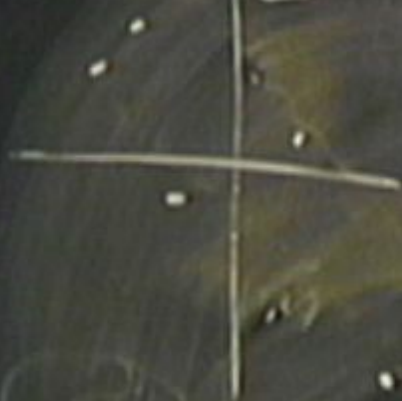
$$U = (m_a \pm m_b)^2$$



$$U = (m_c \pm m_d)^2$$

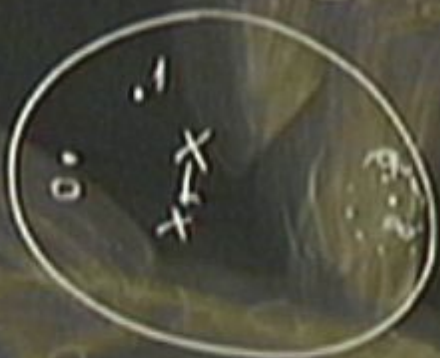
$$q \gg 1$$

\mathbb{R}



$$\lambda^2 \sim \frac{2V}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \frac{\sqrt{2V}}{z} \sim a$$



$$\lambda^2 \sim \frac{m_a^2}{z^2(1-z)} + \frac{m_b^2}{z^2(z-1)^2} + \frac{2V}{z(z-1)}$$

$$U = (m_a \pm m_b)^2$$



$$U = (m_a \pm m_b)^2$$

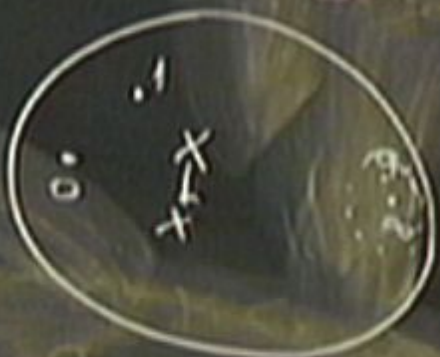
$$q \gg 1$$

\mathbb{R}



$$\lambda^2 \sim \frac{\gamma_0}{2V} \frac{1}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \frac{\sqrt{2V}}{2} \sim a$$



$$\lambda^2 \sim \frac{m_a^2}{z^2(1-z)} + \frac{m_b^2}{1-z(1-z)} + \frac{2V}{z(1-z)}$$

$$U = (m_a + m_b)^2$$



$$U = (m_c + m_d)^2$$

$$Z = q_+ a + q_- a_0 + q_f m$$

$$Z_f = \int \lambda$$

$$a_{D+2a} \sim -\frac{1}{\gamma-2} \sim -\frac{c}{2\pi} \ln a_{D+2a}$$

$$\lambda = y \frac{dz}{z^2}$$

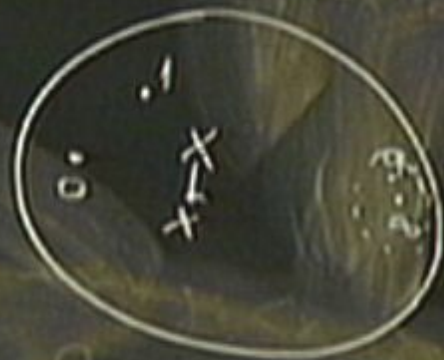
$$\lambda_v = y_v \frac{dv}{z^L} = \frac{1}{c} \frac{2z^L}{y} \frac{dz^v}{z^L} = \frac{dc}{y} = \omega$$

$$\lambda \sim \frac{\Lambda}{z^L} + \frac{\gamma}{z^L}$$

$$\lambda^L = \frac{dz^L}{z^L} \left(\frac{\Lambda^L}{z^L} + 2V + \frac{2\Lambda y}{z} + \frac{\Lambda^L}{z^L} \right)$$

$$\lambda^L = \frac{dz^L}{z^L} \left(\Lambda^L z + 2V + \frac{\Lambda^L}{z} \right)$$

$$q \gg 1$$



$$\lambda^2 \sim \frac{2V}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \dots$$

$$\lambda^L \sim \frac{m^L}{z^L}$$



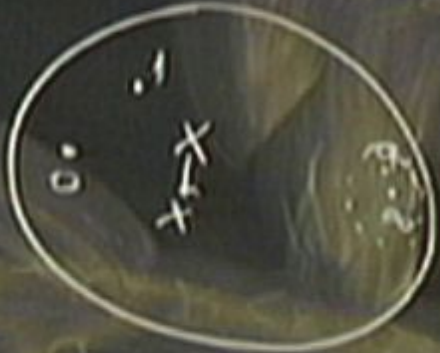
$$q \gg 1$$

\mathbb{R}



$$\lambda^2 \sim \frac{2V}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{2V}{z}} \sim a$$



$$\lambda^2 \sim \frac{m_1^2}{z^2(1-z)} + \frac{m_2^2}{z^2(2-z)} + \frac{2V}{c(z)}$$

$$U = (m_a \pm m_b)^2$$



$$U = (m_c \pm m_d)^2$$

$q \gg 1$

E



$$\lambda^2 \sim \frac{2V}{z^2}$$



$q \rightarrow \infty$

$q \rightarrow 1$

$q \rightarrow 0$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{2V}{z}} \sim a$$

$$\frac{P_2}{z^2(2-i)^2}$$

$$\lambda^2 \sim \frac{m_1^2}{z^2(1-z)} + \frac{m_2^2}{z^2(2-i)^2} + \frac{2V}{z^2(2-i)}$$

$$U = (m_1 \pm m_2)^2$$



$$U = (m_1 \pm m_2)^2$$

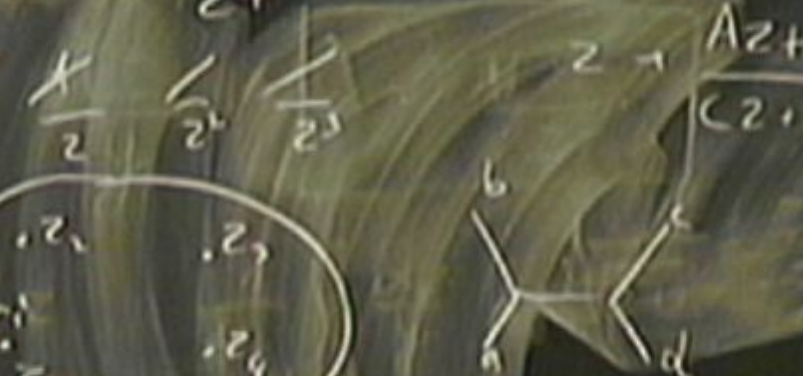
$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$m_a \pm m_b \rightarrow SU(2)_a \times SU(2)_b \times SU(2)_c$
 $(m_a - m_b)$
 m_a^2
 $\lambda \sim \pm \frac{m_a}{z - z_a}$

$$\lambda^2 \sim \left[\frac{m_a^2}{(z - z_a)^2} + \frac{c_{m_a}}{z - z_a} \right] dz^2$$

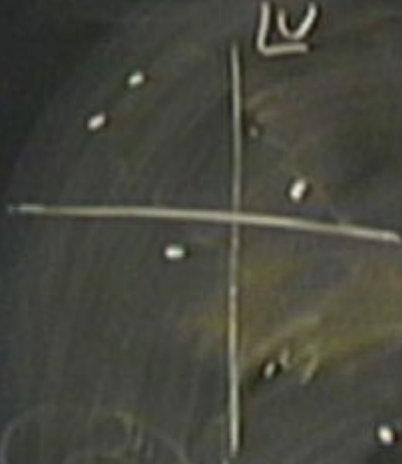
$$\lambda^2 = \frac{P_0}{\prod (z - z_n)^2} + \frac{U}{\prod (z - z_n)}$$

$$z_n = 0, 1, q, \infty$$



$$q \gg 1$$

\mathbb{R}



$$\lambda^2 \sim \frac{2U}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{U}{z}} \sim a$$

$$q \rightarrow \infty$$

$$q \rightarrow 1$$

$$q \rightarrow 0$$



$$\lambda^2 \sim \frac{m_a^2}{z^2(1-z)} + \frac{m_b^2}{z^2(z-1)^2} + \dots$$

$$U = (m_a \pm m_b)^2$$



$$U = (m_a)^2$$

$$q \gg 1$$

$$a_0 \sim a \log q$$

$$q = e^{ix\tau_{00}}$$



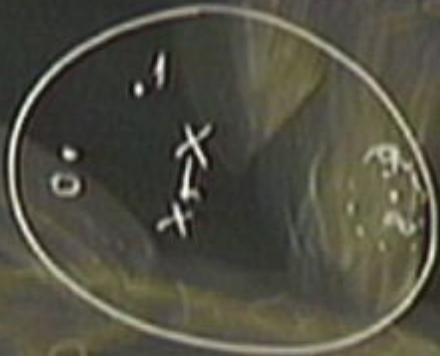
$$\lambda^2 \sim \frac{2V}{z^2}$$

$$\frac{1}{4\pi i} \int_{\gamma_c} \lambda \sim \sqrt{\frac{2V}{z}} \sim a$$

$$q \rightarrow \infty$$

$$q \rightarrow 1$$

$$q \rightarrow 0$$



$$\lambda^2 \sim \frac{m_a^2}{z^2(1-z)} + \frac{m_b^2}{z^2(1-z)^2} + \frac{2V}{z(1-z)}$$

$$U = (m_a \pm m_b)^2$$



$$U = (m_a \pm m_b)^2$$

$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$m_a \in m_b$ $SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$

$$\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix} \lambda \sim \pm \frac{m_a}{z-z_a} dz$$

$$\lambda^2 \sim \left[\frac{m_a^2}{(z-z_a)^2} + \frac{\chi_{n_a}}{z-z_a} \right] dz^2$$

$$\frac{dz^2}{z^4} \quad z \pm \frac{1}{z}$$

$$\lambda^2 = \frac{P_a}{\pi(z-z_a)^2} + \frac{U}{\pi(z-z_a)}$$

$$z_a = 0, 1, q, \infty$$



$$\lambda^2 = \phi_c(z) = R(z) dz^2$$

$m_A \pm m_B$ $SU(2)_a \times SU(2)_b \times SU(2)_c \times SU(2)_d$
 $\begin{pmatrix} m_a & \\ & -m_a \end{pmatrix}$ $\lambda \sim \pm \frac{m_c}{z-z_a} dz$

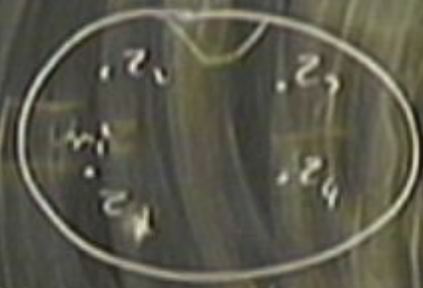
$$\lambda^2 \sim \left[\frac{m_a^2}{(z-z_a)^2} + \frac{\kappa_a}{z-z_a} \right] dz^2$$

$$\lambda^2 = \frac{P_a}{\prod (z-z_a)^2} + \frac{U}{\prod (z-z_a)}$$

$$z_a = 0, 1, q, \infty$$

$$\frac{dz^2}{z^4} \quad z \rightarrow \frac{1}{z}$$

$$z \rightarrow \frac{Az+B}{Cz+D}$$



$$q \gg 1$$

$$a_0 = a \log q$$

$$q = e^{i\pi \tau_{00}}$$



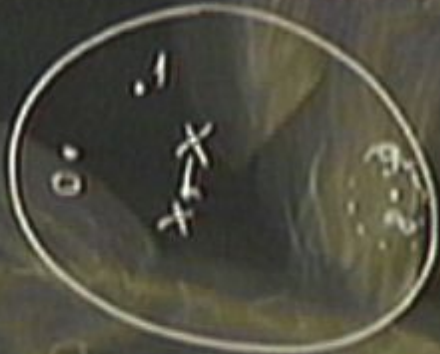
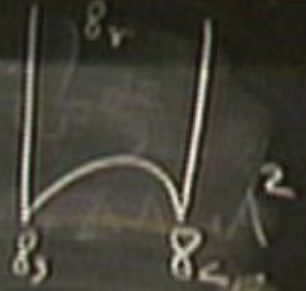
$$\lambda^2 \sim \frac{2U}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{2U}{z}} = a$$

$$q \rightarrow \infty$$

$$q \rightarrow 1$$

$$q \rightarrow 0$$



$$\lambda^2 \sim \frac{m_1^2}{z^2(1-z)} + \frac{m_2^2}{z(1-z)^2} + \frac{2U}{z(1-z)}$$

$$U = (m_a \pm m_b)^2$$



$$U = (m_c \pm m_d)^2$$

$$q \gg 1$$

$$a_0 = a \log q$$

$$q = e^{ix\tau_{00}}$$



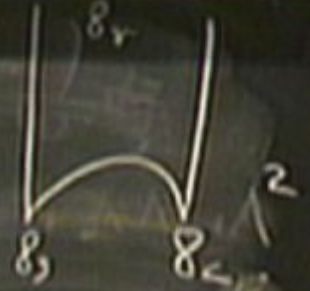
$$\lambda^2 \sim \frac{2V}{z^2}$$

$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{2V}{z}} \sim a$$

$$q \rightarrow \infty$$

$$q \rightarrow 1$$

$$q \rightarrow 0$$



$$\frac{P_2}{z^2(z-1)^2}$$

$$\lambda^2 \sim \frac{m_1^2}{z^2(z-2)} + \frac{m_2^2}{z^2(z-1)^2} + \frac{2V}{z(z-1)}$$

$$U = (m_a \pm m_b)^2$$



$$U = (m_a \pm m_b)^2$$

$$\lambda = \frac{dz y_0}{K(z-a)}$$

$$y^2 = P_4(z)$$

$$q \gg 1$$

$$a_0 \sim a \log q$$

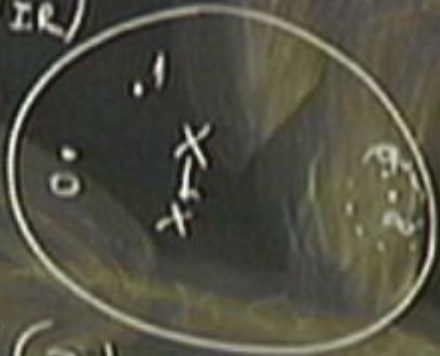
$$q = e^{ix} \tau_{00}$$

$$q = \frac{\theta_2^4}{\theta_3^4}(\tau_{IR})$$

$$\tau_{IR} = \frac{2\pi i}{\omega} \rightarrow 0$$

$$\lambda = \frac{dz y_0}{K(z-a)}$$

$$y^c = P_4(z)$$



$$q \rightarrow \infty$$

$$q \rightarrow 1$$

$$q \rightarrow 0$$



$$\frac{1}{4\pi i} \int \lambda \sim \sqrt{\frac{U}{2}} \sim a$$

$$\lambda^c \sim \frac{m_1^2}{z^2(1-z)} + \frac{m_2^2}{z(1-z)^2} + \frac{cU}{z(1-z)}$$

$$U = (m_a \pm m_b)^2$$

$$U = (m_c \pm m_d)^2$$

$$\lambda^2 = \phi_2(z)$$

SU(2)

$$\phi_2(z) \sim \frac{2m^2 G_{\text{ADM}}}{(z-z_0)^2} dz^2$$



$\lambda^2 = \phi_2(z)$
 $\phi_2(z) \sim \frac{m^2 dz^2}{(z-z_n)^2}$



$3g - 3 + m$

QUADRATIC
 DIFFERENTIALS
 WITH SIMPLE POLES

λ^2

$P(\Gamma_{g,m}, \text{SU}(2))$ $N = 2m^2 C_{\text{ADDE}}$ $\phi_1(z) \sim \frac{m^2 C_{\text{ADDE}}}{(z-z_n)^2} dz^2$ $C_{g,m}$



$3g - 3 + m$

QUADRATIC DIFFERENTIALS

$U_i = \int \phi_i^2$

W/ SIMPLE POLES

1/4



$P(\mathbb{T}_{g,m} \text{ SU}(2))$
 $\lambda^2 = \phi_2(z)$

$\phi_2(z) \sim \frac{2m^2 C_{g,m}}{(z-z_n)^2} dz^2$



$3g - 3 + m$

QUADRATIC DIFFERENTIALS

$a_i U_i = \int \phi_i^2$

WKT - SIMPLE POLES

$\int \lambda = a, a_D$



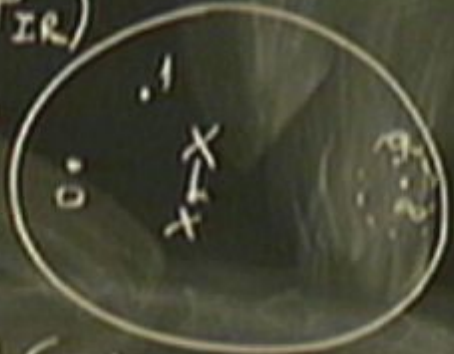
$$q \gg 1$$

$$a_0 \sim a \log q$$

$$q = e^{ix \tau_{UV}}$$

$$q = \frac{\theta^4}{\theta^2} (\tau_{IR})$$

$$\tau_{IR} = \frac{2\pi}{\epsilon} \rightarrow 0$$



$$y^c = P_4(z)$$

$$q \rightarrow \infty$$

$$q \rightarrow 1$$

$$q \rightarrow 0$$



$$\frac{1}{4\pi i} \int_{\gamma_c} \lambda \sim \sqrt{\frac{2U}{z}} \sim a$$

$$\lambda^c \sim \frac{m_1^2}{z^2(1-z)^2} + \frac{m_2^2}{15(z-1)^2} + \frac{2U}{z(z-1)}$$

$$U = (m_a \pm m_b)^2$$



$$U = (m_c \pm m_d)^2$$

$$\lambda^2 = \phi_2(z)$$

$$\phi_2(z) \sim \frac{2m^2 C_{g,m}}{(z-z_0)^2} dz^2$$



$$3g - 3 + m$$

QUADRATIC DIFFERENTIALS

$$a_i U_i = \text{Tr } \phi_i^2$$

W/ SIMPLE POLES

$$\int_{\gamma} \dots$$



$$q \gg 1$$

$$a_0 \sim a \log q$$

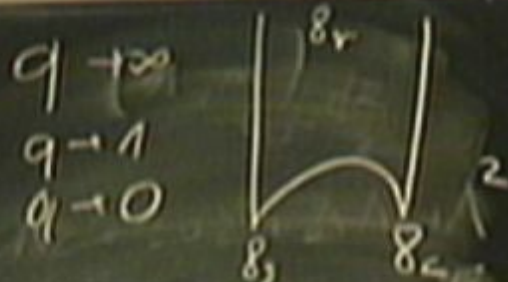
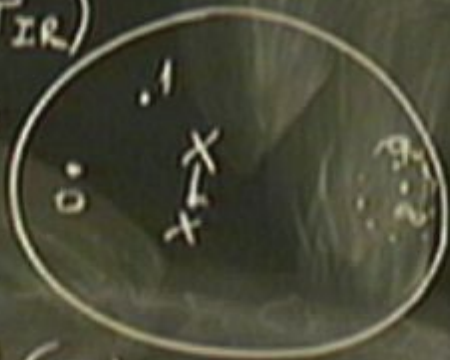
$$q = e^{ix \tau_{UV}}$$

$$q = \frac{\theta_2^4}{\theta_3^4}(\tau_{IR})$$

$$\tau_{IR} = \frac{2\pi a}{\hbar} \rightarrow 0$$

$$\lambda = \frac{dz y^c}{K(z, a)}$$

$$y^c = P_4(z)$$



$$\frac{1}{4\pi i} \int_{\gamma_c} \lambda \sim \sqrt{\frac{2U}{z}} \sim a$$

$$\lambda^2 \sim \frac{m_a^2}{z^2(1-z)^2} + \frac{m_b^2}{z^2(z-1)^2} + \frac{2U}{c(z-1)}$$

$$U = (m_a + m_b)^2$$

$$U = (m_c + m_d)^2$$

$$\lambda^2 = \phi_2(z)$$

$$\phi_2(z) \sim \frac{m^2 C_{ADM}^2}{(z - z_0)^2} dz^2$$



$$3g - 3 + m$$

QUADRATIC DIFFERENTIALS

SIMPLE POLES

$$a_i U_i = \int \phi_i^2$$

$$\int \lambda = a, a_0$$



$$\lambda^2 = \phi_2(z)$$

$$\phi_2(z) \sim \frac{2m^2 C_{g,m}}{(z-z_0)^2} dz^2$$



$$3g - 3 + m$$

QUADRATIC
DIFFERENTIALS

$$U_i = \int \phi_i^2$$

W/ SIMPLE POLES

$$\int \lambda = a, a_0$$



$$\lambda^2 = \phi_2(z)$$

$$\phi_2(z) \sim \frac{2m^2 C_{g,m}}{(z-z_0)^2} dz^2$$



$$3g - 3 + m$$

QUADRATIC
DIFFERENTIALS

$$U_i = \int \phi_i^2$$

W/ SIMPLE POLES

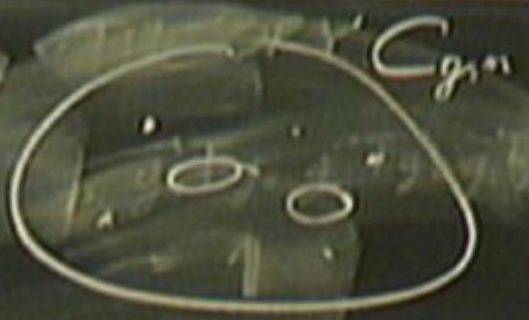
$$\int \lambda = a, a_0$$



$$P(\lambda) = T_{g,n}[A_1] \prod_{i=1}^n (z - z_i)$$

$$\lambda^2 = \phi_2(z)$$

$$\phi_2(z) \sim \frac{2m^2 C_{g,n}}{(z-z_0)^2} dz^2$$



$$3g - 3 + n$$

QUADRATIC DIFFERENTIALS

$$a_i U_i = \int \phi_i^2$$

WKT - SIMPLE POLES

$$\int \lambda = a, a_0$$



$$T_{g,n}[A_1] \lambda^3 + \phi_2(z)\lambda + \phi_1(z) = 0$$



$$P(\lambda) = T_{g,m}[A_1] \prod_{i=1}^m (z - z_i)$$

$$\lambda^2 = \phi_2(z)$$

$$\phi_1(z) \sim \frac{2m^2 C_{g,m}}{(z - z_0)^2} dz^2$$



$$3g - 3 + m$$

QUADRATIC DIFFERENTIALS

$$a_i U_i = T_{g,m} \phi_i^2$$

WITH SIMPLE POLES

$$\int_{\gamma} \lambda = a, a_0$$

$$T_{g,m}[A_1] \lambda^3 + \phi_1(z) \lambda + \phi_2(z)$$



$$P(\lambda) = T_{g,m}[A_1] U(z)$$

$$\lambda^2 = \phi_2(z)$$

$$\phi_1(z) \sim \frac{2m^2 C_{g,m}}{(z-z_0)^2} dz^2$$



$$3g - 3 + m$$

QUADRATIC DIFFERENTIALS

$$U_i = T_2 \phi_i^2$$

W/ SIMPLE POLES

$$\int_{\gamma} \lambda = a, a_0$$



$$T_{g,m}[A_1] \lambda^3 + \phi_1(z)\lambda + \phi_2(z) = 0$$

