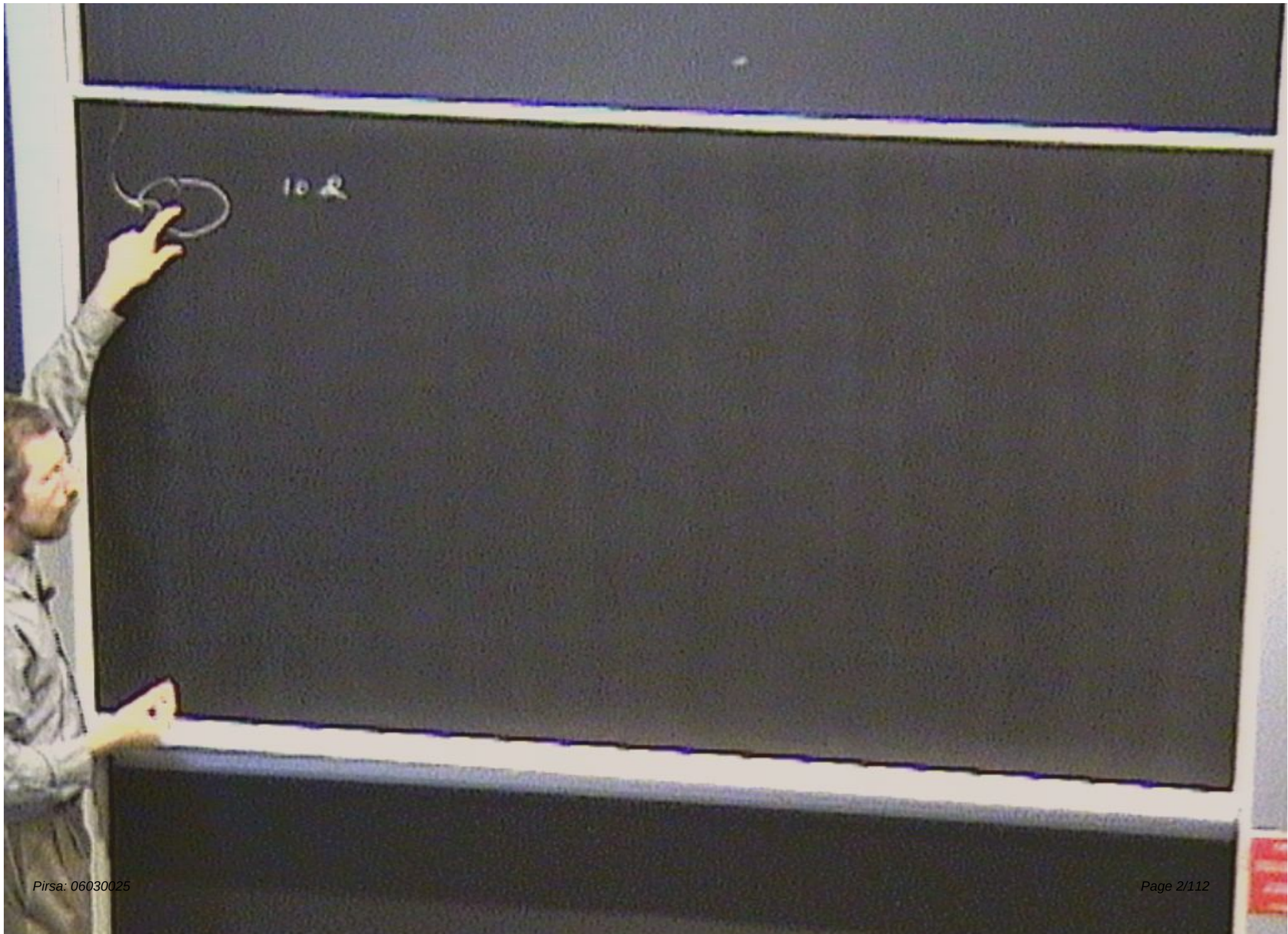


Title: Computational Complexity of the Landscape

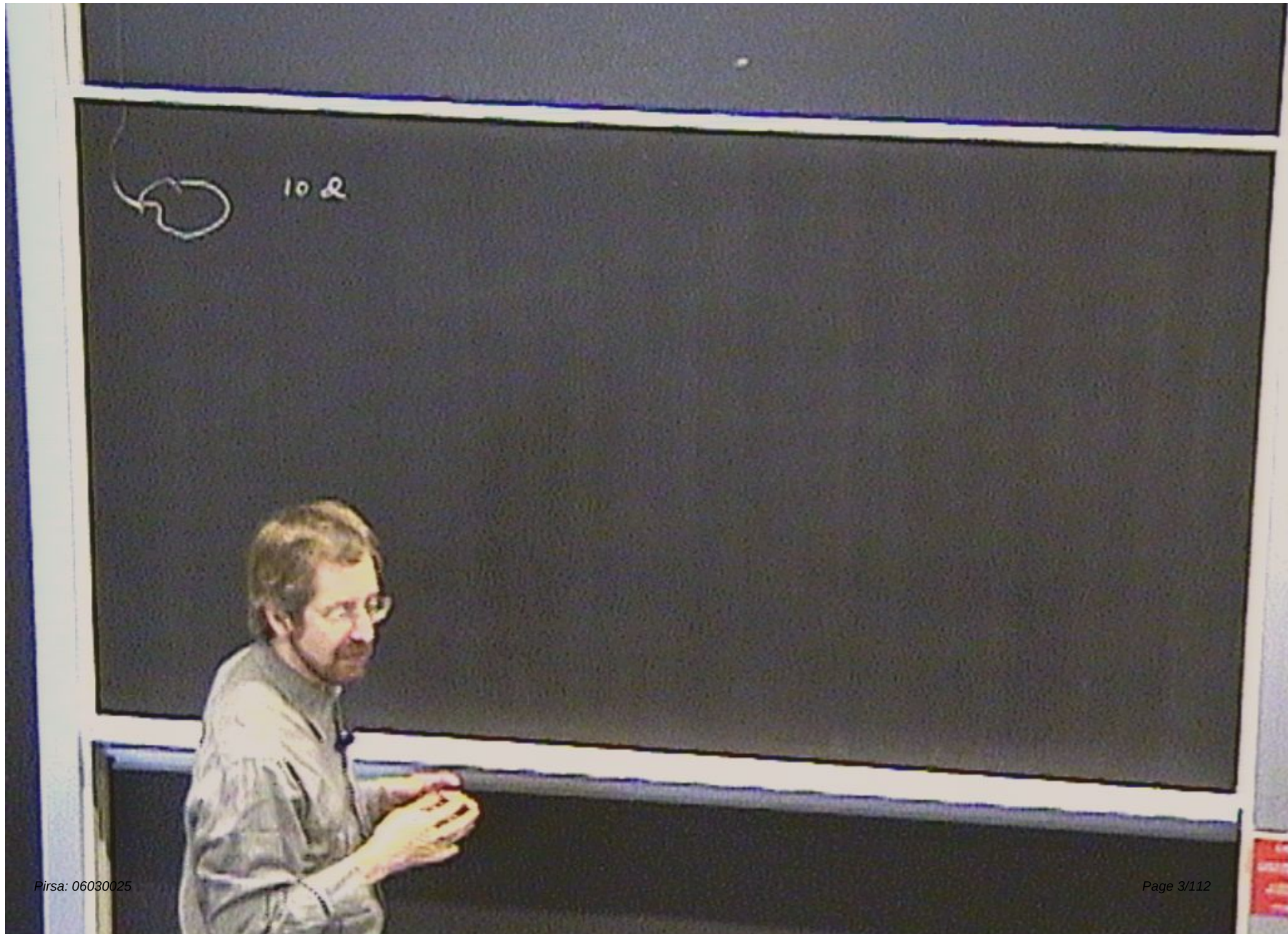
Date: Mar 29, 2006 02:00 PM

URL: <http://pirsa.org/06030025>

Abstract:











102



62  
M





102

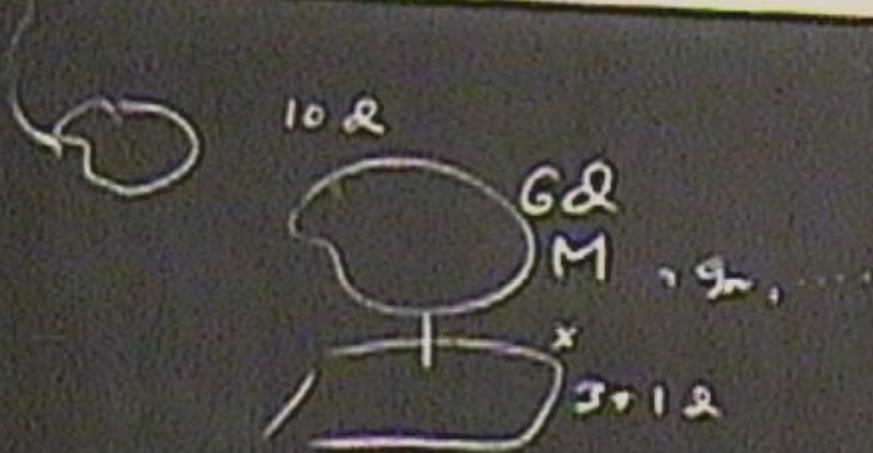


G2  
M

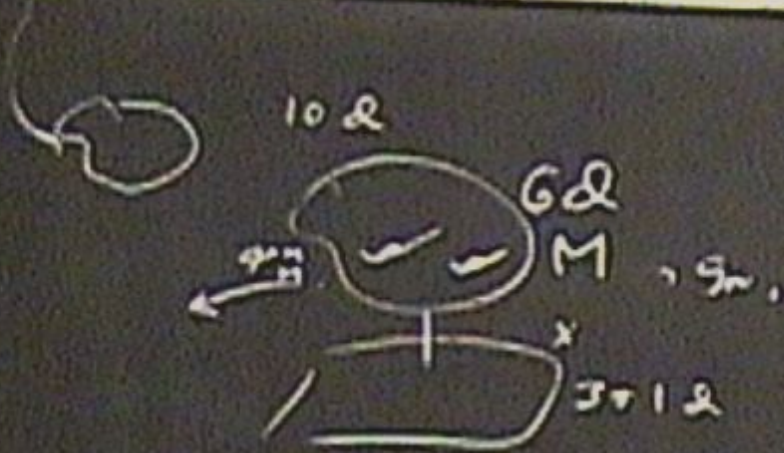


x  
3712

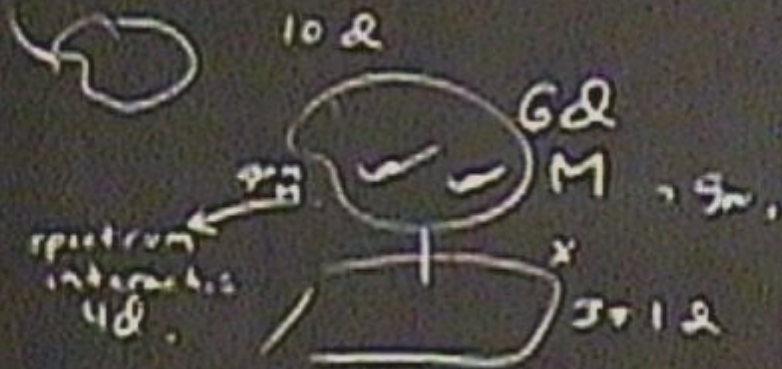




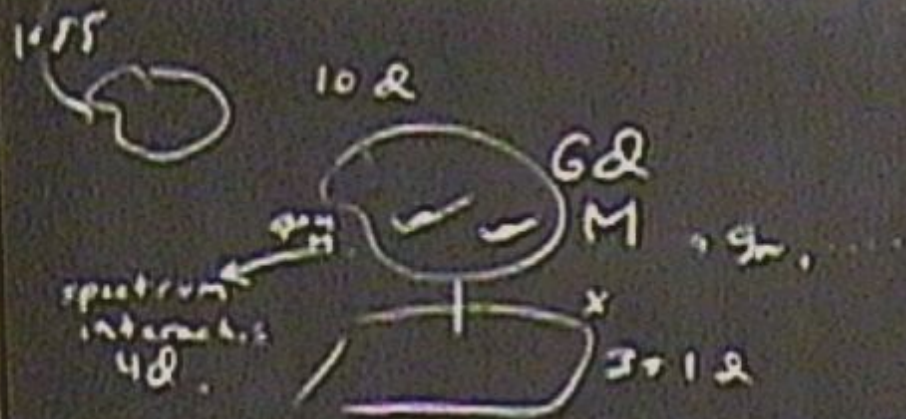






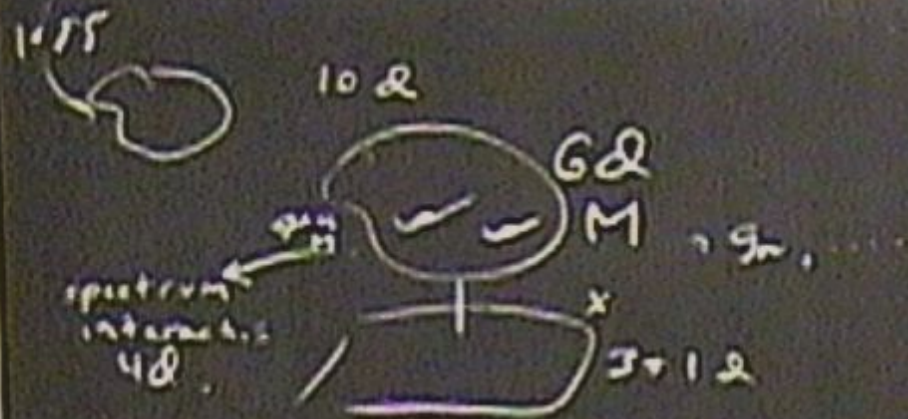






1995

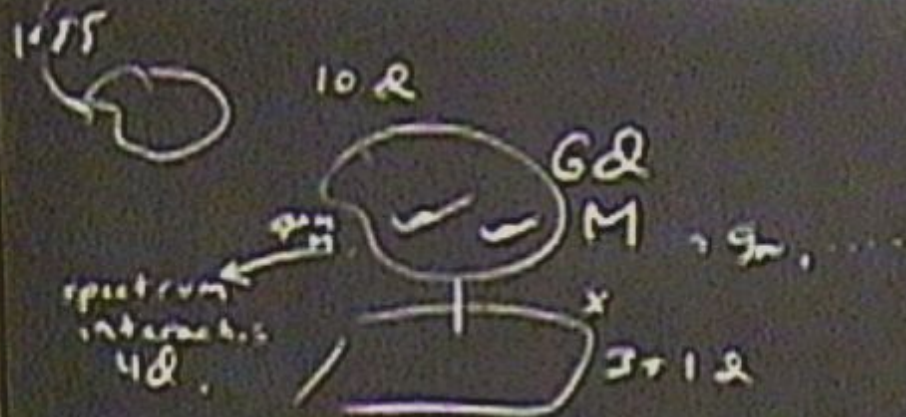




1995

let  $g_1 = n \Rightarrow \widetilde{g_1} = \frac{1}{g_1}$





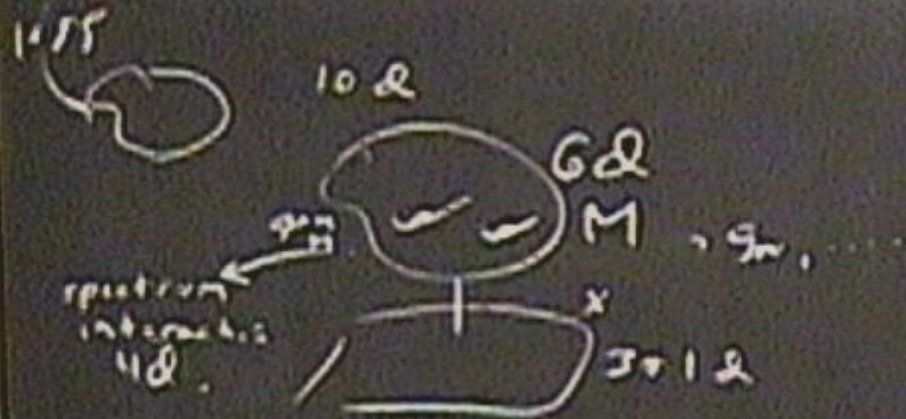
1995

let  $\bigcirc$

$g_1 = \dots \Rightarrow \widetilde{g_1 = \dots}$

$g_2 = \dots$





1995

let  $g_1 = \infty \Rightarrow \widetilde{1+I}$

$g_2 = \gamma g_1$

2005



1975



10.2

62

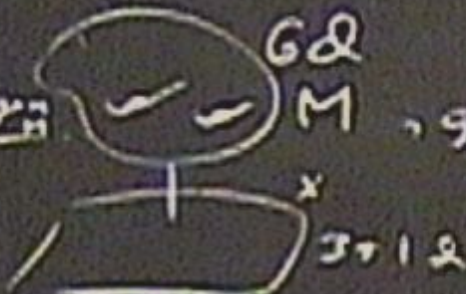
M

$\rightarrow g_m$

Centrifugal

$$\sum_{i=1}^n \epsilon_i^2 = 0 \text{ is } \epsilon^2 = -12.$$

spectrum  
interacts  
48



1995

let  
 $g_1 = \infty$

$\Rightarrow$

$$\frac{1}{g_1} \approx \frac{1}{g_2} \approx \frac{1}{g_3}$$

2005



1955



10 d

6 d

M

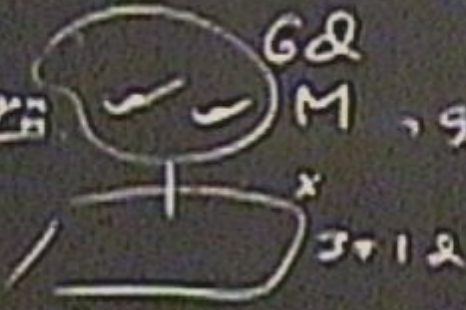
$\rightarrow g_m$

Centrifugal



$\frac{1}{2} \omega^2 r^2 = 0$  is  $r^2 = 2z$ .

spectrum  
interacts  
4 d



$3 \pm 1 d$

1995

let  
 $g_1 = \infty$

$$\Rightarrow \sqrt{\frac{1}{g_1} \frac{I}{g_2}} \frac{1}{g_1}$$

2005





10 d



$G \otimes M = g_m$

Calabi-Yau



$\mathcal{N} = 0$  is  $\mathcal{N} = 2$

$SU(2) \times SU(2) / SU(1)$

1995

let  $g_1 = \infty \Rightarrow$

2005



1975



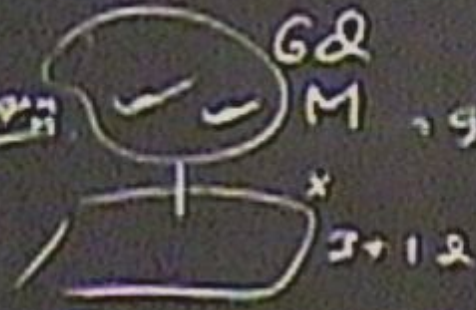
10 d

6 d

M

$\approx g_m$

spectrum  
interacts  
4 d



Calculus



$\sum \epsilon_i = 0$  if  $\epsilon = \lambda \epsilon$

$SU(2) \times SU(2) \times U(1)$

1995

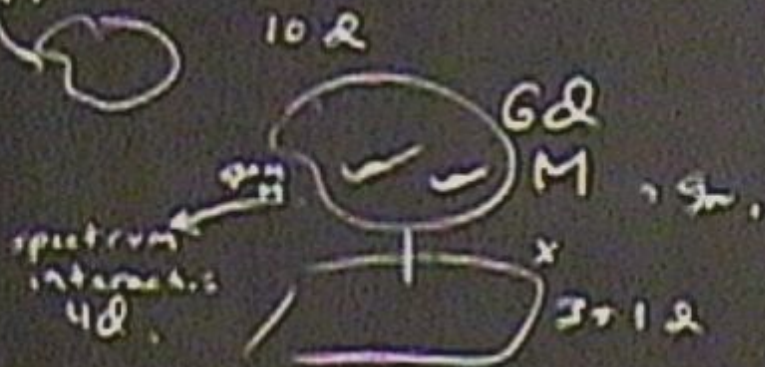
let  $g_i \rightarrow$

$\Rightarrow \overline{g_i} \approx \frac{1}{g_i}$

2005



1975

Calculus



is  $r^2 e^{-2\phi}$

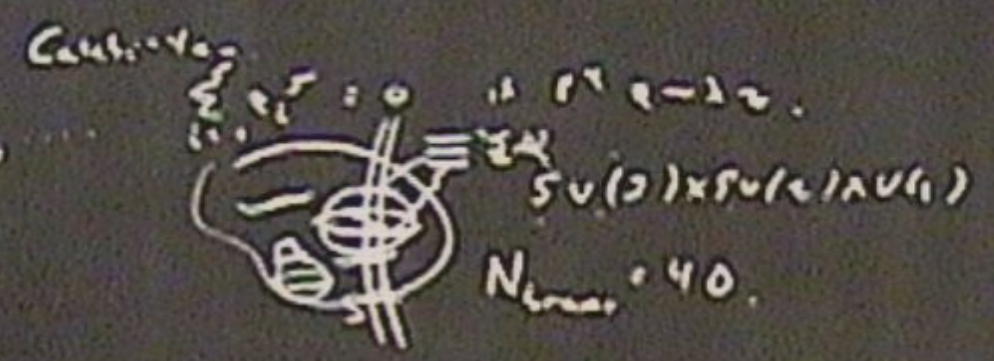
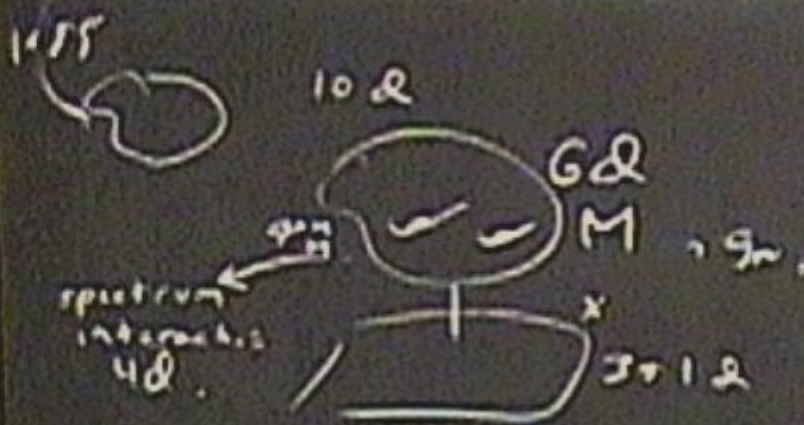
$SU(2) \times SU(2) / SU(1)$

1995

let  $g_1 = \pi \Rightarrow \sqrt{g_1} = \frac{1}{\sqrt{g_1}}$

2005





1995

let  $g_1 \rightarrow \infty \Rightarrow \widetilde{11d I}$   
 $g_2 \sim g_1$

2005



1055



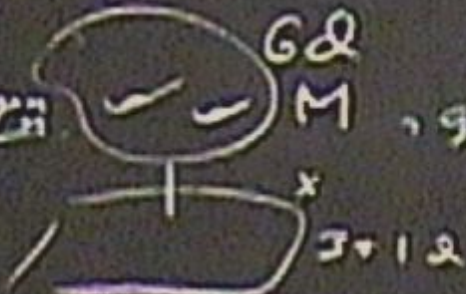
102

62

M

$g_m$

spectrum  
interacts  
40



Centrifugal



$\sum p_i^2 = 0$  is  $p^2 = -\lambda^2$

$SU(2) \times SU(2) / SU(1)$

$N_{\text{lines}} = 40$

1995

let  
 $g_1 = \pi$

$\Rightarrow \sqrt{g_1} \approx \sqrt{g_2}$

2005



1975



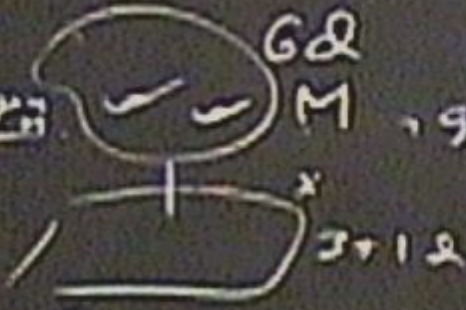
10 d

6 d

M

$\rightarrow g_m$

spectrum  
interacts  
4 d



Contributing



$\sum_i \epsilon_i^2 = 0$  if  $\epsilon^2 = -2\epsilon$ .

$SU(2) \times SU(2) \times U(1)$

$N_{\text{bosons}} = 40$

1995

let  $g_1 = 0$

$\Rightarrow \frac{1}{g_1} \frac{1}{g_2} \frac{1}{g_3}$

2005

landscape





1955

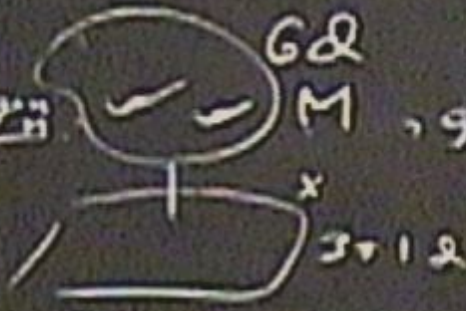


10 d

6 d

$M = g_m$

spectrum interacts  
4 d



Cauchy

$$b^2 = 204$$



$$\int \mathcal{L} = 0 \quad \text{if } \mathcal{L} = -\lambda \mathcal{L}$$

$$SU(2) \times SU(2) / \Lambda U(1)$$

$$N_{\text{brane}} = 40. \quad G_2(TM)$$

1995

let  $g_1 = \infty$

$$\Rightarrow \frac{1}{g_1} \frac{1}{g_2} \frac{1}{g_3}$$

2005

landscape

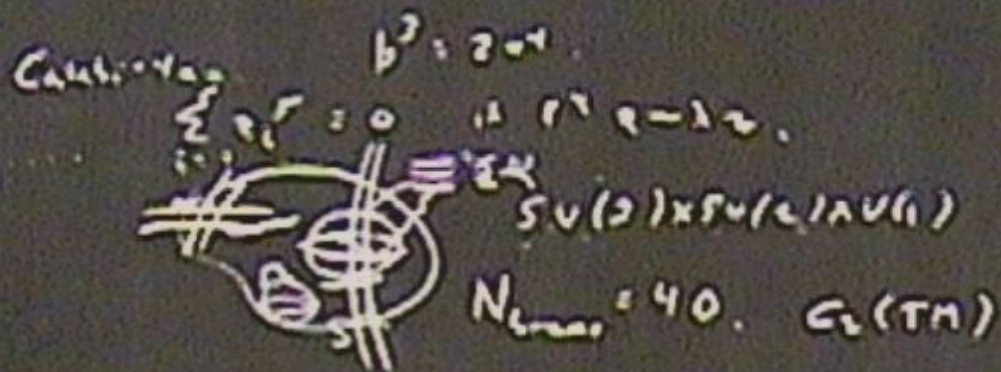




1985



10d



1995

let  $g_i = \pi \Rightarrow \overline{g_i} = \frac{1}{g_i}$

2005

landscape





conjugate

$$R_{\mu} = \frac{1}{2} R \cdot g_{\mu\nu} + \frac{1}{2} g_{\mu\nu}$$



calculus

$$R_{\mu\nu} = \frac{1}{2} R g_{\mu\nu} + \frac{1}{2} \Lambda g_{\mu\nu}$$

$$\Lambda \sim 0$$



calculus

$$R_{\mu\nu} = \frac{1}{2} R g_{\mu\nu} - \nabla_\mu \nabla_\nu \Lambda$$

$$\Lambda \sim 0$$



cosmological

$$R_{\mu} = \frac{1}{2} R \cdot g_{\mu\nu} + \Lambda g_{\mu\nu}$$

$$\ll (100 \text{ m})^2$$

$$\Lambda \sim 0$$



cal no log = 2

$$R_{\mu} = 12 R \cdot \ln T_{10} + \Lambda g_{\mu}$$

$$\ll (100 \text{ nm})^{10}$$

$$\Lambda \sim 0$$
$$\sim 10^{-152} M_{\text{Planck}}^4$$



cosmological

$$R_{\mu\nu} = 12R \cdot \frac{c^2 T_{\mu\nu}}{3} + \Lambda g_{\mu\nu}$$

$$\ll (100 \text{ m})^2$$

$$\Lambda \sim 0$$

$$\sim 10^{-122} M_{\text{Planck}}^4$$

$$10^{-50} M_{\text{Pl}}^4$$



cosmological

$$R_{\mu\nu} = \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu}$$

$$\ll (100 \text{ km})^{-2}$$

$$\Lambda \sim 0$$

$$\sim 10^{-122} M_{\text{Planck}}^4$$

$$10^{-50} M_{\text{Pl}}^4$$

late 90's

$\Rightarrow$



cosmological

$$R_{\text{pc}} = \frac{1}{2} R_{\text{vir}} \approx \frac{1}{2} \left( \frac{2 \pi \rho_{\text{vir}}}{3 H^2} \right)^{1/3} \approx 1 \text{ Mpc}$$

$$\ll (100 \text{ Mpc})^3$$

$$\Lambda \sim 0$$

$$\sim 10^{-122} M_{\text{Planck}}^4$$

$$10^{-50} M_{\text{Planck}}^2$$

late 90's

$\Rightarrow$  SN ...

WMAP



cosmological

$$R_{\mu\nu} = \frac{1}{2} R g_{\mu\nu} - \Lambda g_{\mu\nu}$$

$$\ll 100 \text{ km}^2$$

$$\Lambda \sim 0$$
$$\sim 10^{-51} \text{ m}^2$$
$$10^{-51} \text{ m}^2$$

late 90's

$\Rightarrow$  SN ...

WHAT

$$\Lambda > 0$$
$$\sim 0.7 \Omega_c$$



cosmological

$$R_{\mu} = \frac{1}{2} R_{\mu} + \Lambda g_{\mu\nu}$$

$$\ll 100 \text{ m}^{-1}$$

$$\Lambda \sim 0$$

$$\sim 10^{-112} M_{\text{Planck}}^4$$

$$10^{-50} M_{\text{Planck}}^4$$

late 90's

$\Rightarrow$  5N ...

WMAP

$$\Lambda > 0$$

$$\sim 0.7 \Omega_c$$



cosmological

$$R_{\text{pc}} = \frac{1}{2} R_{\text{c}} \ln T_{\text{fo}} + \Lambda_{\text{Spc}}$$

$$\ll (100 \text{ pc})^{1/4}$$

$$\Lambda \sim 0$$
$$\sim 10^{-15} M_{\text{pl}}^4$$
$$10^{-20} M_{\text{pl}}^4$$

late 90's

SN ...

WMAP

$$\Lambda > 0$$

$$\sim 0.7 \Omega_c$$



1985



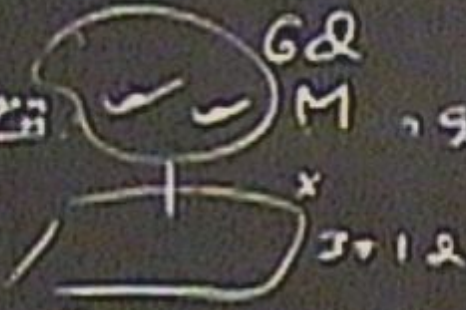
10 d

6d

M

$g_m$

spectrum  
interacts  
4d



Contribution

$b^2 = 204$

is  $r^2 e^{-2\sigma}$

$SU(2) \times SU(2) \times U(1)$

$N_{\text{brane}} = 40$   $G_2(TM)$

1995

let  $g_1 = 0$

$\Rightarrow$   $\widetilde{g_1, I}$   
 $g_2, \gamma g_1$

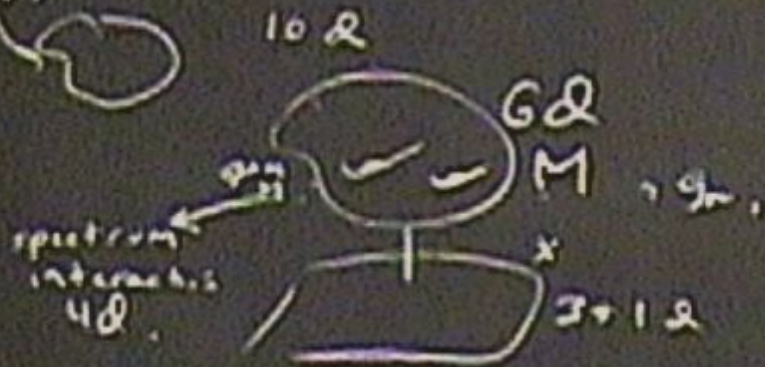
2005

landscape

W



1975

Calculation  $b^2 = 204$   
 $\sum_{i,j} \epsilon_{ij}^2 = 0$  is  $\epsilon^2 = 12$   
 $SU(2) \times SU(2) / \Lambda U(1)$   
 $N_{\text{bosons}} = 40$   $G_2(TM)$



1995

let  $g_1 =$   
 $g_2 = \frac{1}{2} g_1$

2005

1.



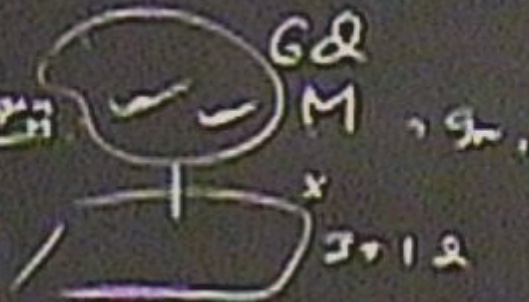


1975



10 d

spectrum  
interacts  
4d



Calculus

$$b^2 = 204$$



1995

let  $g_1 \rightarrow \Rightarrow \widetilde{g_1} \propto g_1$   
 $g_2 \propto g_1$

2005

landscape





1995

10 d

6 d

$M = 9m$

spectrum  
interacts  
4d

3+1 d

Calculus

$b^2 = 204$

$11^2 = 121$

$SU(3) \times SU(2) \times U(1)$

$N_{\text{families}} = 40$   $G_2(TN)$

1995

let  
 $g_{1,00}$

$\Rightarrow$

$1 \mu I$   
 $9 \mu I$

2005

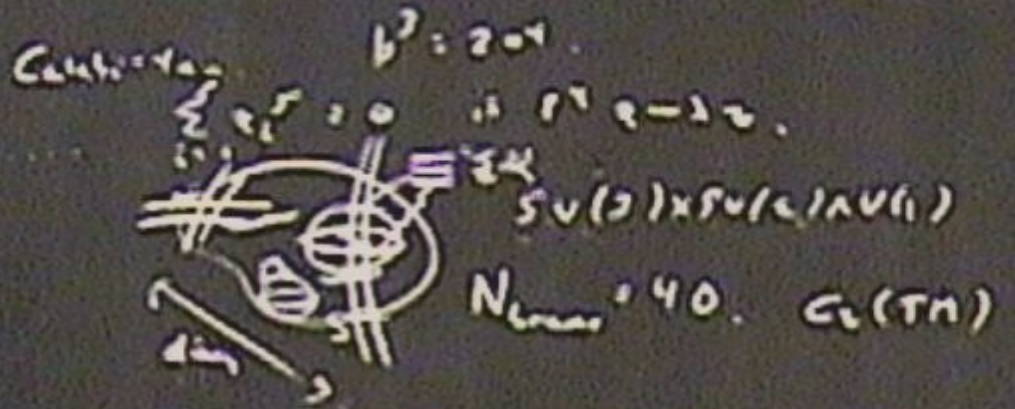
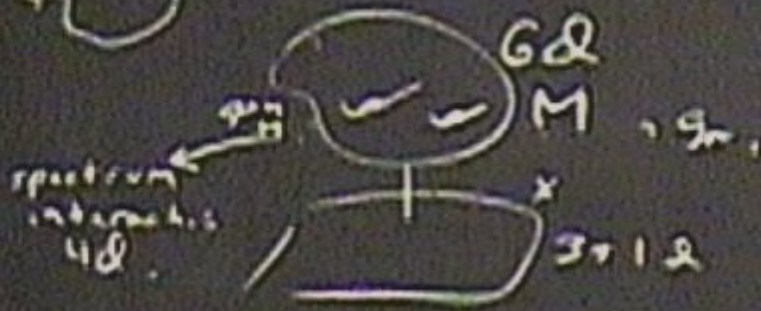
landscape

$V_{\text{eff}}(\phi)$   
 $\rightarrow 4$

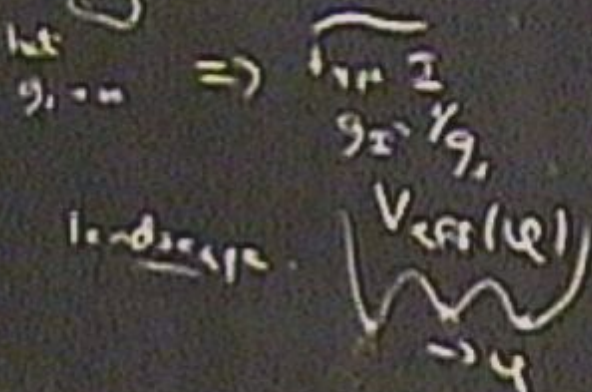




10 d



1995



2005

landscape



1.55



10 d

6 d

M

$\rightarrow 5m$

spectrum  
interacts  
4d

3+1 d

Calculus

$b^3 = 204$



$\sum_{i=1}^n x_i^2 = 0$  is  $1^2 + 2^2 = 5$

$SU(2) \times SU(2) \times U(1)$

$N_{\text{brane}} = 40$   $G_2(TN)$

1995

let  $g_{1,0} =$

$\Rightarrow \begin{cases} 1 + \sqrt{2} \\ g_2 = \sqrt{g_1} \end{cases}$

2005

landscape

$V_{\text{eff}}(q)$   
 $\rightarrow 4$



1975



10 d

6d

$M = g_m$

spectrum  
interacts  
4d

3+1 d

Calculus

$b^2 = 204$

$11^2 = 121$

$SU(2) \times SU(2) \times U(1)$

$N_{\text{lines}} = 40$   $G_2(TN)$

1995

let

$g_1 = 0$

$\Rightarrow$

$\sqrt{1 + \frac{1}{g_1}}$

$g_1 \sim \gamma g_1$

2005

landscape

$V_{\text{eff}}(\varphi)$

$1/2$

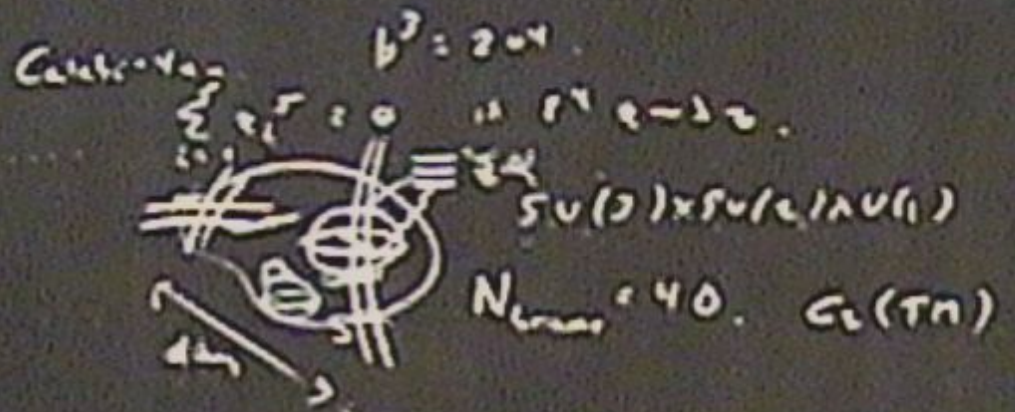
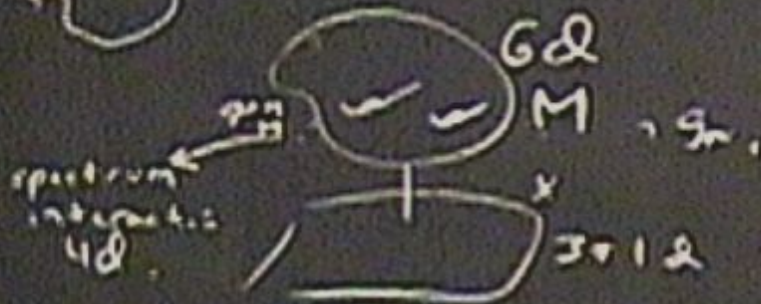
$\rightarrow 4$



1975



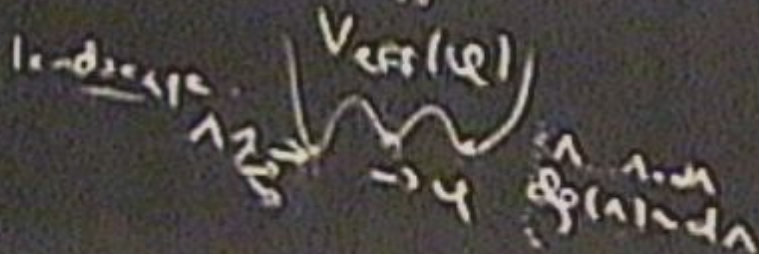
10 d



1995

let  $g_1 = \dots \Rightarrow$   $\widetilde{g_1} = I$   
 $g_2 = \gamma g_1$

2005

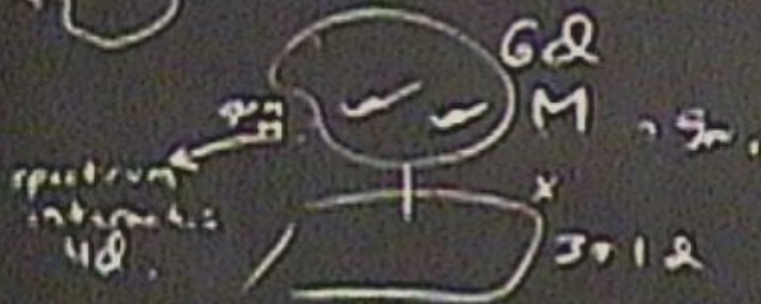




1975

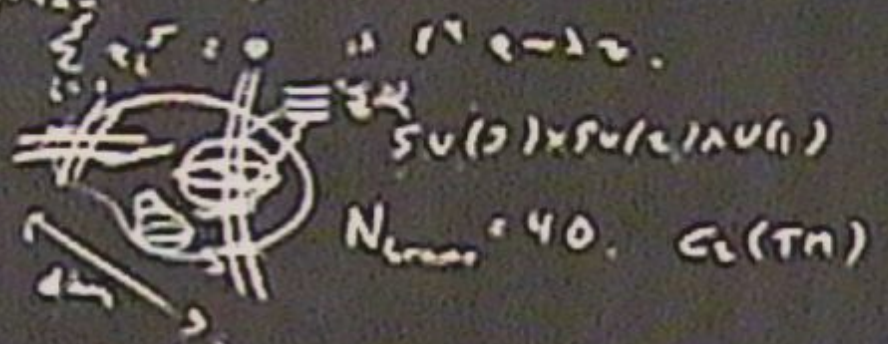


10 d



Calculation

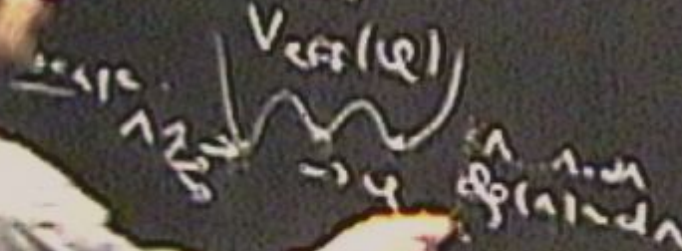
$b^3 = 204$



1995

$\Rightarrow$   $\frac{1}{16} \frac{1}{g}$   
 $9 \frac{1}{2} \frac{1}{g}$

2005





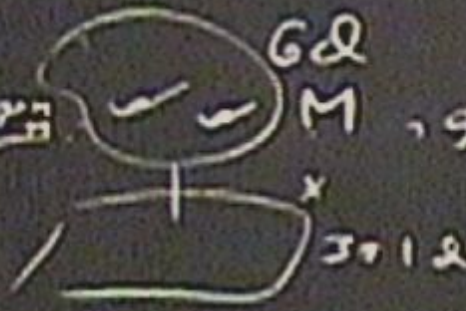


10 d

6 d

M = 9m

spectrum  
interacts  
4d



Calculation

$b^2 = 204$



$\sum_{i=1}^n x_i^2 = 0$  is  $1^2 + 2^2 + \dots + n^2 = 0$

$SU(2) \times SU(2) \times U(1)$

$N_{\text{lines}} = 40$ ,  $G_2(TN)$

1995

let  $g_1 = 0$

$\Rightarrow \frac{1}{2} \pi I$   
 $g_2 = \gamma g_1$

2005

landscape

$V_{\text{eff}}(Q)$

$12 \rightarrow 5$

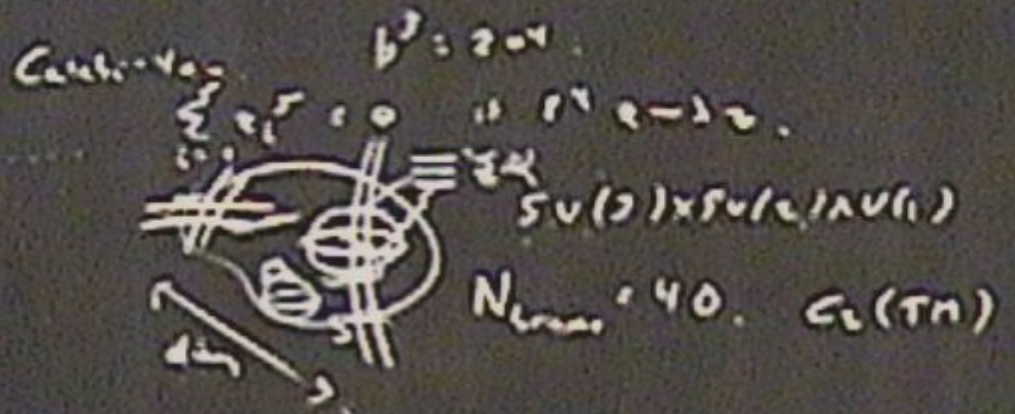
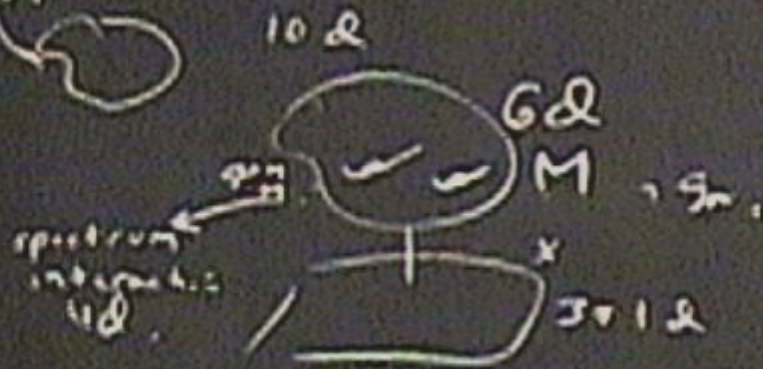
$\rightarrow 4$

$\rightarrow 1.5$   
 $\rightarrow 1.5$





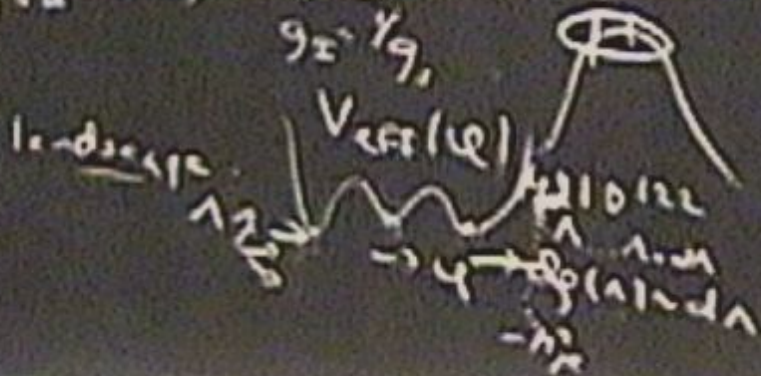
1995



1995

let  $g_{1,00} \Rightarrow \sqrt{g_{1,00}}$

2005





cosmological

$$R_{\mu\nu} = \frac{1}{2} g_{\mu\nu} R + \delta_{\mu\nu} T_{\mu\nu} + \Lambda g_{\mu\nu}$$

$$\ll (100 \text{ km})^2$$

$$\Lambda \sim 0$$

$$\sim 10^{-122} M_{\text{plank}}^4$$

$$10^{-50} M_{\text{plank}}^4$$

late 90's

$\Rightarrow$  SN ...

WMAP

$$\Lambda > 0$$

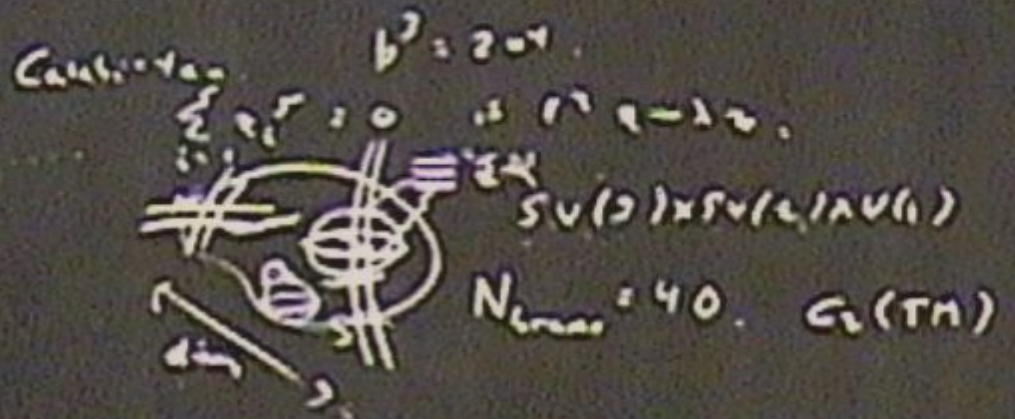
$$\sim 0.7 \Omega_c$$







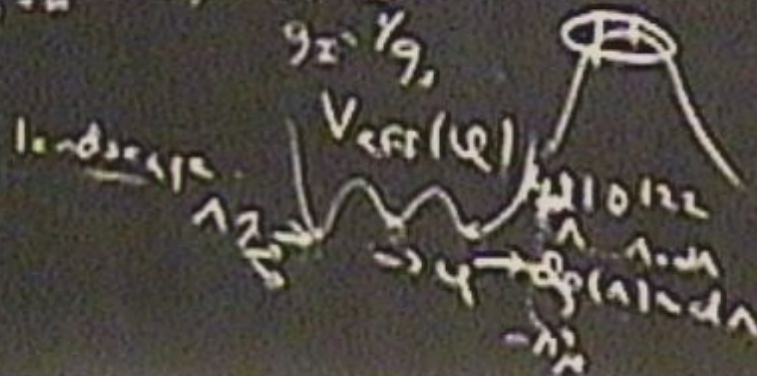
10 d



1995

let  $g_1 = m \Rightarrow \begin{cases} g_1 = 1 \\ g_2 = \gamma g_1 \end{cases}$

2005







10 d

6 d

M = 9 d

spectrum  
interacts  
4 d



Calculation

$b^2 = 204$

$11 \times 11 \times 11 = 1331$

$SU(3) \times SU(2) \times U(1)$

$N_{\text{free}} = 40$   $G_2(TM)$

$B: j$



1995

let

$g_1 = 0$

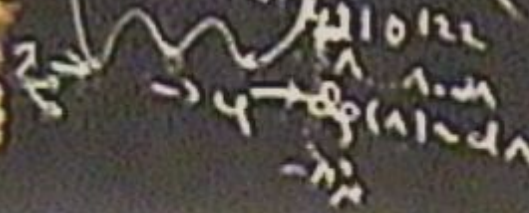
$\Rightarrow$

$1 + 1 + 1$   
 $g_2 = 1/9$

$V_{\text{eff}}(\phi)$



2005



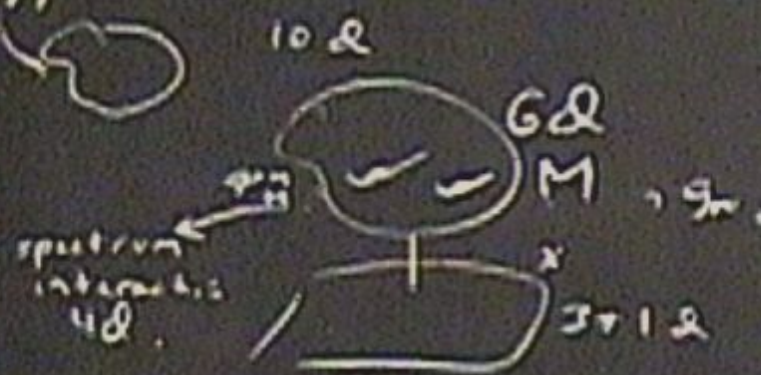








1985

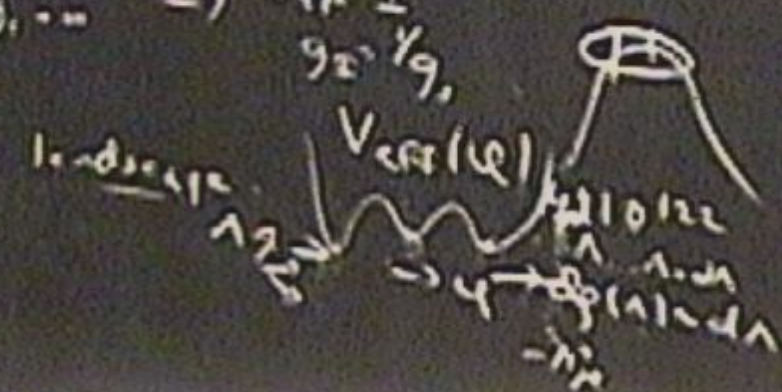


Calabi-Yau  
 $b^3 = 207$   
 $\sum_{i=1}^6 c_i^2 = 0$  or  $c_i^2 = -12$   
 $SU(3) \times SU(2) \times U(1)$   
 $N_{\text{families}} = 40$   $G_2(TM)$   
 $B: j \rightarrow \frac{1}{2\pi} \int_{\Sigma} B \in \mathbb{Z}$   
 $\text{th} = \int \text{th} + \partial^2$

1995

let  $g_1 = \infty \Rightarrow \frac{1}{g_1} \rightarrow 0$   
 $g_2 = \gamma g_1$

2005







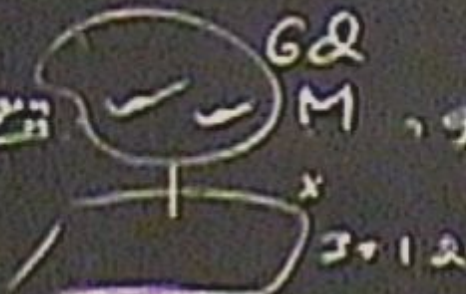
102

62

M

g<sub>m</sub>

spectrum  
interactions  
40



Calculation

b<sup>3</sup> = 204



$SU(3) \times SU(2) \times U(1)$

$N_{\text{bosons}} = 40$   $G_2(TM)$

$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B$

$TH = \int \frac{1}{2} \omega^2 = B^2$

1995

let  
 $g_1 = 0$

$\gamma_1 = 0$   
 $\gamma_2 = 0$

2005

land

$V_{\text{eff}}(\varphi)$



$\rightarrow 4 \rightarrow \rightarrow 4 \rightarrow$   
 $\rightarrow 4 \rightarrow$   
 $\rightarrow 4 \rightarrow$





10 d

6 d

M

3+1 d

spectrum  
interacts:  
4 d

Calculation

$b^2 = 204$



$SU(3) \times SU(2) \times U(1)$

$N_{\text{color}} = 40, C_2(TM)$

$B_{ij} = \frac{1}{2\pi} \int \vec{B} \cdot \vec{A}^i$

$\mathcal{H} = \int \vec{E} \cdot \vec{B}$

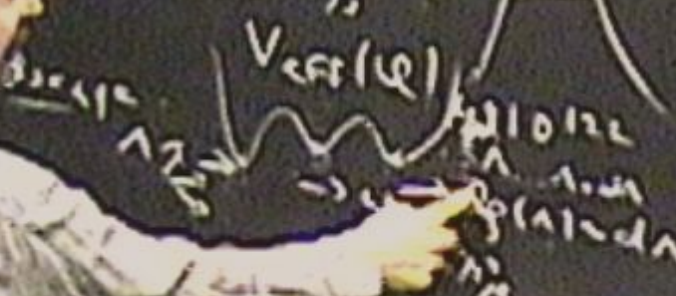
$V = -\Lambda_0 + g_{ij} N^i N^j$

$\{V | N^i \in \mathbb{Z}\}$

1995

$\Rightarrow \frac{1}{\sqrt{2}} \frac{1}{g_2} \frac{1}{g_3}$

2005







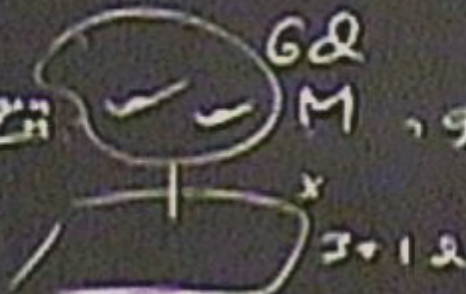
10 d

6 d

M

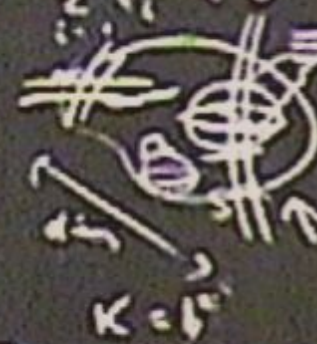
$g_m$

spectrum  
interacts  
4 d



Calculation

$b^2 = 204$



$\sum_{i,j} \epsilon_{ij} = 0$

$SU(3) \times SU(2) \times U(1)$

$N_{\text{color}} = 40$   $G_2(TM)$

$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B = \frac{1}{2\pi} \int_{\Sigma} \mathcal{F}$

$\mathcal{F} = \frac{1}{2} \mathcal{F}_{\mu\nu} dx^\mu dx^\nu$

$V = -\Lambda_0 + g_{ij} N^i N^j$

$\{V | N^i \in \mathbb{R}^3\}$

$V \in (-10^{11}, 10^{11})?$

1995

let  
 $g_i$

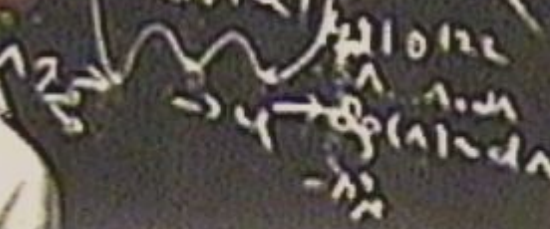
$1/g_i$   
 $g_i = 1/g_i$

$V_{\text{eff}}(\varphi)$

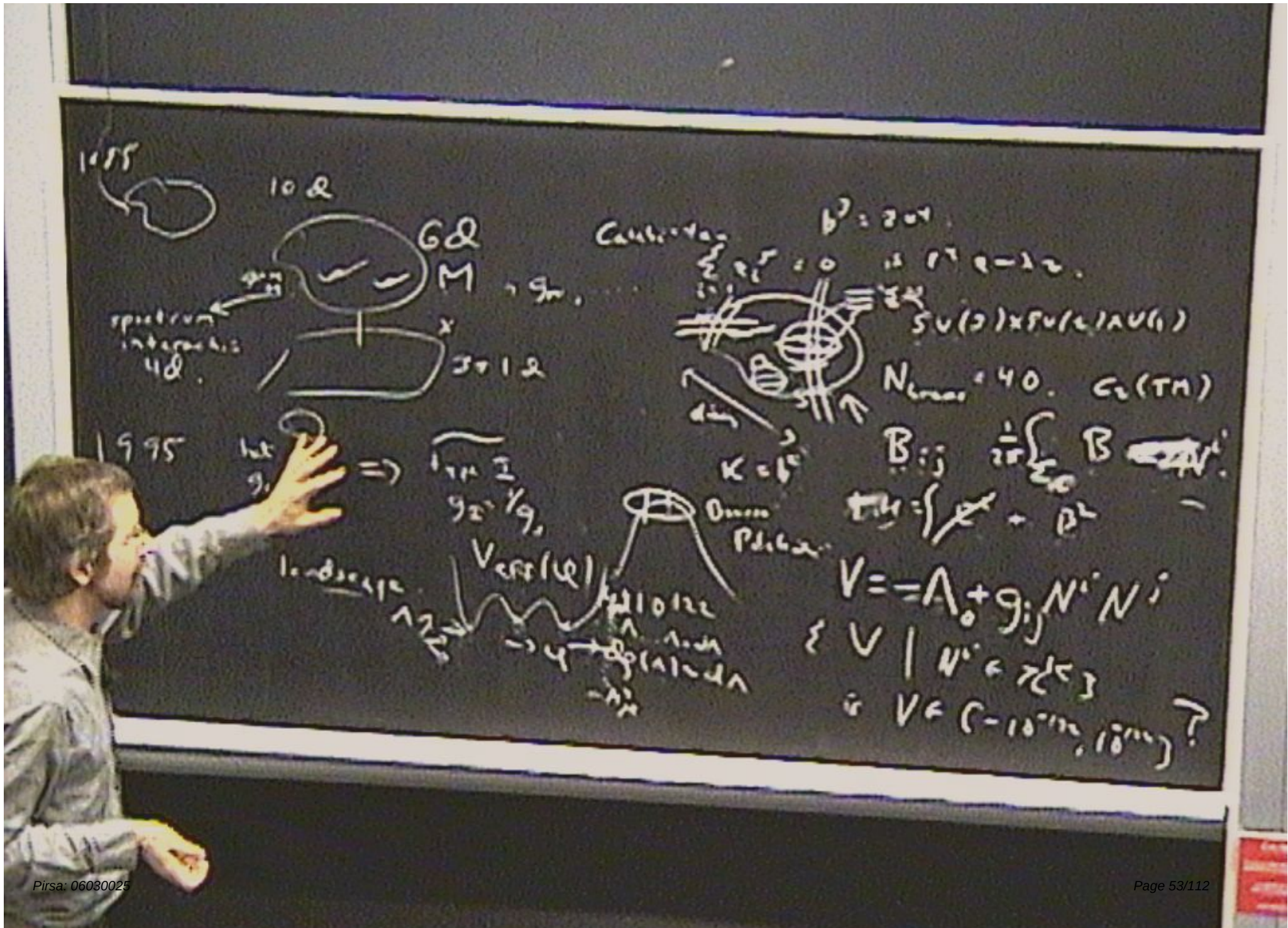


2005

1



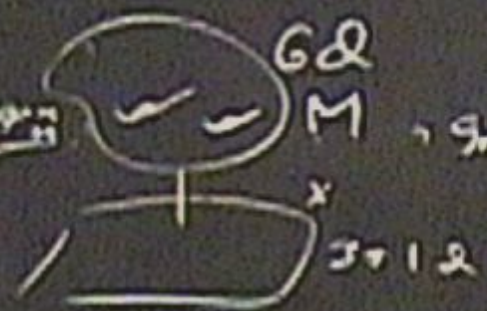




10 d

6d M  $\rightarrow g_m$

spectrum interactions 4d



Calculation

$b^2 = 204$



$SU(3) \times SU(2) \times U(1)$

$N_{\text{lines}} = 40$   $C_2(TM)$

$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B = \frac{1}{2\pi} \int_{\Sigma} \omega$

$\mathcal{H} = \int \omega + B^2$

$V = -\Lambda_0 + g_{ij} N^i N^j$

$\{V | N^i \in \mathbb{R}^3\}$

$V \in (-10^{11} m, 10^{11} m)?$

1995

let  $g_i$

$\Rightarrow \frac{1}{g_1} \frac{1}{g_2} \frac{1}{g_3}$

landscape

$V_{\text{eff}}(\phi)$



Dimensional Reduction





10d

6d

M = 9m

spectrum  
interacts  
4d



Calabi-Yau



b^3 = 204

$\sum \rho_i^2 = 0$  is  $\rho^2 = -12$

$SU(3) \times SU(2) \times U(1)$

$N_{\text{brane}} = 40$   $G_2(TM)$

$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B_{ij} \wedge \omega^i \wedge \omega^j$

$\mathcal{H} = \int \mathcal{L} = \mathcal{H}$

$V = -\Lambda_0 + g_{ij} N^i N^j$

$\{V | N^i \in \mathbb{R}^3\}$

$V \in (-10^{-11}, 10^{-11})$ ?

1995

let  $g_1 = \dots$

$\Rightarrow \frac{1}{\sqrt{12}} \frac{1}{g_1} \frac{1}{g_2} \frac{1}{g_3}$

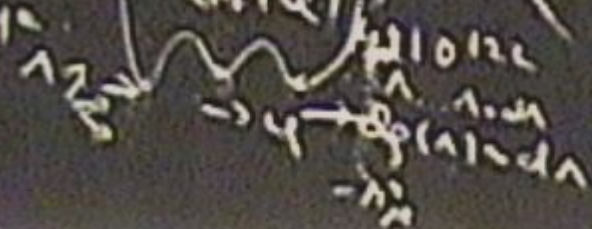


Open  
Physics

2005

landscape

$V_{\text{eff}}(\varphi)$





cosmological

$$R_{\mu} = \frac{1}{2} R_{\mu} \cdot \sigma_{\mu} + \Lambda g_{\mu}$$

$$\ll (100 \text{ km})^4$$

$$\Lambda \sim 0$$

$$\sim 10^{-35} \text{ m}^4$$

$$10^{-35} \text{ m}^4$$

$$L \sigma^2$$

$$\begin{matrix} \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{matrix}$$

late 90's

SN ...

WHAP

$$\Lambda > 0$$

$$\sim 0.7 \Omega_c$$





cosmological

$$R_{\text{ph}} = 12 R_{\odot} \cdot \left( \frac{M_{\text{pl}}}{M_{\odot}} \right)^{-1} \cdot \left( \frac{\Lambda}{\text{g cm}^{-3}} \right)^{-1/3}$$

$$\ll 100 \text{ km}^3$$

$$\Lambda \sim 0$$

$$\sim 10^{-10} M_{\text{pl}}^4$$

$$10^{-10} M_{\text{pl}}^4$$



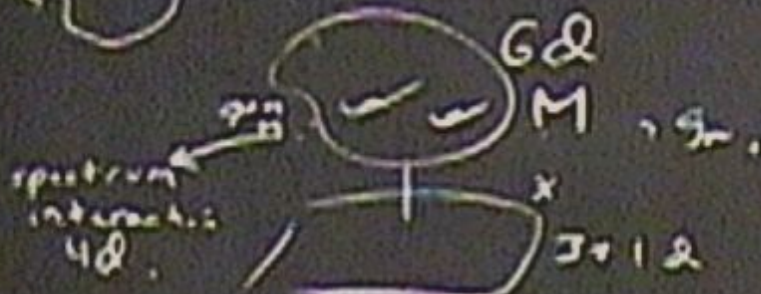
late 90's  
 $\Rightarrow$  SN ...

WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$





10 d



Calculus

$$b^2 = 204$$

$$\sum_{i=1}^n x_i^2 = 0 \quad \text{if } x_i = \pm 1$$

$$SU(2) \times SU(2) / U(1)$$



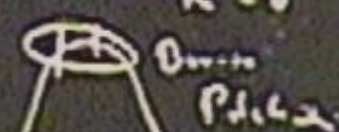
$$N_{\text{brane}} = 40 \quad G_2(TM)$$

$$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B = \frac{1}{2\pi} \int_{\Sigma} \omega$$

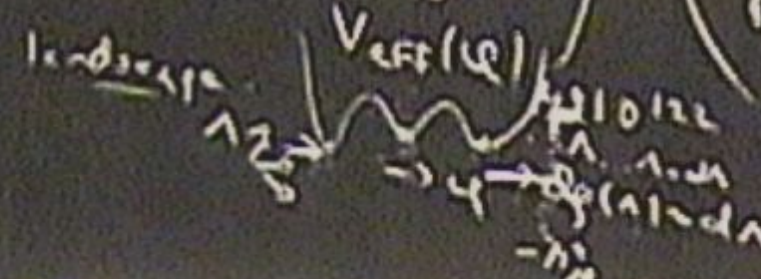
$$H = \int \omega = \beta^2$$

1995

$$g_1 = \dots \Rightarrow \frac{1}{\sqrt{2}} \frac{1}{g_1} \frac{1}{g_2} \frac{1}{g_3}$$



2005



$$V = -\Lambda_0 + g_{ij} N^i N^j$$

$$\{V | V^i \in \pi^i\}$$

$$V \in (-10^{10}, 10^{10})?$$



cosmological

$$R_{\mu\nu} = 12R \cdot \sigma_{T\nu} + \Lambda g_{\mu\nu}$$

$$\ll (100 \text{ Mpc})^2$$

$$\Lambda \sim 0$$

$$\sim 10^{-122} M_{\text{Planck}}^4$$

$$10^{-120} M_{\text{Planck}}^4$$



90's  
SN ...  
WMAP  
→ 0  
~ 0.715  $\Omega_c$



calculus

$$R_{\mu\nu} = \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu}$$

$$\Lambda \sim 10^{-52} \text{ m}^{-2}$$

$$\Lambda \sim 0$$

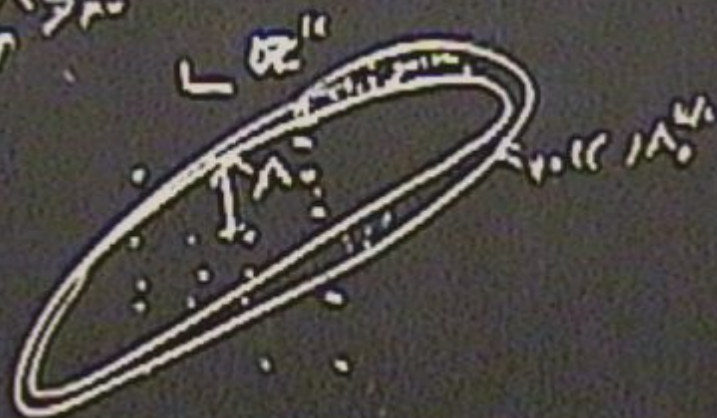
$$\sim 10^{-52} \text{ m}^{-2}$$

$$10^{-52} \text{ m}^{-2}$$

late 90's

SN

$$\Lambda > 0$$





calculated

$$R_{\mu} = 12R = 6.7 \times 10^4 + \Lambda g_{\mu}$$

$$\ll (100 \text{ km})^2$$

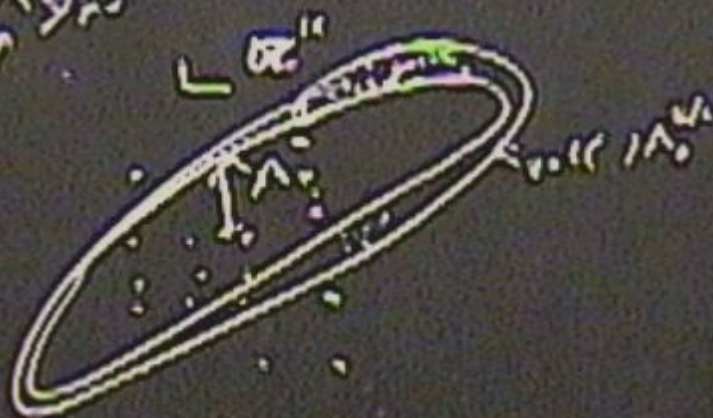
$$\Lambda \sim 0$$

$$\sim 10^{-11} \text{ M}_{\text{plank}}^4$$

$$10^{-11} \text{ M}_{\text{plank}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WHAT  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$







10 d

$G \mathcal{M} \sim g_m$

spectrum  
interacts  
4d



Calculus

$b^3 = 204$



$\sum_{i=1}^n \mathbf{r}_i = 0$  is  $\mathbf{r}_i = \mathbf{r}_n$   
 $SU(2) \times SU(2) / SU(1)$

$N_{\text{brane}} = 40$   $G_2(TM)$

$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B_{ij} \cdot \mathbf{N}^i$

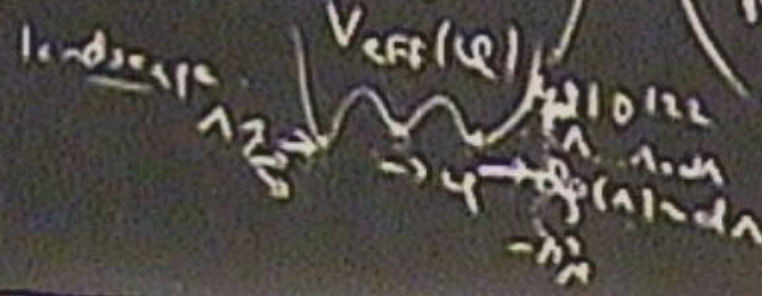
$\mathcal{H} = \int \mathcal{L} = \mathcal{P}^2$

1995

let  $g_{1,0} \Rightarrow \text{for } \mathbb{I}$   
 $g_{\mathbb{I}} = \gamma g$

Dimension  
Phase

2005



$V = -\Lambda_0 + g_{ij} N^i N^j$

$\{V | N^i \in \mathbb{R}^3\}$

$V \in (-10^{10}, 10^{10})?$



cosmological

$$R_{\text{pu}} = 1.5 R_{\odot} \approx 10^4 \text{ km} \approx \Lambda_{\text{SN}}$$

$$\ll 100 \text{ m} \text{ s}^{-1}$$

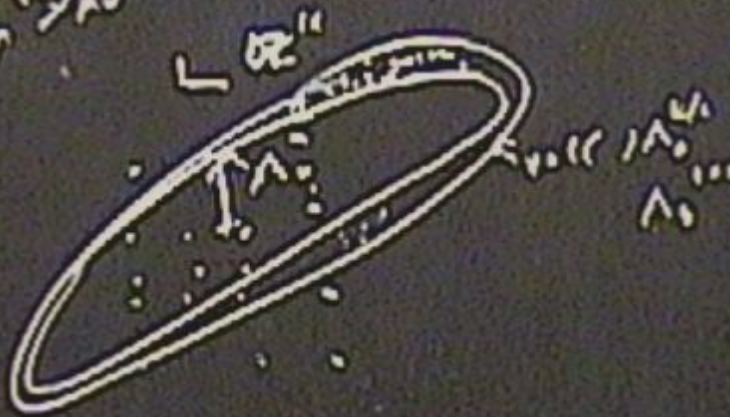
$$\Lambda \sim 0$$

$$\sim 10^{-11} M_{\text{pl}}^4$$

$$10^{-50} M_{\text{pl}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$





cosmology

$$R_{\text{pu}} = 1.5 R_{\odot} \approx 10^4 \text{ km} \quad \Lambda \approx 10^{-50}$$

$$\ll (100 \text{ m})^{-10}$$

$$\Lambda \sim 0$$

$$\sim 10^{-100} M_{\text{Planck}}^4$$

$$10^{-50} M_{\text{Planck}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$









cosmological

$$R_H = 12R \cdot \Omega_m T_0 + \Lambda g_{\text{m}}$$

$$\ll 100 \text{ Mpc}$$

$$\Lambda \sim 0$$

$$\sim 10^{-12} \text{ Mpc}^4$$

$$10^{-50} \text{ Mpc}^4$$

late 90's  
 $\Rightarrow$  SN ...

WMAP

$$\Lambda > 0$$

$$\sim 0.7 \Omega_c$$



$$\dots - 10^{150} \cdot \frac{1}{\Omega_c} > 1$$

sury 10<sup>150</sup>



cosmological

$$R_{\text{pu}} = 1.5 R_{\odot} \approx 10^{10} \text{ cm} \quad \Lambda \approx 10^{-5}$$

$$\ll 100 \text{ m}^{10}$$

$$\Lambda \sim 0$$

$$\sim 10^{-152} M_{\text{plank}}^4$$

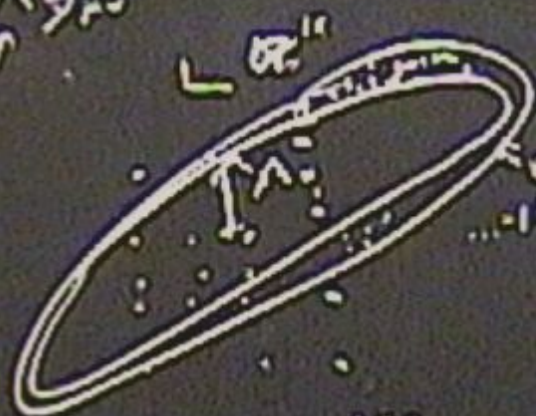
$$10^{-50} M_{\text{plank}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WMAP

$$\Lambda > 0$$

$$\sim 0.7 \Omega_c$$

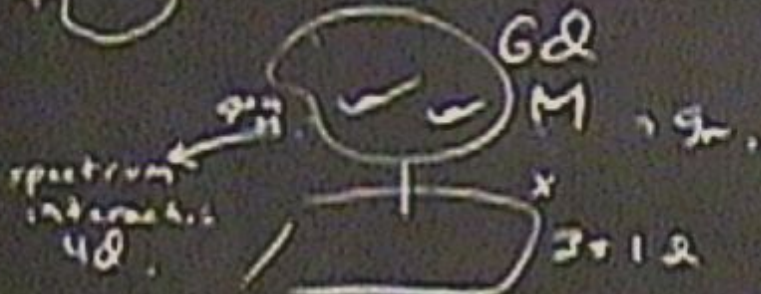


surv  $10^{150}$   
~~surv~~  $10^{100}$





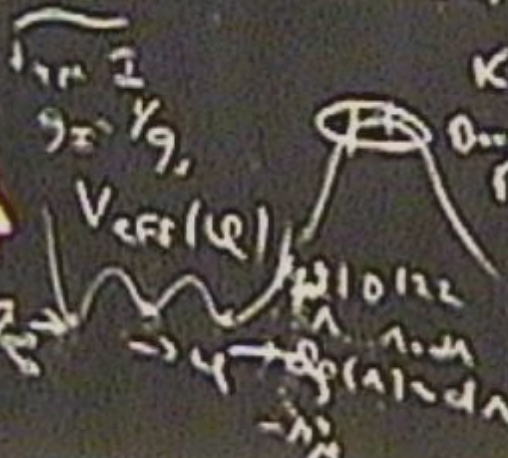
10 2



1995

let  $g_i$

2005



Calculation

$b^2 = 204$

$$\sum_i \epsilon_i^2 = 0 \quad \text{if } \epsilon_i = \lambda_i$$

$$SU(3) \times SU(2) \times U(1)$$



$N_{\text{bosons}} = 40$   $G_2(TM)$

$$B_{ij} = \frac{1}{2\pi} \int_{\Sigma_0} B = \frac{1}{2\pi} \int_{\Sigma_0} \omega$$

$$T_H = \int_{\Sigma_0} \omega + \partial^2$$

$$V = -\Lambda_0 + g_{ij} N^i N^j$$

$$\{V \mid N^i \in \pi^i \}$$

$$V \in (-10^{-10}, 10^{-10})?$$



cosmological

$$R_{\mu} = 15 R_{\odot} \approx 10^4 \text{ km} \quad \Lambda \approx 10^{-5} \text{ m}^{-1}$$

$$\ll (100 \text{ m})^{-1}$$

$$\Lambda \sim 0$$

$$\sim 10^{-10} \text{ m}^{-1}$$

$$10^{-10} \text{ m}^{-1}$$

late 90's  
 $\Rightarrow$  SN ...  
 WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$

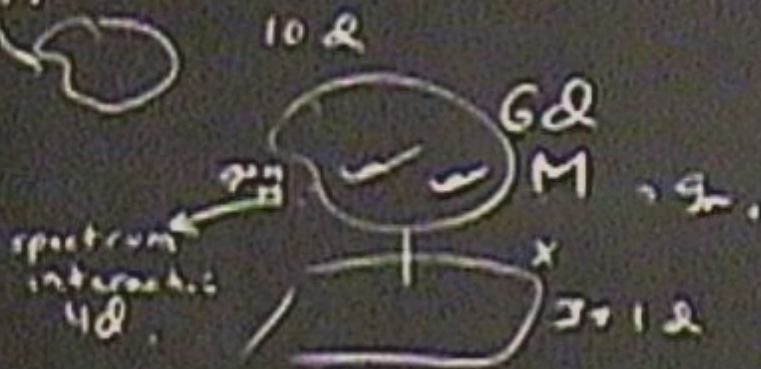


$$\dots \sim 10^{-10} \text{ m}^{-1} \dots > 1$$





1975



Calculus

$b^3 = 204$

$\sum_{i=1}^n x_i^2 = 0$  and  $x_i = 1, 2$

$SU(3) \times SU(2) \times U(1)$

$N_{\text{color}} = 40$   $G_c(TN)$

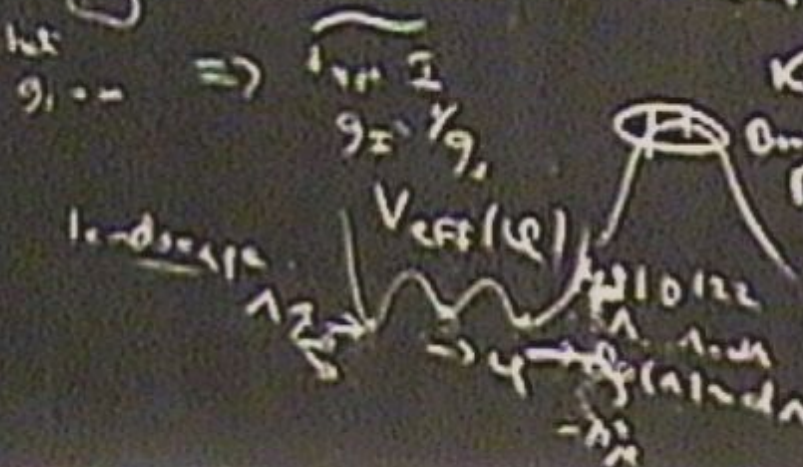
$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B$

$\mathcal{H} = \int \mathcal{L} = \mathcal{P}^2$

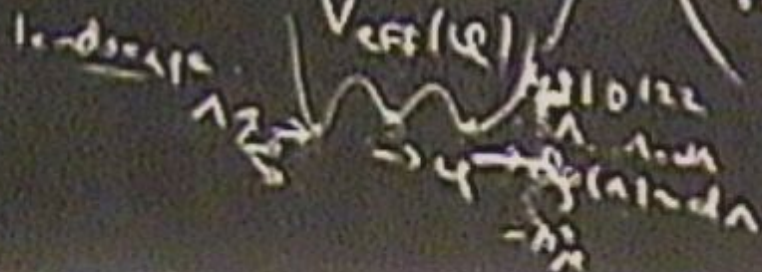
$K = b^2$

Dirac Phase

1995



2005



$V = -\Lambda_0 + g_{ij} N^i N^j$

$\{V | V^i \in \mathbb{R}^3\}$

$V \in (-10^{-10}, 10^{-10})?$



cosmological

$$R_{\text{pu}} = 1.5 R_{\odot} \approx 10^4 \text{ km} \quad \Lambda \approx 0$$

$$\ll 100 \text{ m}^{-1}$$

$$\Lambda \sim 0$$

$$\sim 10^{-10} M_{\text{pl}}^4$$

$$10^{-50} M_{\text{pl}}^4$$

late 90's

$\Rightarrow$  SN ...

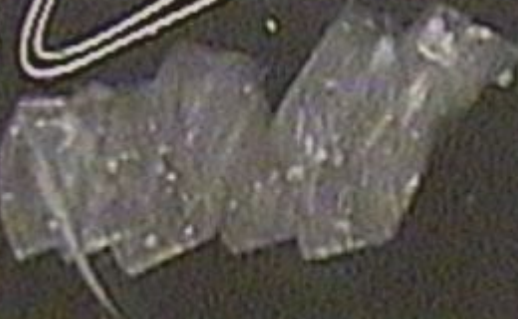
WMAP

$$\Lambda > 0$$

$$\sim 0.7 \Omega_c$$



$$\frac{v_{\text{orb}}}{c} \frac{\Lambda_{\text{eff}}}{H^2} > 1$$





cosmological

$$R_{\text{ph}} = \frac{1}{2} R_{\text{c}} \left( \frac{c}{v} \right)^2 + \Delta g_{\text{ph}}$$

$$\ll (100 \text{ km})^2$$

$$\Lambda \sim 0$$

$$\sim 10^{-10} M_{\text{pl}}^4$$

$$10^{-50} M_{\text{pl}}^4$$



$$\dots - \frac{1}{10} \frac{\Lambda_{\text{ph}}}{\dots} > 1$$

late 90's  
 $\Rightarrow$  SN ...

WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$

SVP  
 $v = 9 \text{ km/s}$   
 EN 10/15?



cosmology

$$R_{\text{pc}} = 15 R_{\odot} \approx 10^4 \text{ km} \approx \Lambda_{\text{pc}}$$

$$\ll (100 \text{ m})^2$$

$$\Lambda \sim 0$$

$$\sim 10^{-10} M_{\text{pl}}^4$$

$$10^{-50} M_{\text{pl}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$



$$\dots -10^{11} \cdot \frac{1}{\text{cm}^3} \cdot \frac{1}{\text{cm}^3} > 1$$

SVP  
 $v = 9.5 \text{ km/s}$   
 EN NE  
 $\approx 3.5/11$



cosmological

$$R_{\text{H}} = \frac{1}{H} = \frac{c}{H_0} \approx 14.4 \text{ Gpc}$$

$$c \approx 3 \times 10^8 \text{ m s}^{-1}$$

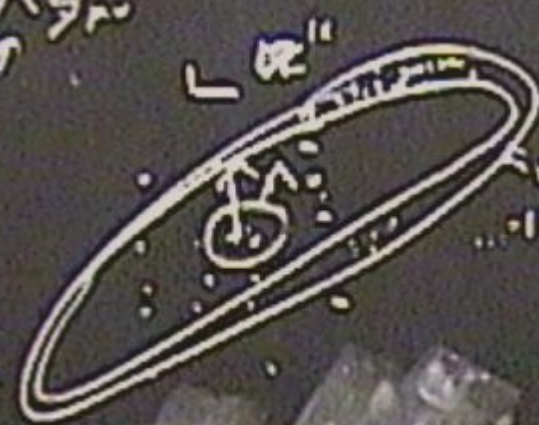
$$\Lambda \sim 0$$

$$\sim 10^{-122} M_{\text{Planck}}^4$$

$$10^{-50} M_{\text{Planck}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$



$$\frac{v_i}{c} \approx \frac{H_0 r_i}{c} \approx \frac{H_0}{c} r_i$$

$$\sum v_i \cdot (w_i)$$

$$V = \sum N_i \cdot v_i$$

SVP  
 $v = g, N, M$   
 $\Rightarrow$  NE



cosmological

$$R_{\text{ph}} = \frac{1}{2} R_{\text{ph}} + \frac{1}{2} R_{\text{ph}} + \Lambda g_{\mu\nu}$$

$$\ll (100 \text{ m})^{-1}$$

$$\Lambda \sim 0$$

$$\sim 10^{-122} M_{\text{pl}}^4$$

$$10^{-50} M_{\text{pl}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$



SVP  
 $V = g_{\mu\nu} N^{\mu} N^{\nu}$   
 $\exists N \quad |V| < 1$

$$\sum V_i \cdot (u_i)$$

$$V = \sum_{i=1}^n N_i \cdot V_i + \dots$$



cosmological

$$R_{\mu\nu} = \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu}$$

$$\ll (100 \text{ m})^{-2}$$

$$\Lambda \sim 0$$

$$\sim 10^{-52} \text{ m}^{-2}$$

$$10^{-52} \text{ m}^{-2}$$

late 90's  
SN ...

WMAP

$$> 0$$

$$\sim 0.7 \Omega_c$$



SVP

$$V = g_{ij} N^i N^j$$

EN  $|v| < c$ ?

$$\dots - \frac{1}{10^{100}} \cdot \frac{1}{10^{100}} \dots > 1$$

$$\sum V_i \cdot (u_i)$$

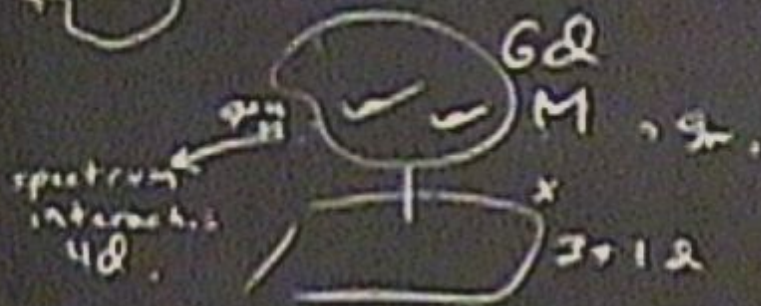
$$V = \sum N_i \cdot V_i + \dots$$

NP complete.





10 d



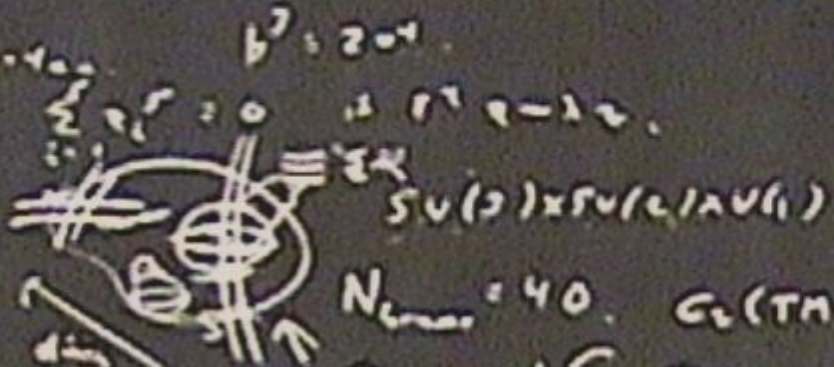
1995

let  $g_i \rightarrow \Rightarrow \sqrt{g_i} \frac{1}{g_i}$

2005

landscape  $V_{eff}(\phi)$

Calabi-Yau



$b^2 = 204$

$\sum_{i=1}^n x_i^2 = 0$  is  $r^2 = -12$

$SU(3) \times SU(2) \times U(1)$

$N_{\text{chiral}} = 40$   $G_2(TM)$

$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B$

$\mathcal{H} = \int \mathcal{L} = \mathcal{H}$

$V = -\Lambda_0 + g_{ij} N^i N^j$

$\{V | \psi^i \in \pi^i \}$   
 $\{10^{16}, 10^{17}\}?$



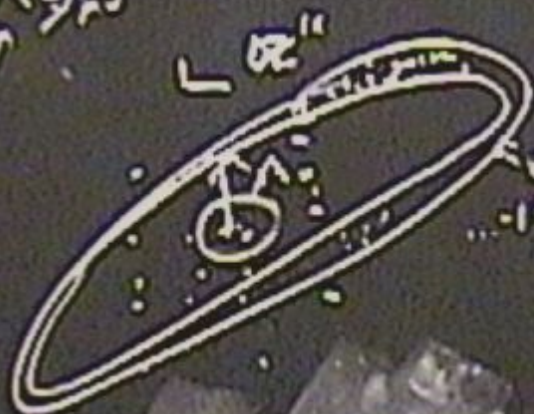
cosmological

$$R_{pu} = 1.5 R_{\odot} \approx 10^6 \text{ km} \approx \Lambda_{gr}$$

$$\begin{aligned} \Lambda &\ll (100 \text{ km})^2 \\ \Lambda &\sim 0 \\ &\sim 10^{-10} M_{\text{plank}}^4 \\ &10^{-50} M_{\text{plank}}^4 \end{aligned}$$

late 90's  
 $\Rightarrow$  SN ...

WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$



SVP  
 $V = 9 \times 10^{11}$   
 $\exists N \text{ NE}$   
 $|v| < \epsilon$

trial (opt size)

$$\sum_{i=1}^n \frac{1}{\lambda_i} \geq 1$$

$$\begin{aligned} &\sum V_i \cdot (u_i) \\ V &= \sum N_i \cdot V_i + \\ &- \Lambda_0 \end{aligned}$$

NP complete.



cosmological

$$R_{\text{pu}} = 1.5 R_{\odot} \approx 10^4 \text{ km} \approx \Lambda_{\text{gr}} \uparrow$$

$$\ll (100 \text{ km})^4$$

$$\Lambda \sim 0$$

$$\sim 10^{-12} M_{\text{pl}}^4$$

$$10^{-10} M_{\text{pl}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WMAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$



$$\dots - \frac{1}{10} \frac{\Lambda_{\text{gr}}}{\text{km}^4} \dots > 1$$

$$\sum V_i \cdot (u_i)$$

$$V = \sum N_i \cdot V_i + \dots - \Lambda_0$$

NP complete.

trial (input size) polynomial P.

SVP  
 $V = g_1, \dots, g_n$   
 $\exists N \text{ } |v| \leq \epsilon$



cosmology

$$R_{\mu\nu} = \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu}$$

$$\Lambda \sim 10^{-122} \text{ m}^{-2}$$

$$\Lambda \sim 0$$

$$10^{-122} \text{ m}^{-2}$$

$$10^{-122} \text{ m}^{-2}$$

90%

NP

MAP

NP

$\sim 10^{11}$



...  $10^{11}$  ...

$$\sum V_i \cdot (u_i)$$

$$V = \sum N_i \cdot V_i + \Lambda_0$$

NP complete.

trial (opt size) polynomial P.

Exp

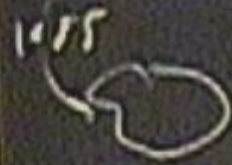
SVP

$$V = g_1, N, \dots$$

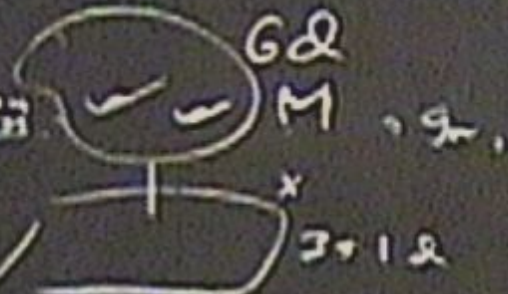
NE

$\geq 3/4$





102



spectrum  
interactions  
40

Calculation

$$b^2 = 204$$

$$\sum_i v_i^2 = 0 \quad \text{is } v^2 = -\lambda v$$

$$SU(3) \times SU(2) \times U(1)$$



$$N_{\text{bosons}} = 40 \quad G_2(TM)$$

$$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B = \frac{1}{2\pi} \int_{\Sigma} \omega$$

$$T_H = \int_{\Sigma} \omega + B^2$$

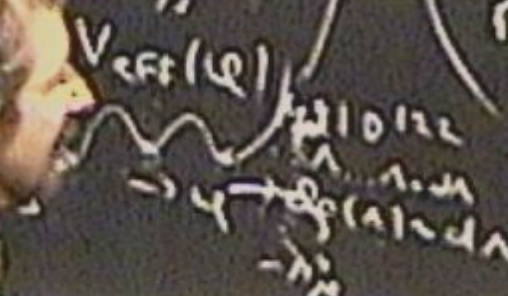
1995



$$g_i \Rightarrow \frac{1}{2\pi} \int_{\Sigma} \omega$$

2005

1026



Open  
Physics

$$V = -\Lambda_0 + g_{ij} N^i N^j$$

$$\{V \mid N^i \in \mathbb{R}^3\}$$

$$V \in (-10^{-10}, 10^{-10})?$$



NP. <sup>on.</sup> checkable  
in poly time.



cosmology

$$R_{\mu} = \frac{1}{2} R_{\mu} + \frac{1}{2} \Lambda g_{\mu}$$

$$\ll (100 \text{ m})^2$$

$$\Lambda \sim 0$$

$$\sim 10^{-52} \text{ m}^4$$

$$10^{-50} \text{ M}_{\text{pl}}^4$$

late 90's  
 $\Rightarrow$  SN ...  
 WHAP  
 $\Lambda > 0$   
 $\sim 0.7 \Omega_c$



SVP  
 $V = g_{\mu\nu} N^{\mu} N^{\nu}$   
 $\exists N \text{ s.t. } V < 0$

$$\dots - \frac{1}{2} \Lambda_0 \dots > 1$$

$$\sum V_i \cdot (u_i)$$

$$V = \sum N_i \cdot V_i + \dots$$

NP complete.

trial (input size) polynomial P.  
 EXP



calculus

$$R_{\mu} = \frac{1}{2} R_{\mu\nu} g^{\mu\nu} + \Lambda g_{\mu\nu}$$

$$CC (100 \text{ m})^2$$

$$\Lambda \sim 0$$

$$\sim 10^{-122} M_{\text{Planck}}^4$$

$$10^{-50} M_{\text{Planck}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WHAP

$$\Lambda > 0$$

$$\sim 0.7 \Omega_c$$



SVP

$$V = g_{\mu\nu} N^{\mu} N^{\nu}$$

$\exists N \text{ } |v| < c$

$$\dots = \frac{1}{2} \frac{1}{\Lambda_0} \cdot \frac{1}{\Lambda_0} \dots > 1$$

$$\sum V_i \cdot (u_i)$$

$$V = \sum N_i \cdot V_i + \dots$$

NP complete.

trial (input size) polynomial P.  
 EXP



NP. <sup>can</sup> check in poly time.

SAT is  $\text{P}^{\text{NP}}$ .  
is NP complete?



NP. <sup>ex.</sup> checkable  
in poly time.

SAT is  $\text{Fcd. 1.4}$   
is NP complete?  
 $x_i \in \{\text{true, false}\}$

AND {  $x_1 \vee \overline{x_7} \vee x_{15} \dots$



NP. <sup>ans.</sup> checkable  
in poly time.  $\downarrow$  poly  
verif.  $\uparrow$   
input problem, witness.

SAT is  $\text{NP-complete}$ .  
is NP complete?

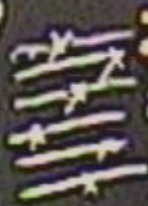
$x_i \in \{\text{true}, \text{false}\}$

AND  $\left\{ \begin{array}{l} x_1 \vee \overline{x_7} \vee x_{15} \dots \end{array} \right.$



NP. <sup>can.</sup> checked  
in poly time.

input problem; witness.  
↓ poly  
verif.



SAT is fixed.  
is NP complete?

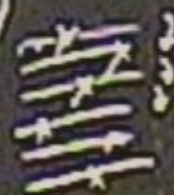
$x_i \in \{\text{true, false}\}$

AND {  $x_1 \vee \overline{x_7} \vee x_{15} \dots$



NP. <sup>ans.</sup> checkable  
in poly time.

PL <sup>input</sup> problem, witness. 1  
↓ poly  
yes/no.



SAT is  $\text{NP-complete}$   
is NP complete?

$x_i \in \{\text{true}, \text{false}\}$

AND {  $x_1 \vee \overline{x_2} \vee x_{15} \dots$

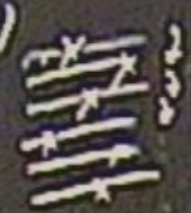


NP. <sup>ans.</sup> checkable  
in poly time.  $\downarrow$  poly  
verif. input problem; witness. 1

$\Downarrow$  reduction  
SAT is  $\text{NP-complete}$ .  
is NP complete?  
 $x_i \in \{\text{true, false}\}$

AND {  $x_1 \vee \overline{x_2} \vee x_{15} \dots$



NP. <sup>ans.</sup> checkable  
in poly time.  $\downarrow$  poly  
yes/no. 

P/NP.  $\Downarrow$  reduction  
SAT is  $\text{NP-complete}$ .  
is NP complete?  
 $x_i \in \{\text{true, false}\}$

AND  $\left\{ \begin{array}{l} x_1 \vee \overline{x_2} \vee x_{15} \dots \end{array} \right.$



F. Donaf

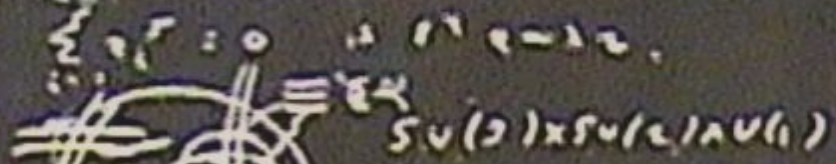


10 d



Calculus

$b^2 = 204$



$\sum \epsilon_i = 0$  is it  $e=12$

$SU(2) \times SU(2) \times U(1)$

$N_{\text{max}} = 40$   $G_2(TM)$

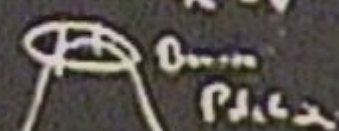
$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B = \frac{1}{2\pi} \int_{\Sigma} \omega$

$TH = \int \omega = D^2$

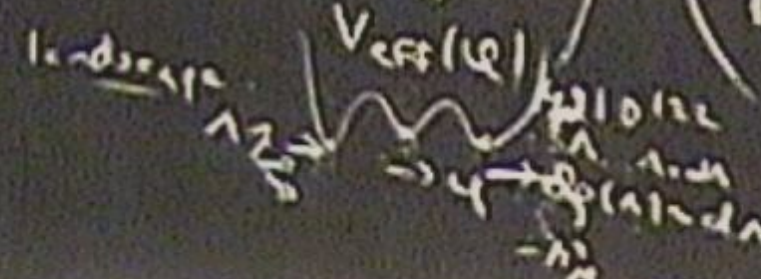
1995

let  $g_i \Rightarrow$

$\Rightarrow \frac{1}{2\pi} \int \omega = \frac{1}{2\pi} \int \gamma_i$



2005



$V = -\Lambda_0 + g_{ij} N^i N^j$

$\{V | N^i \in \pi^i\}$

$\in V \in (-10^{10}, 10^{10})?$



NP. <sup>ans.</sup> checkable  
in poly time.  $\downarrow$  poly  
verif. 

P NP.  $\Downarrow$  reduction

SAT is dec.  $\downarrow$   
is NP complete?

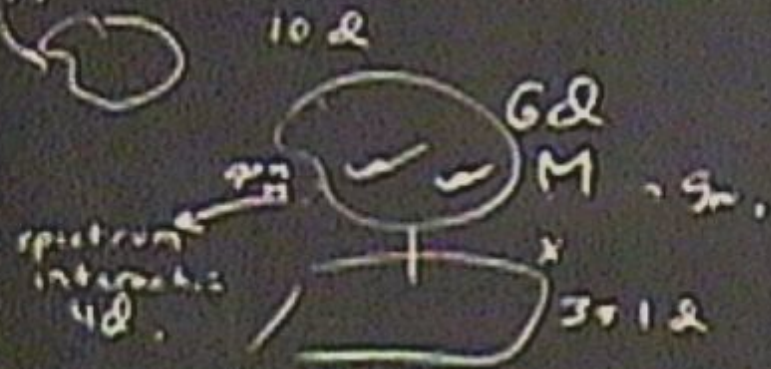
$x_i \in \{\text{true}, \text{false}\}$

AND  $\left\{ \begin{array}{l} x_1 \vee \overline{x_2} \vee x_{15} \dots \end{array} \right.$

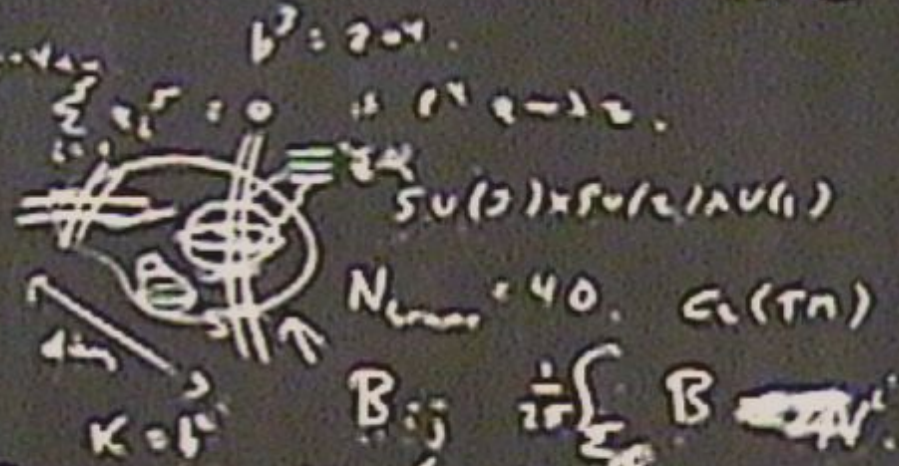


F. Doreif

1975



Calculation



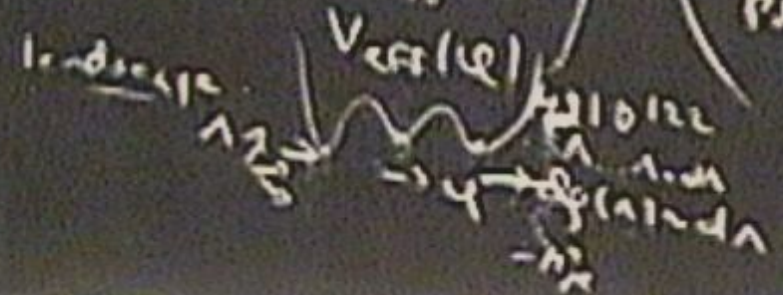
1995

let  $g_{i=0} \Rightarrow \frac{1}{4\pi} \int \frac{1}{g_i} \frac{1}{g_i} \frac{1}{g_i}$

Onion  
P. 16.2

$B_{ij} = \frac{1}{2\pi} \int \frac{B}{\sqrt{V}}$

2005



$V = -\Lambda_0 + g_{ij} N^i N^j$   
 $\{V | N^i \in \mathbb{Z}^3\}$   
 $\& V \in (-10^{-10}, 10^{-10})?$



cosmological

$$R_{\mu} = \frac{1}{2} R_{\mu} \cdot \partial_{\mu} T_{\mu} + \Lambda g_{\mu}$$

$$\ll (100 \text{ km})^2$$

$$\Lambda \sim 0$$

$$\sim 10^{-52} \text{ M}_{\text{Planck}}^4$$

$$10^{-50} \text{ M}_{\text{Planck}}^4$$

late 90's  
 $\Rightarrow$  SN ...

WMAP

$$\Lambda > 0$$

$$\sim 0.7 \Omega_c$$



SVP

$$V = 9\pi, N^2 N^2$$

NE 1/155?

$$\dots \frac{1}{10^{12}} \cdot \frac{1}{10^{12}} \cdot \frac{1}{10^{12}} \dots > 1$$

$$\sum V_i \cdot (u_i)$$

$$V = \sum N_i \cdot V_i + \dots$$

NP complete.

trial (input size) polynomial P.  
 EXP



NP. <sup>ans.</sup> checkable in poly time. PL <sup>input</sup> problem; <sup>witness</sup> / 

P/NP.  $\Downarrow$  reduction

SAT is  $\text{NP-complete}$   
is NP complete?

$x_i \in \{\text{true}, \text{false}\}$

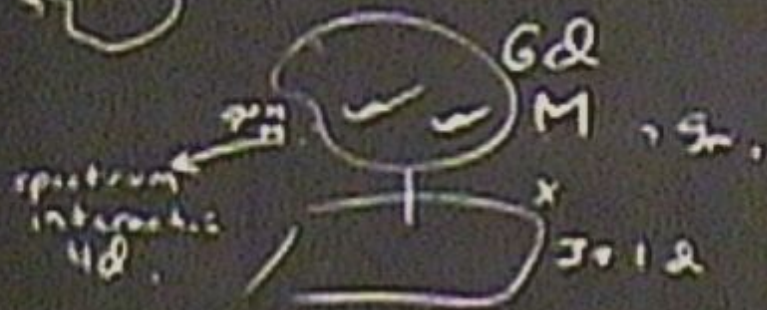
AND {  $x_1 \vee \overline{x_2} \vee x_{15} \dots$



F. Denef



10 d



Center-4d  
 $\sum_{i=1}^4 \epsilon_i^2 = 0$  is  $\epsilon^2 = 12$ .

$SU(3) \times SU(2) \times U(1)$

$N_{\text{brane}} = 40$   $G_2(M)$

$B_{ij} = \frac{1}{i\pi} \int_{\Sigma} B$

$\frac{1}{4\pi} \int_{\Sigma} \epsilon^{\mu\nu} \epsilon_{\mu\nu} = \beta^2$   
 $\sum g_{ij} (N^i)^j$

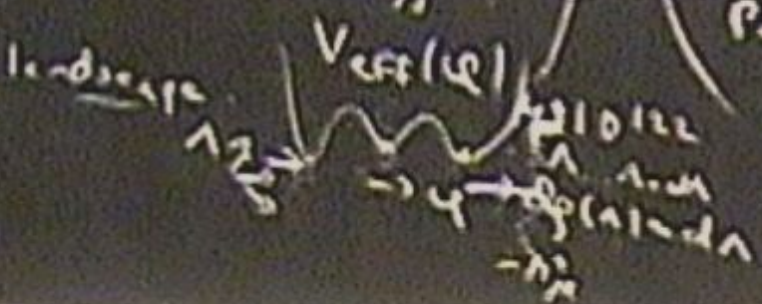
$V = -\Lambda_0 + g_{ij} N^i N^j$

$\{V \mid V^i \in \pi^i\}$   
 $V \in (-10^{10}, 10^{10})?$

1995

let  $g_{ij} \Rightarrow \sqrt{g_{ij}}$   
 $g_{ij} \propto g_{ij}$

2005





cosmological

$$R_H = 1/H_0 \approx 10^{26} \text{ cm} \approx \Lambda^{-1}$$

$$\Lambda \sim 10^{-32} \text{ cm}^{-2}$$

$$\sim 10^{-122} M_{\text{Planck}}^4$$

$$10^{-50} M_{\text{Planck}}^4$$



$$\sum_{i=1}^n \lambda_i^2 > 1$$

$$V = \sum N_i \cdot V_i + \dots$$

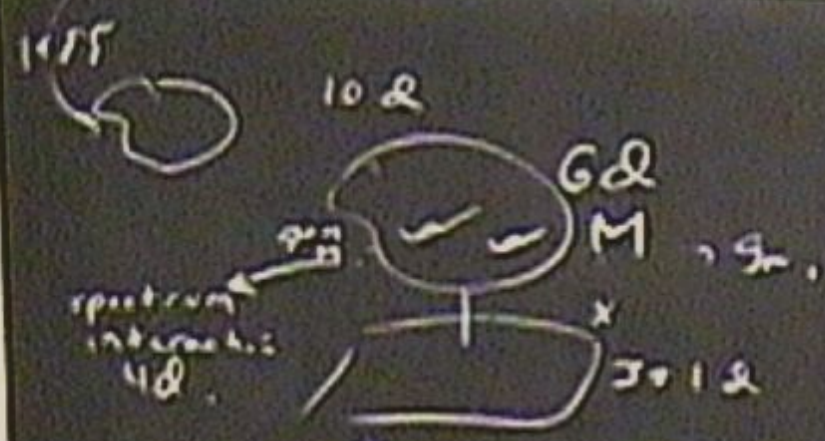
NP complete.

trial (input size) polynomial P.  
EXP

SVP  
V = g, N, M  
EN |v| < ε



F. Denef



Center-Valley

$\sum_{i,j} \tau_{ij}^2 = 0$  is  $\tau_{ij}^2 = 12$

$b^2 = 204$

$SU(3) \times SU(2) \times U(1)$

$N_{\text{brane}} = 40$   $G_2(Tn)$

$B_{ij} \quad \frac{1}{2\pi} \int_{\Sigma} B$

$\frac{1}{2\pi} \int_{\Sigma} \omega = \beta^2$

$\sum g_{ij} (W^{ij})$

$V = -\Lambda_0 + g_{ij} N^i N^j$

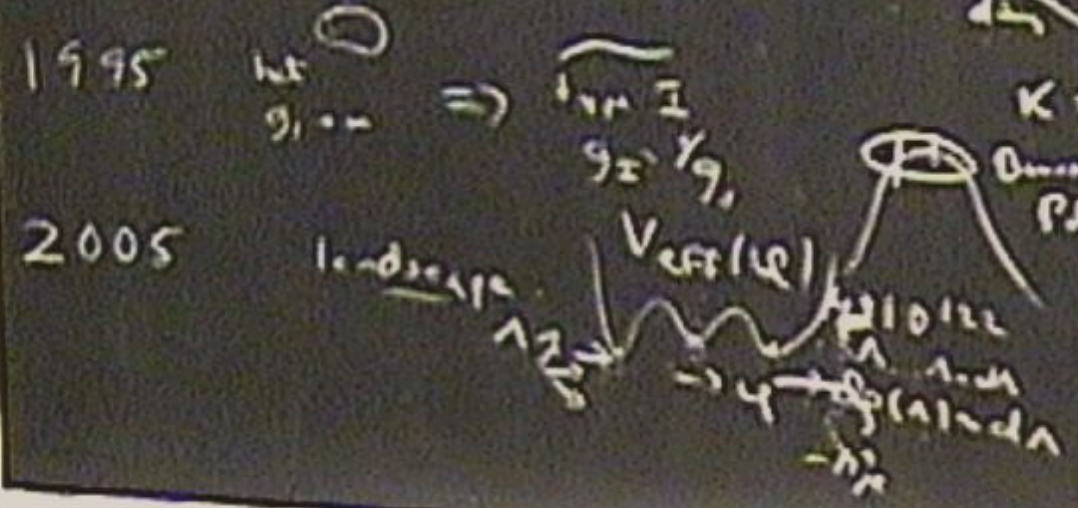
$\{V \mid V^i \in \mathbb{Z}^3\}$

$\in V \in (-10^{10}, 10^{10})?$

$K = 6^2$

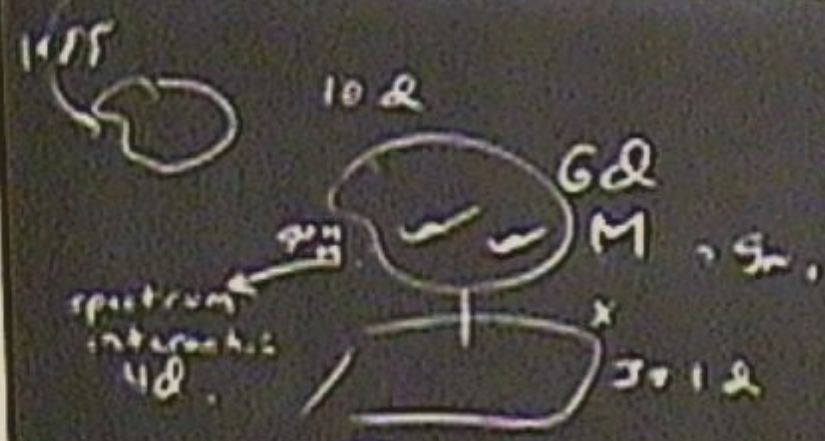
$\text{Dimer}$

$\text{Phases}$





F. Denef



Calculus

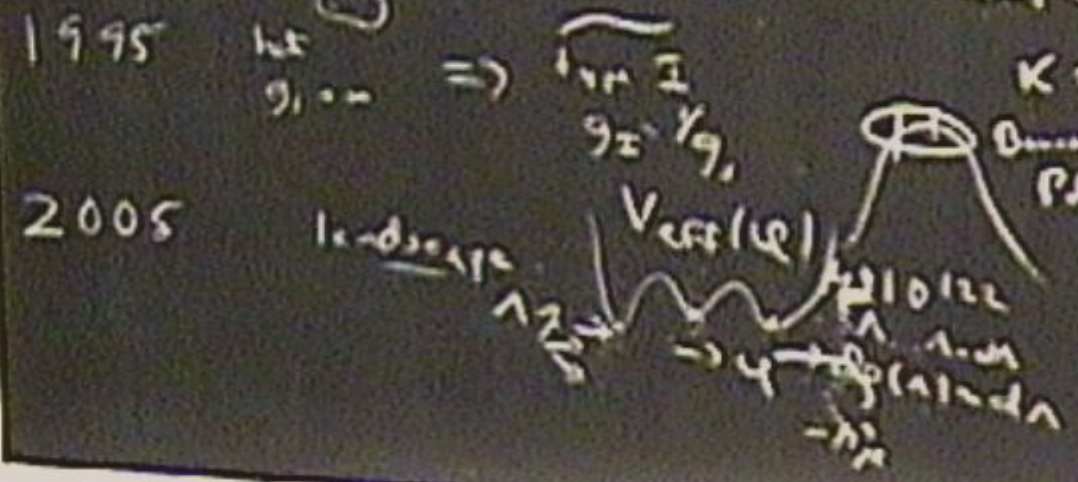
$$\sum_{i,j} \epsilon_{ij}^2 = 0 \quad \text{if } \epsilon_{ij} = \pm 2$$

$$SU(2) \times SU(2) \times U(1)$$

$$N_{\text{brane}} = 40 \quad G_2(TN)$$

$$B_{ij} \quad \frac{1}{2\pi} \int_{\Sigma_0} B = \frac{1}{2\pi} \int_{\Sigma_0} B_{ij} dx^i dx^j$$

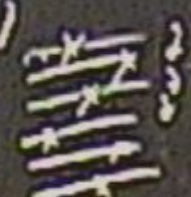
$$K = 6$$





NP. <sup>ans.</sup> checkable  
in poly time.

PL <sup>input</sup> problem, <sup>witness</sup> /  
↓ poly  
time.



$\psi[ \quad ]$

P+NP.  $\Downarrow$  reduction

SAT is  $\text{NP-complete}$ .

is NP complete?

$x_i \in \{\text{true}, \text{false}\}$

AND  $\left\{ \begin{array}{l} x_1 \vee \overline{x_2} \vee x_{15} \dots \end{array} \right.$



NP. <sup>ans.</sup> checkable  
in poly time.  $P \leq$  problem, witness.  $\downarrow$  poly  
yes/no

P=NP.  $\Downarrow$  reduction

SAT is  $\text{NP-complete}$   
is NP complete?

$x_i \in \{\text{true, false}\}$

AND  $\left\{ \begin{array}{l} x_1 \vee \overline{x_2} \vee x_{15} \dots \end{array} \right.$

$P \mid \sim \mid \psi C \quad \exists !^2$



NP. <sup>ans.</sup> checkable  
in poly time.  $P \subseteq$  problem; witness.  $\downarrow$  poly  
yes/no.

P=NP.

$\Downarrow$  reduction

$P/1 \sim |\Psi|$

$\exists!^2$

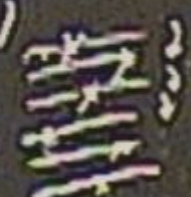
SAT is  $\text{NP-complete}$

is NP complete?

$x_i \in \{\text{true}, \text{false}\}$

AND  $\left\{ \begin{array}{l} x_1 \vee \overline{x_2} \vee x_{15} \dots \end{array} \right.$



NP. <sup>ans.</sup> checkable in poly time. P/C problem, witness. 

P/NP.  $\Downarrow$  reduction  $P/1 \sim |\Psi|$

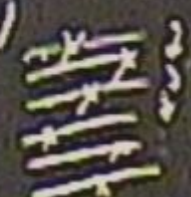
SAT is fact. 1.7  
is NP complete?

$x_i \in \{\text{true}, \text{false}\}$

AND {  $x_1 \vee \overline{x_2} \vee x_{15} \dots$

$\exists !^2$  



NP. <sup>can.</sup> checkable in poly time. PL <sup>input</sup> problem, <sup>witness</sup> / 

P=NP.  $\Downarrow$  reduction  $P/1 \sim |\Psi| \subseteq \mathbb{N}^2$

SAT is decidable.  
is NP complete?

$x_i \in \{\text{true}, \text{false}\}$

$\sim e^{\frac{2^n}{n}}$

AND  $\left\{ \begin{array}{l} x_1 \vee \overline{x_2} \vee x_{15} \dots \end{array} \right.$

HH  
①



NP. <sup>can.</sup> checkable in poly time.      PC problem, witness? 

$P \neq NP$ .  $\Downarrow$  reduction  
 SAT is  $\text{NP-complete}$ .  
 is NP complete?  
 $x_i \in \{\text{true, false}\}$

AND  $\left\{ \begin{array}{l} x_1, \bar{x}_7, x_{15}, \dots \end{array} \right.$

$$P|1 \sim |\psi\rangle \quad \square^2$$

$$\sim e^{\frac{2\pi i}{\Lambda}} \quad \Lambda > 0$$

$$\quad \quad \quad \Theta(\Lambda)$$



NP. <sup>ans.</sup> checkable in poly time. <sup>input problem, witness</sup>  $P \leq$   $\downarrow$  poly  $\rightarrow$   $10$

P=NP.  $\Downarrow$  reduction SAT is  $\text{NP-complete}$ .  
 $x_i \in \{\text{true, false}\}$

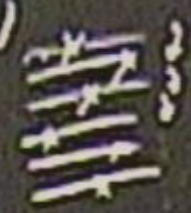
AND  $\left\{ \begin{array}{l} x_1 \vee \overline{x_2} \vee x_{15} \dots \end{array} \right.$

$P(1) \sim |\Psi|$

$\sim e^{\frac{1}{2} \sqrt{n}}$

$\sum_i^2$   $\text{HH}$   $\text{①}$   
 $\wedge \geq 0$   
 $\wedge \wedge \wedge$   
 $\text{min}$



NP. <sup>ev.</sup> checkable in poly time. <sup>input problem, witness</sup>  $P \leq$  

P/NP.  $\Downarrow$  reduction SAT is fact. i.e. is NP complete?  
 $x_i \in \{\text{true, false}\}$

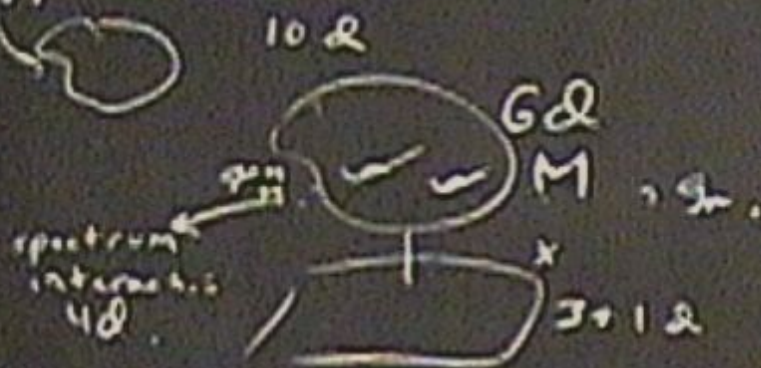
AND  $\left\{ \begin{array}{l} x_1 \vee \overline{x_2} \vee x_{15} \dots \end{array} \right.$

$P(1) \sim |\Psi|$   $\left[ \frac{1}{2} \right]^2$   $\text{HH} \textcircled{1}$   
 $\sim e^{\frac{1}{2} \frac{1}{\Lambda}} \frac{1}{\Lambda} \theta(1)$   
 with  $\Lambda > 0$



F. Denef

1975



Causality

$$\sum_{i=1}^n \epsilon_i^2 = 0 \quad \text{if } \epsilon = 12$$

$$SU(2) \times SU(2) \times U(1)$$

$$b^3 = 204$$



$$N_{\text{brane}} = 40 \quad G_2(M)$$

$$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B$$

$$E_H = \int \sqrt{g} = \int \sqrt{\det g_{ij}} = \int \sqrt{g_{ij}(x^i, x^j)}$$

$$V = -\Lambda_0 + g_{ij} N^i N^j$$

$$\{V | V^i \in \mathbb{R}^3\}$$

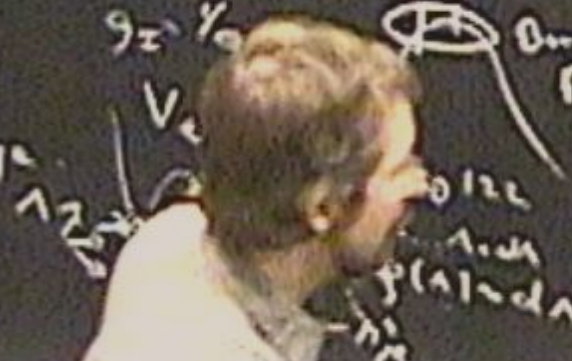
$$V \in C^{\infty}(\Sigma, \mathbb{R}) \quad \text{and } V(N) \in V(N, \mathbb{R})?$$

1995

$$g_{ij} \Rightarrow \frac{1}{\sqrt{g}} \frac{\partial}{\partial x^i} \frac{\partial}{\partial x^j}$$

2005

landscape





NP. <sup>can.</sup> checkable  
in poly time.  $P \subseteq$  problem, witness.  $\downarrow$  poly  
yes/no.

P & NP.

SAT is decidable.  
is NP complete?  
 $x_i \in \{\text{true, false}\}$

AND  $\left\{ \begin{array}{l} x_1 \vee \bar{x}_2 \vee x_{15} \dots \end{array} \right.$

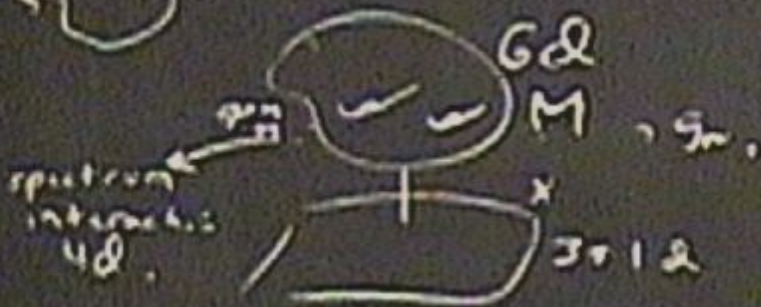
$P(|I| \sim |\Psi|) \subseteq \mathbb{N}$   $\mathbb{N}^2$   $\mathbb{N}$   
 $\sim e^{\frac{2^{|I|}}{\Lambda}} \Theta(\Lambda)$   $\Lambda > 0$   
with  $\Lambda > 0$ .



F. Doreif



10 d



Calculation

$$b^2 = 204$$

$$\sum_{i=1}^n \epsilon_i^2 = 0 \quad \text{is } P^2 = -12$$

$$SU(3) \times SU(2) \times U(1)$$

$$N_{\text{fermions}} = 40, \quad G_2(TN)$$

$$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B$$

$$E_H = \frac{1}{2} \int_{\Sigma} \epsilon - \beta^2 \sum g_{ij} (N^i)^2$$

$$V = -\Lambda_0 + g_{ij} N^i N^j$$

$$\{V \mid N^i \in \mathbb{R}^3\}$$

$$V \in \mathcal{C} \text{ and } V(N) \leq V(N^i)$$

1995

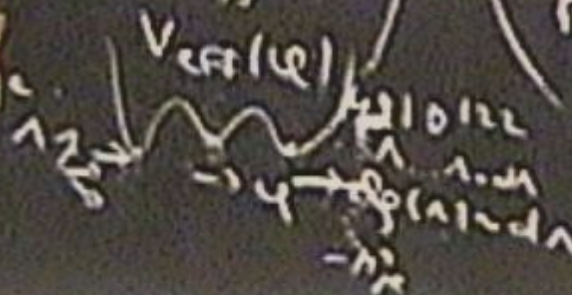


$$\Rightarrow \frac{1}{4\pi} \int \frac{1}{g} \gamma_g$$



Dimensional Reduction

2005





NP. <sup>or.</sup> checkable in poly time.  $P \subseteq$  problem; witness.  $\downarrow$  poly time.

P=NP.  $\Downarrow$  reduction SAT is  $\text{NP-complete}$ .  
 is NP complete?

$x_i \in \{\text{true, false}\}$

AND {  $x_1 \vee \bar{x}_2 \vee x_{15} \dots$

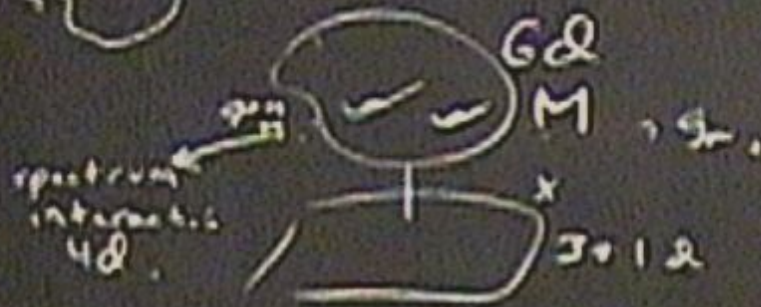
$P \sim |\Psi|$   $\supset |^2$   $\bigwedge \geq 0$   $\bigoplus (\bigwedge)$   
 $\sim e$   $\bigwedge \geq 0$   
 DP min  $\bigwedge \geq 0$



F. Denef



10 d



spectrum  
interacts  
4d

Calabi-Yau

$b^3 = 204$

$$\sum_i v_i F_i = 0 \quad \text{if } v_i = -12$$

$$SU(3) \times SU(2) \times U(1)$$



$N_{\text{brane}} = 40$   $G_2(TM)$

$$B_{ij} = \frac{1}{2\pi} \int_{\Sigma} B$$

$$E_H = \int \left( \frac{1}{2} \dot{\phi}^2 + \frac{1}{2} B^2 \right)$$

$$\sum g_{ij} (N^i)^2$$

$$V = -\Lambda_0 + g_{ij} N^i N^j$$

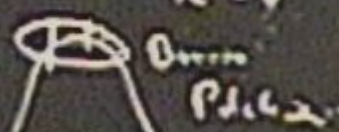
$$\{ V \mid N^i \in \pi^1 \}$$

$$V \in \mathcal{V}(\mathcal{M}) \quad \text{and} \quad V(N) \leq V(N_0)$$

1995

ht

$$\Rightarrow \int_{\Sigma} \tilde{F} = \int_{\Sigma} \tilde{F}_g$$



2005

