Title: Radiation from the non-extremal fuzzball

Date: Feb 12, 2008 11:00 AM

URL: http://pirsa.org/08020007

Abstract: TBA

Plan of Talk

- Information Paradox: Need to study Black Holes
- Structure of Black Holes
- AdS/CFT
- Making Black Holes in String Theory
- Smooth geometries and fuzzballs
- Non-extremal smooth geometries
- Instability of these geometries
- CFT derivation of these instabilities
- Some additional results and future directions

Plan of Talk

Information Paradox: Need to study Black Holes

Structure of Black Holes

AdS/CFT

Making Black Holes in String Theory

Smooth geometries and fuzzballs

Non-extremal smooth geometries

Instability of these geometries

CFT derivation of these instabilities

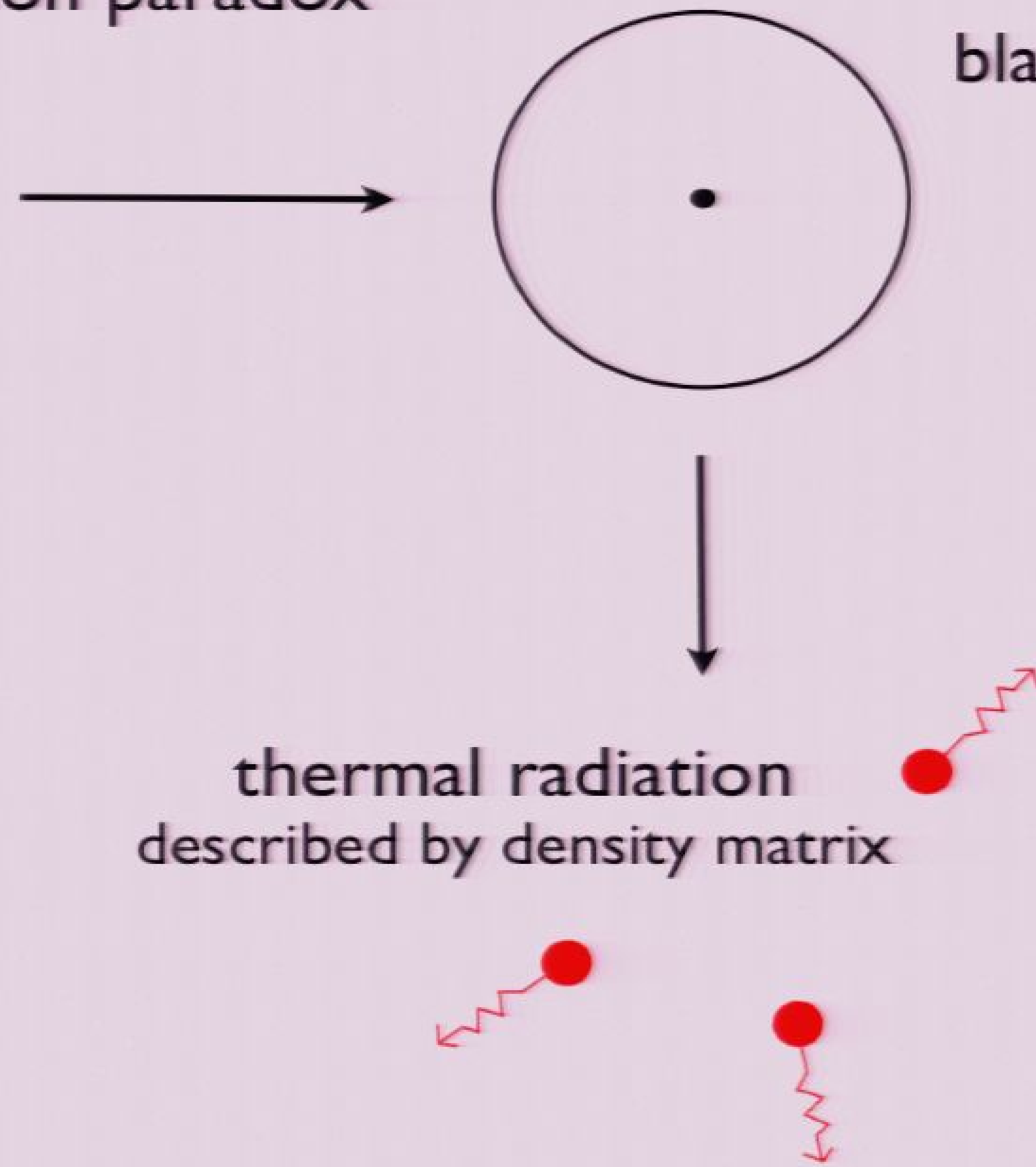
Some additional results and future directions

The information paradox

black hole

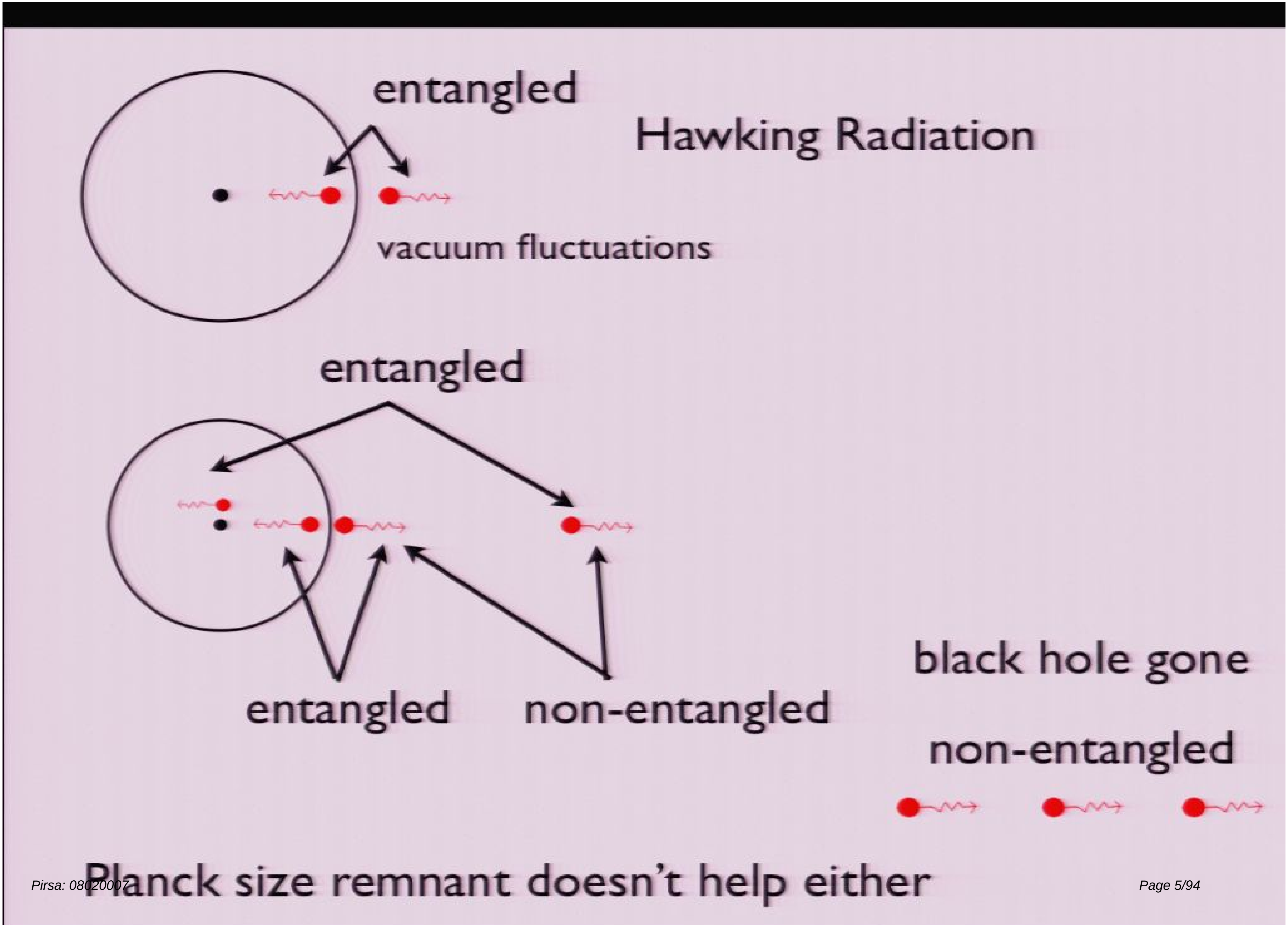
$|\Psi\rangle$

pure state

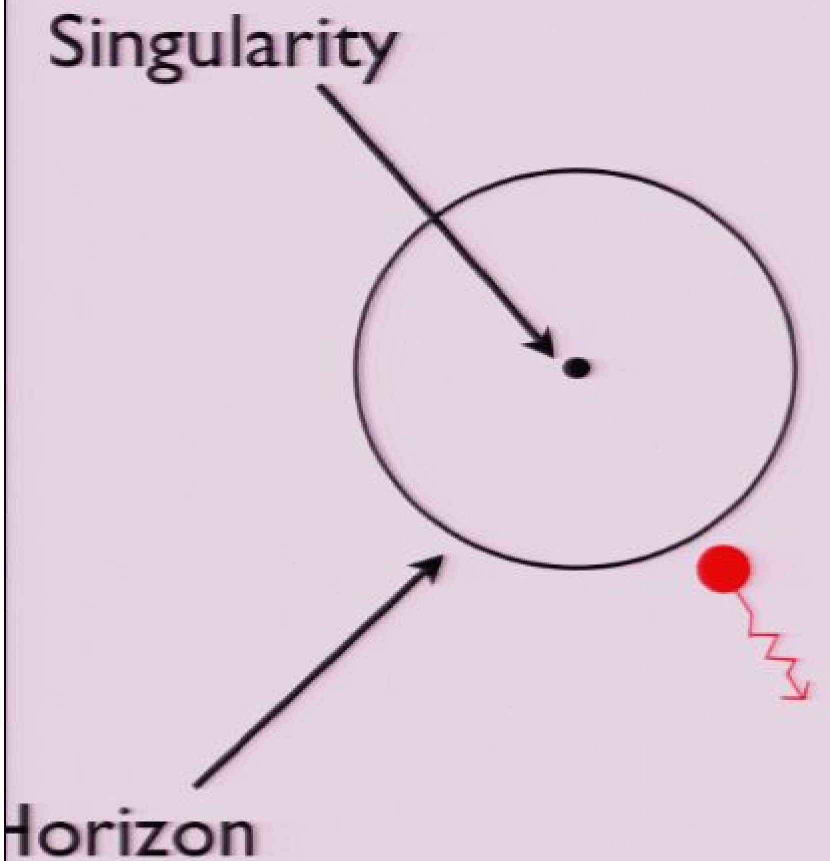


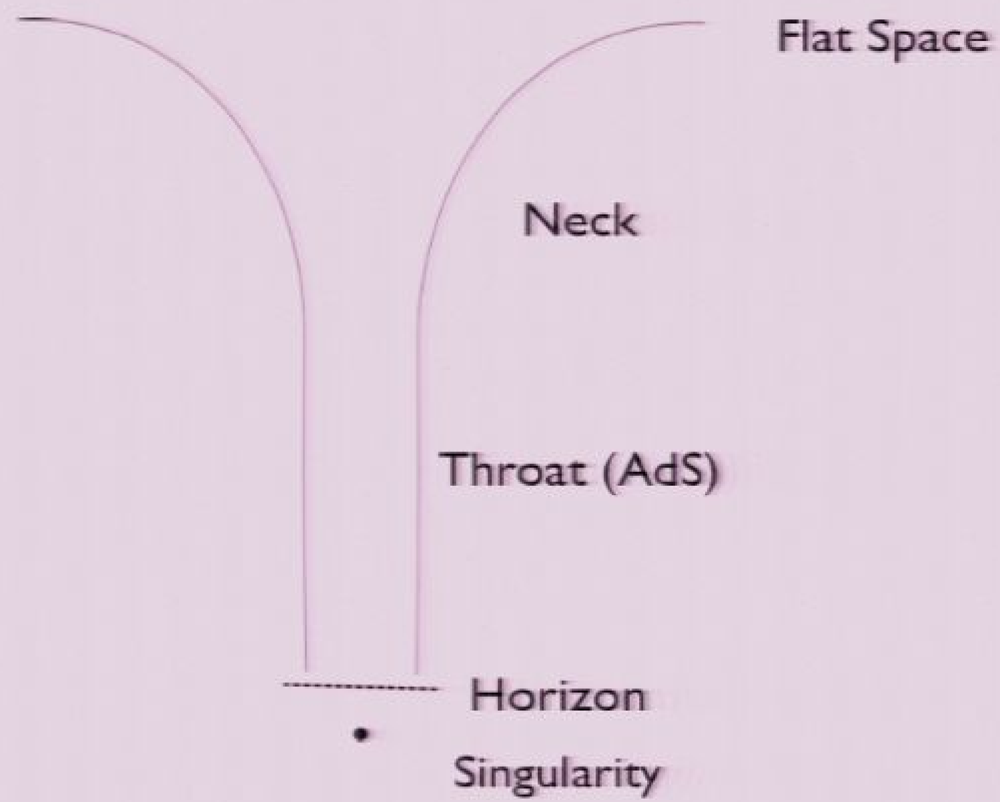
thermal radiation
described by density matrix

<u>*Quantum Unitarity is lost*</u>

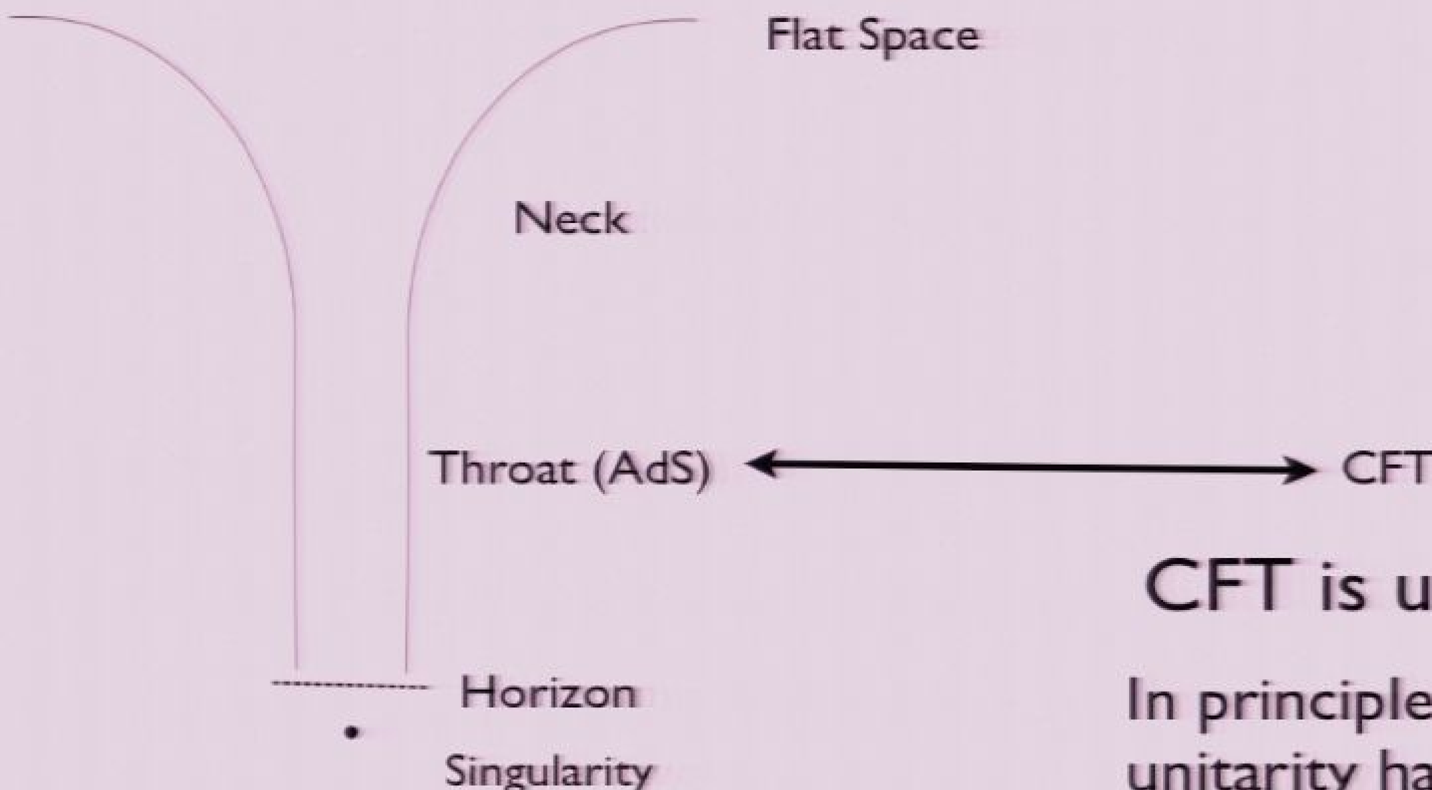

entangled
Hawking Radiation
vacuum fluctuations
entangled
entangled
non-entangled
black hole gone
non-entangled
Planck size remnant doesn't help either

Structure of Black Holes





AdS/CFT



CFT is unitary

In principle one can say unitarity has to be restored and paradox is resolved.

Where are the states in gravity ?

Making Black Holes in SUGRA (Low energy String Theory)

Example

Compactify 5 dimensions out of 10

$$R^{1,9} \longrightarrow R^{1,4} \times T^4 \times S^1$$

Take n_1 D1 branes along S^1

Take n_5 D5 branes along $T^4 \times S^1$

Take n_p momentum units along S^1

Form their bound state

Extremal and Non-Extremal Black Holes

Extremal Black Holes have minimum mass for given charges

$M_{D1} \sim R$ $M_{D5} \sim RV$ $M_P \sim 1/R$

where volume of $S^1 \sim R,\ T^4 \sim V$

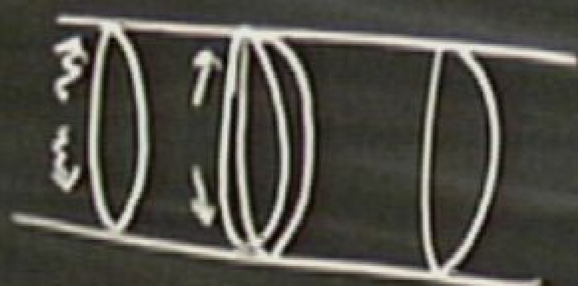
Extra energy excites anti-charges

For large R only anti-momentum is excited

$$D1 - D5 - P + Energy \longrightarrow D1 - D5 - P\bar{P}$$

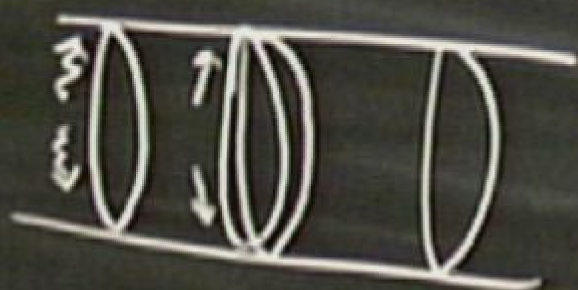
$$R^{1,9} \longrightarrow R^{1,4} \times \underbrace{T^4}_{(2\pi)^4 V} \times \underbrace{S^1}_{2\pi R}$$

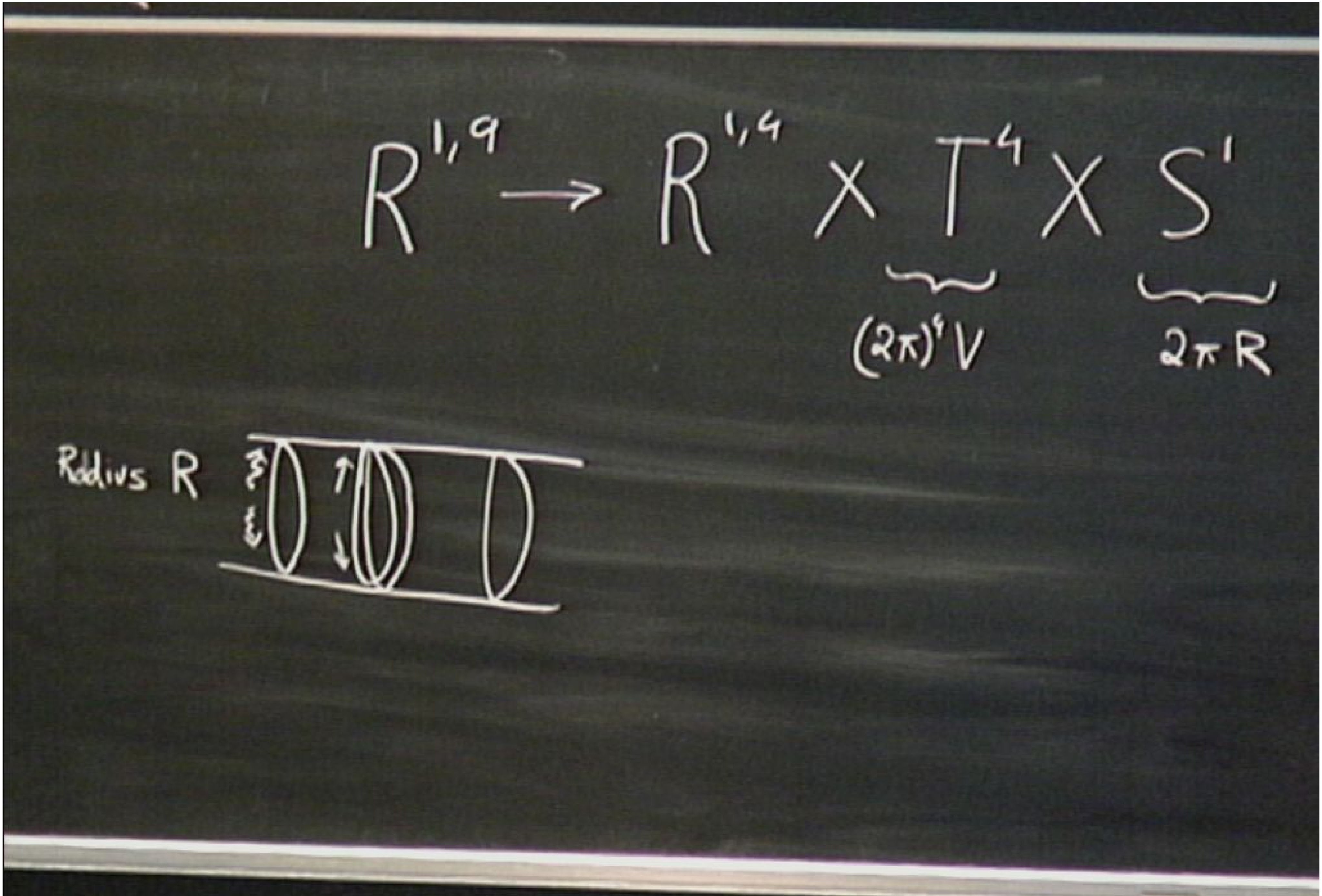
Radius R



$$R^{1,9} \to R^{1,4} \times \underbrace{T^4}_{(2\pi)^4 V} \times \underbrace{S^1}_{2\pi R}$$

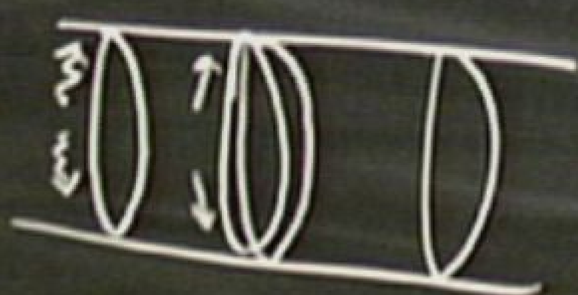
Radius R




R^{1,9} → R^{1,4} × T^4 × S^1
(2π)^4 V
2π R
Radius R

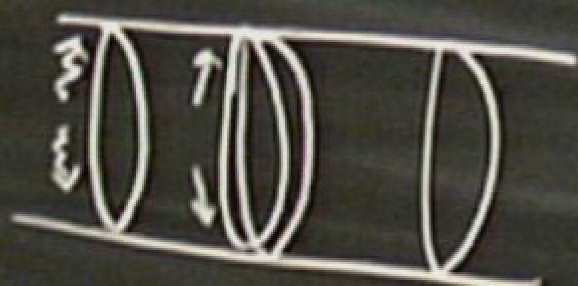
$$R^{1,9} \longrightarrow R^{1,4} \times \underbrace{T^4}_{(2\pi)^4 V} \times \underbrace{S^1}_{2\pi R}$$

Radius R



$$R^{1,9} \longrightarrow R^{1,4} \times \underbrace{T^4}_{(2\pi)^4 V} \times \underbrace{S^1}_{2\pi R}$$

Radius R



Extremal and Non-Extremal Black Holes

Extremal Black Holes have minimum mass for given charges

$M_{D1} \sim R$ $M_{D5} \sim RV$ $M_P \sim 1/R$

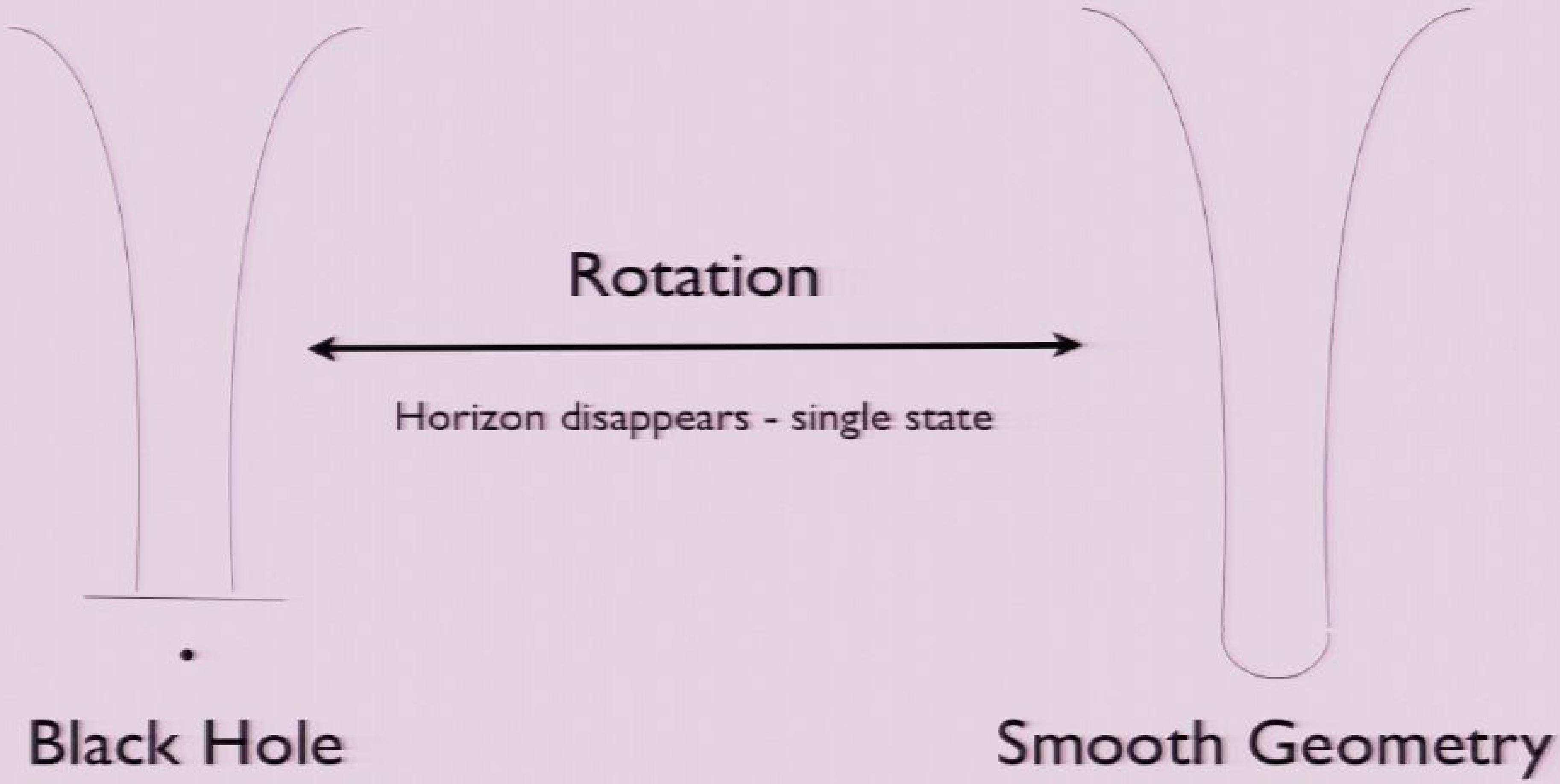
where volume of $S^1 \sim R$, $T^4 \sim V$

Extra energy excites anti-charges

For large R only anti-momentum is excited

$$D1 - D5 - P + Energy \longrightarrow D1 - D5 - P\bar{P}$$

Smooth Solutions (Extremal)



Originally done for 2-charge D1-D5 hep-th/0012025,0109154,0202072,0212210

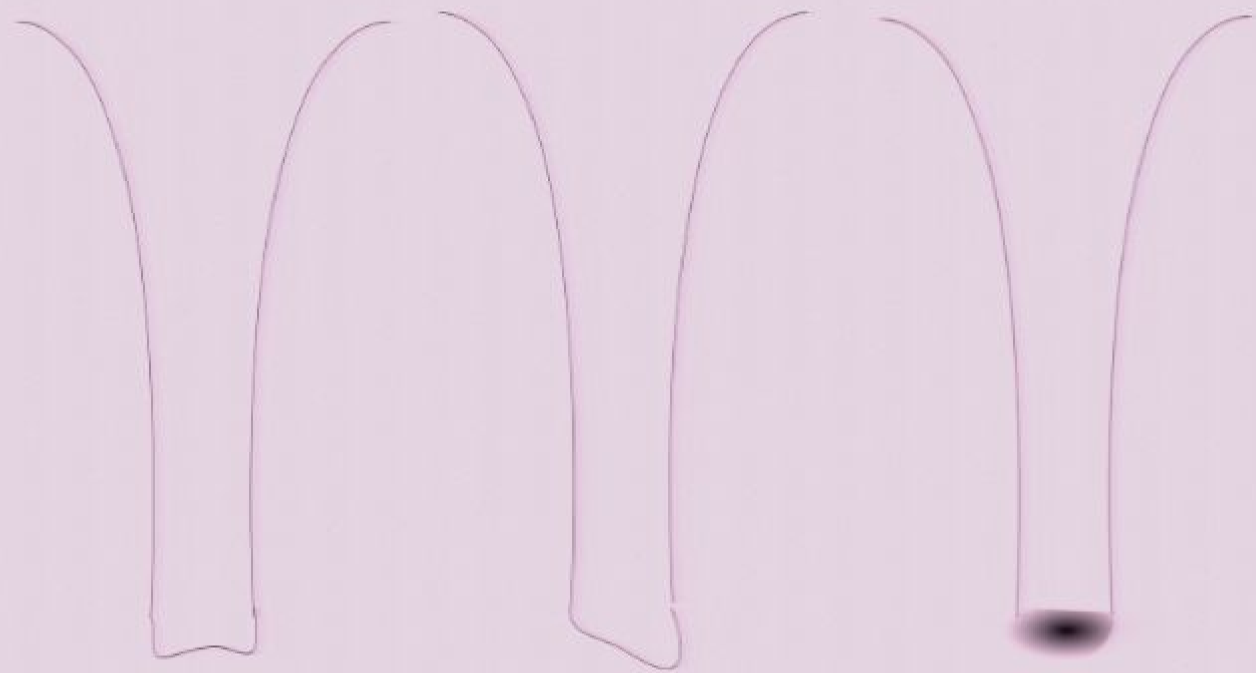
Later on same was done for 3-charge D1-D5-P

hep-th/0311092,0405017,0406103,0404006,0408106

and many more

Fuzzballs

=



Macrostate

many microstates

specific microstates consistent
with macroscopic charges

some are classical

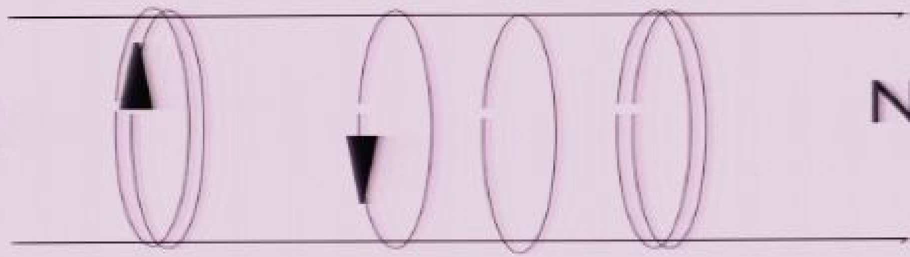
some quantum

CFT side of story

specific microstates consistent
with macroscopic charges

1+1 (4,4) CFT with target space $(T^4)^N/S^N$

CFT side of story - II



Radius=R

$N = n_1 n_5$ total winding number

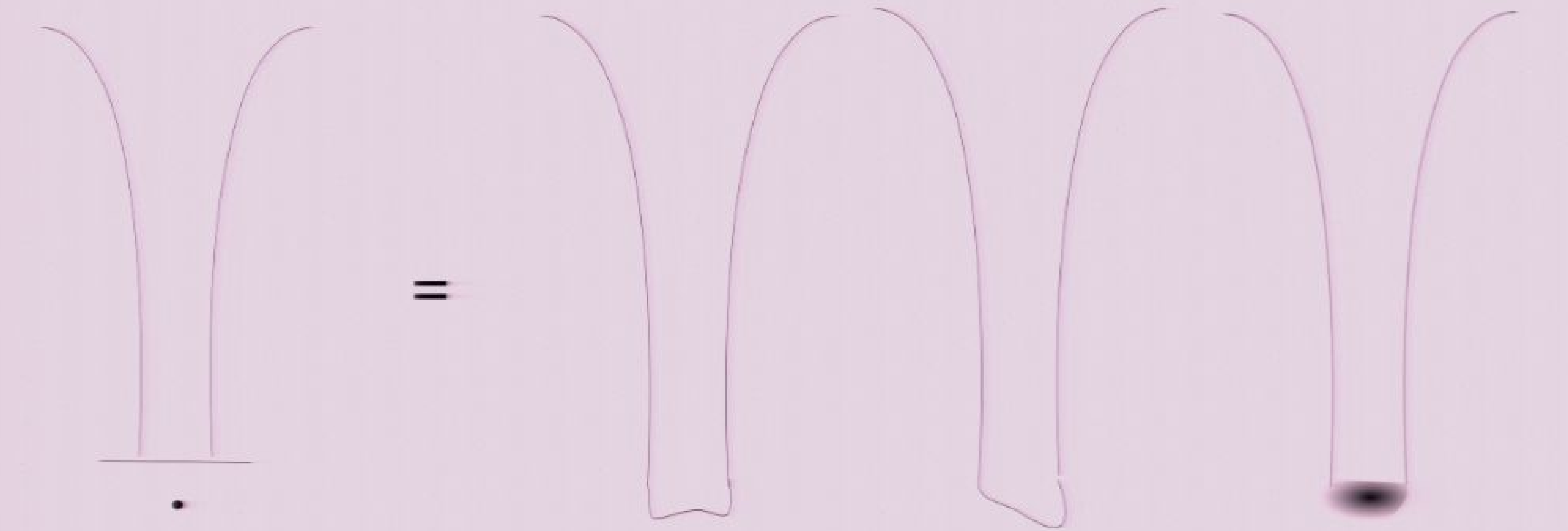
1+1 (4,4) CFT with target space $(T^4)^N/S^N$

Four bosonic excitations carrying spacetime indices

Two flavors of fermions in each sector (left and right)

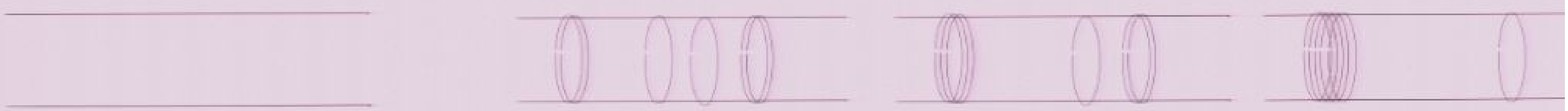
spin of fermions in CFT = angular momentum

$SO(4) \sim SU(2)_L \times SU(2)_R$



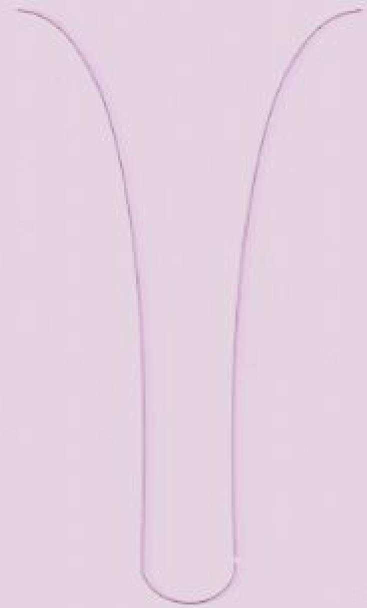
Ensemble

Specific Microstates

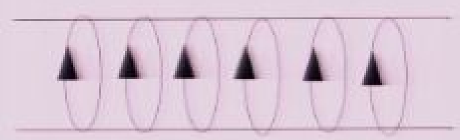


There can be bosonic and/or fermionic excitations

Two and three charge maximally rotating

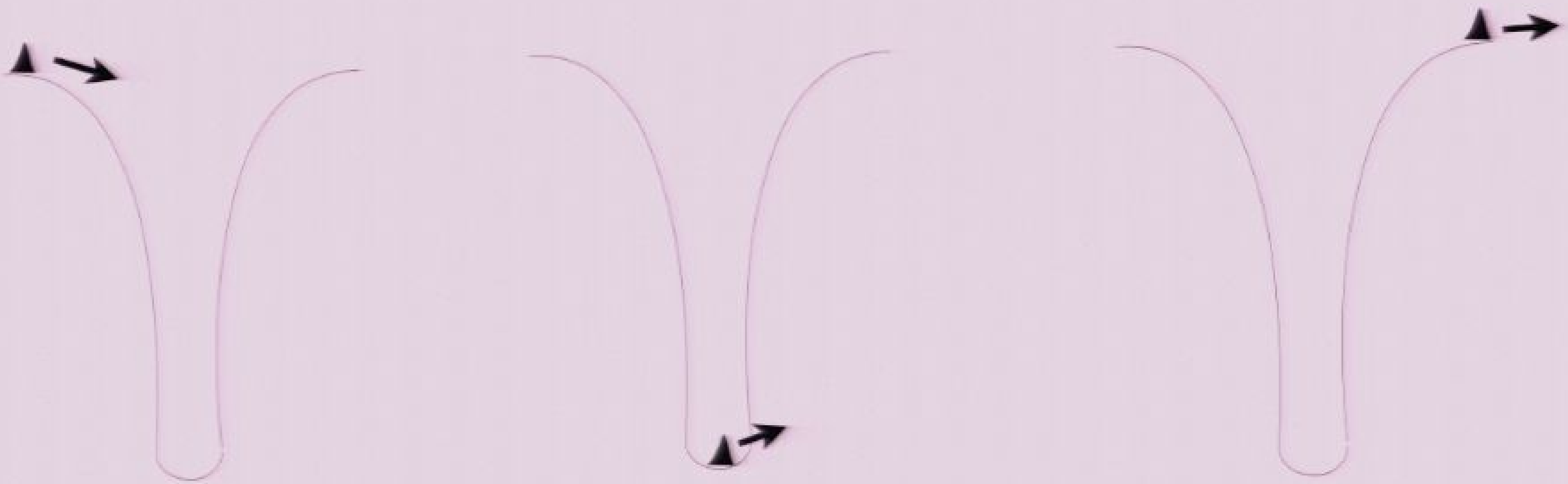


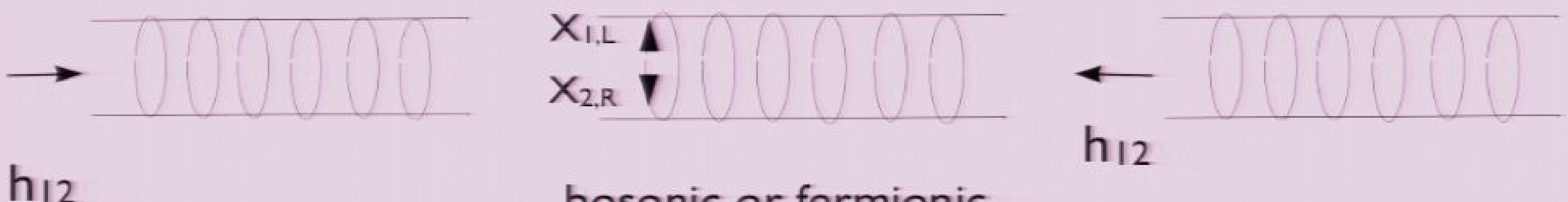
fermions on left sector



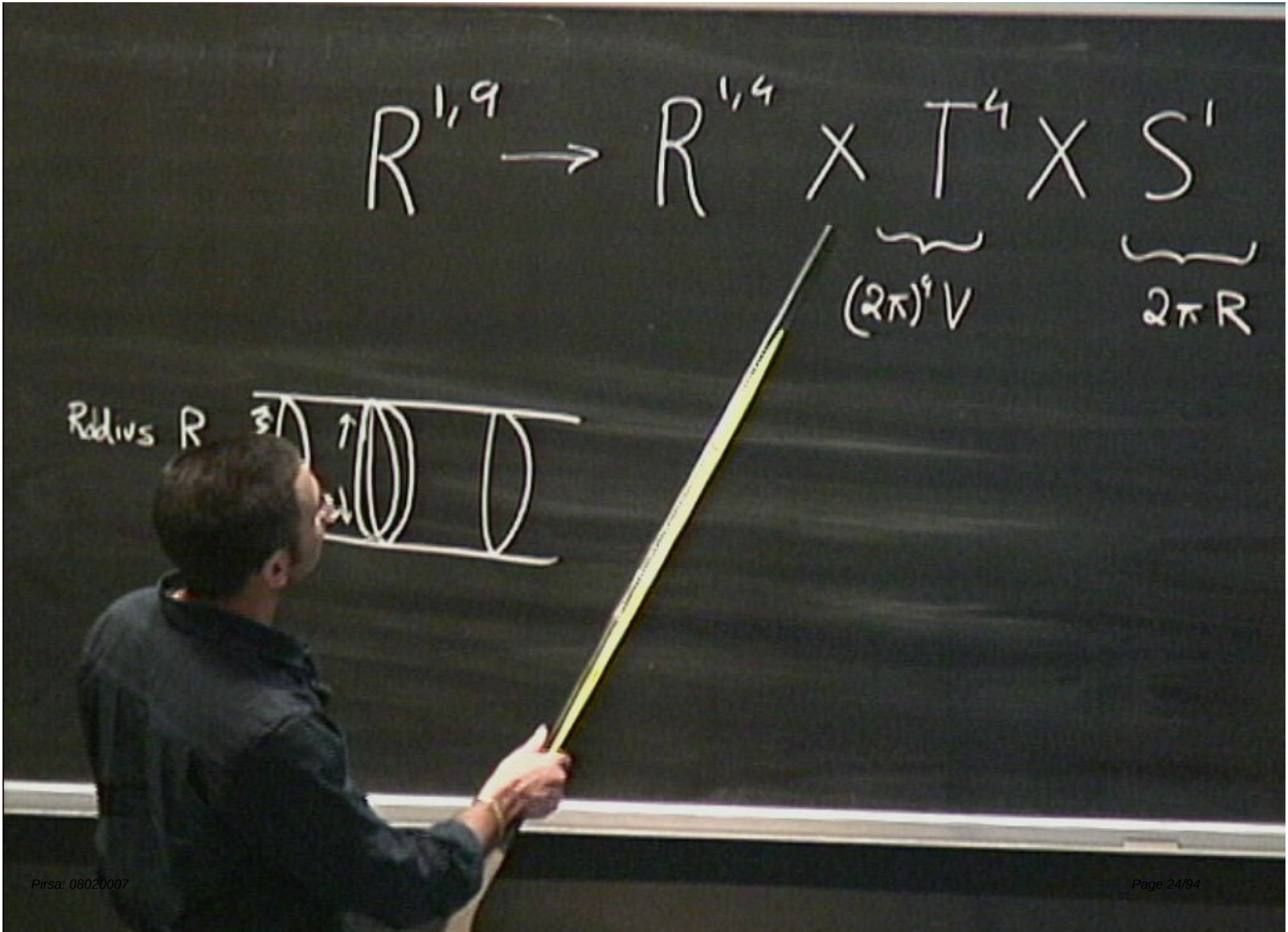
No Horizon => Zero Entropy => Single State

Some previous results - Time of travel



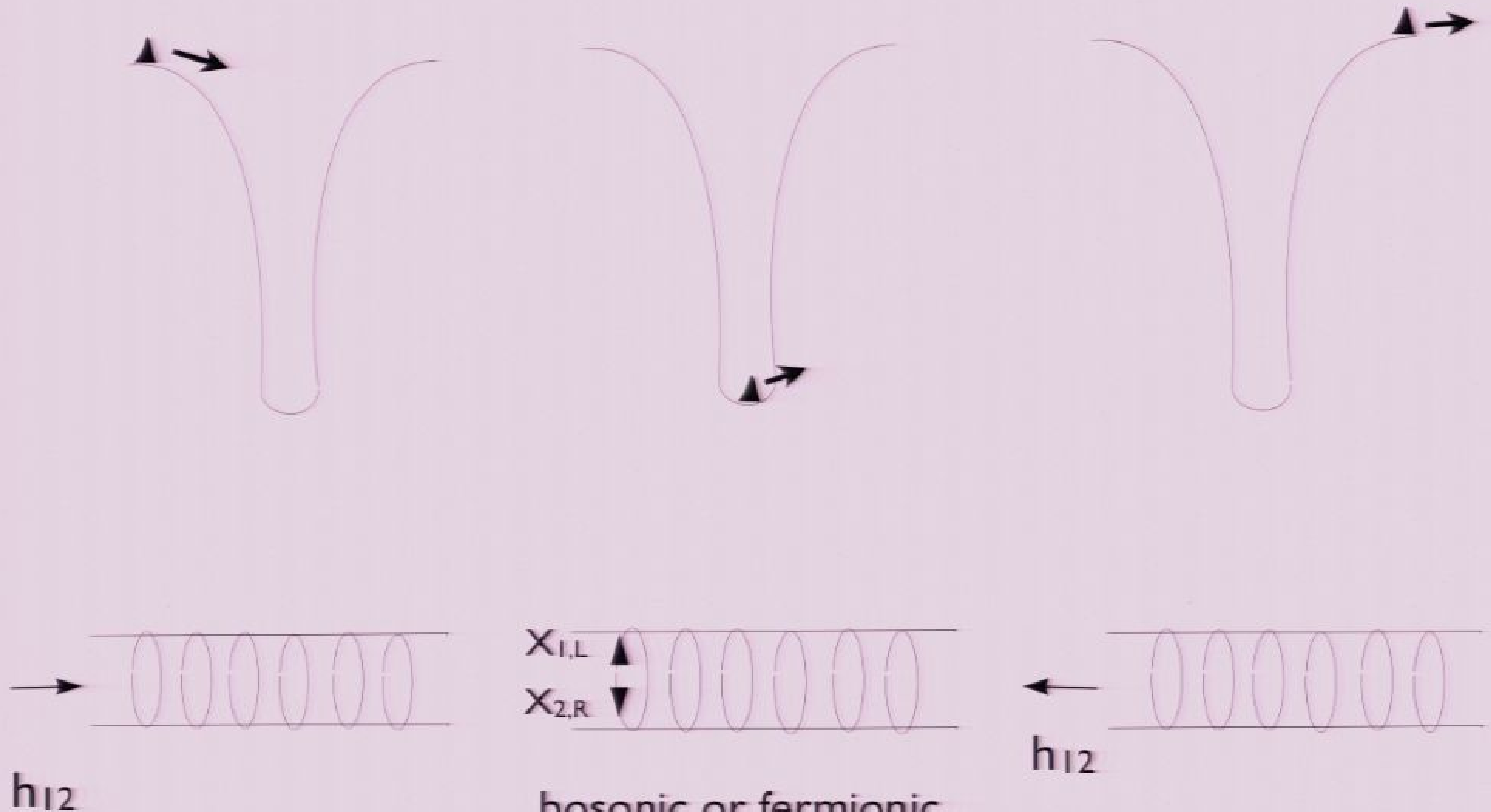


bosonic or fermionic
excitations in both sectors



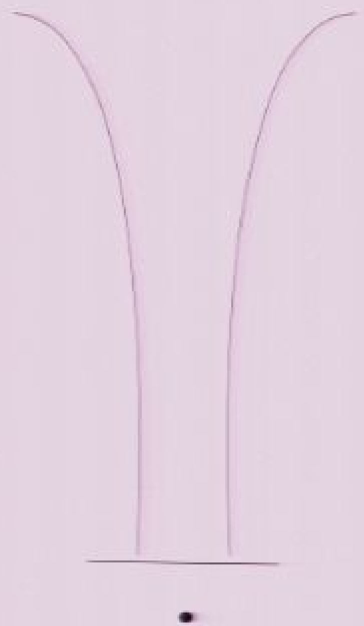
$R^{1,9} \to R^{1,4} \times T^4 \times S^1$
$(2\pi)^4 V$
$2\pi R$
Radius R

Some previous results - Time of travel

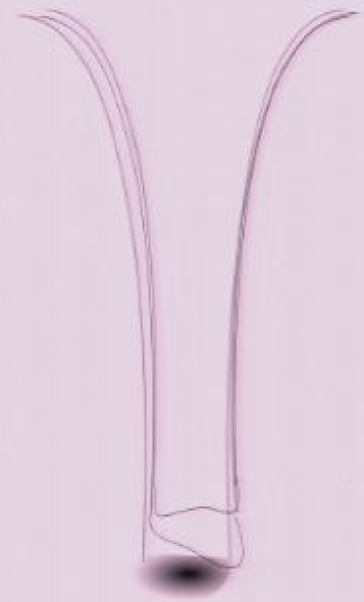


bosonic or fermionic
excitations in both sectors

Some previous results - Hawking Radiation

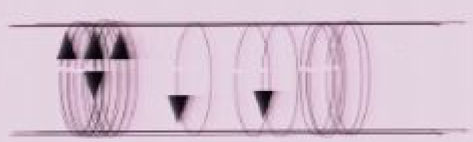


=



Hawking Radiation

Black Hole



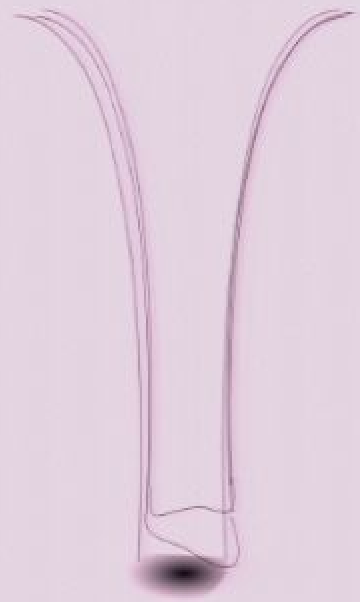
Left + Right movers collide to radiate

Thermally distibution on CFT

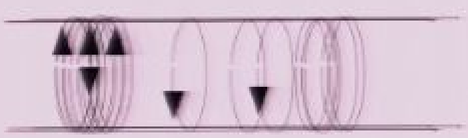
Some previous results - Hawking Radiation

Black Hole

=



Hawking Radiation



Left + Right movers collide to radiate

Thermally distibution on CFT

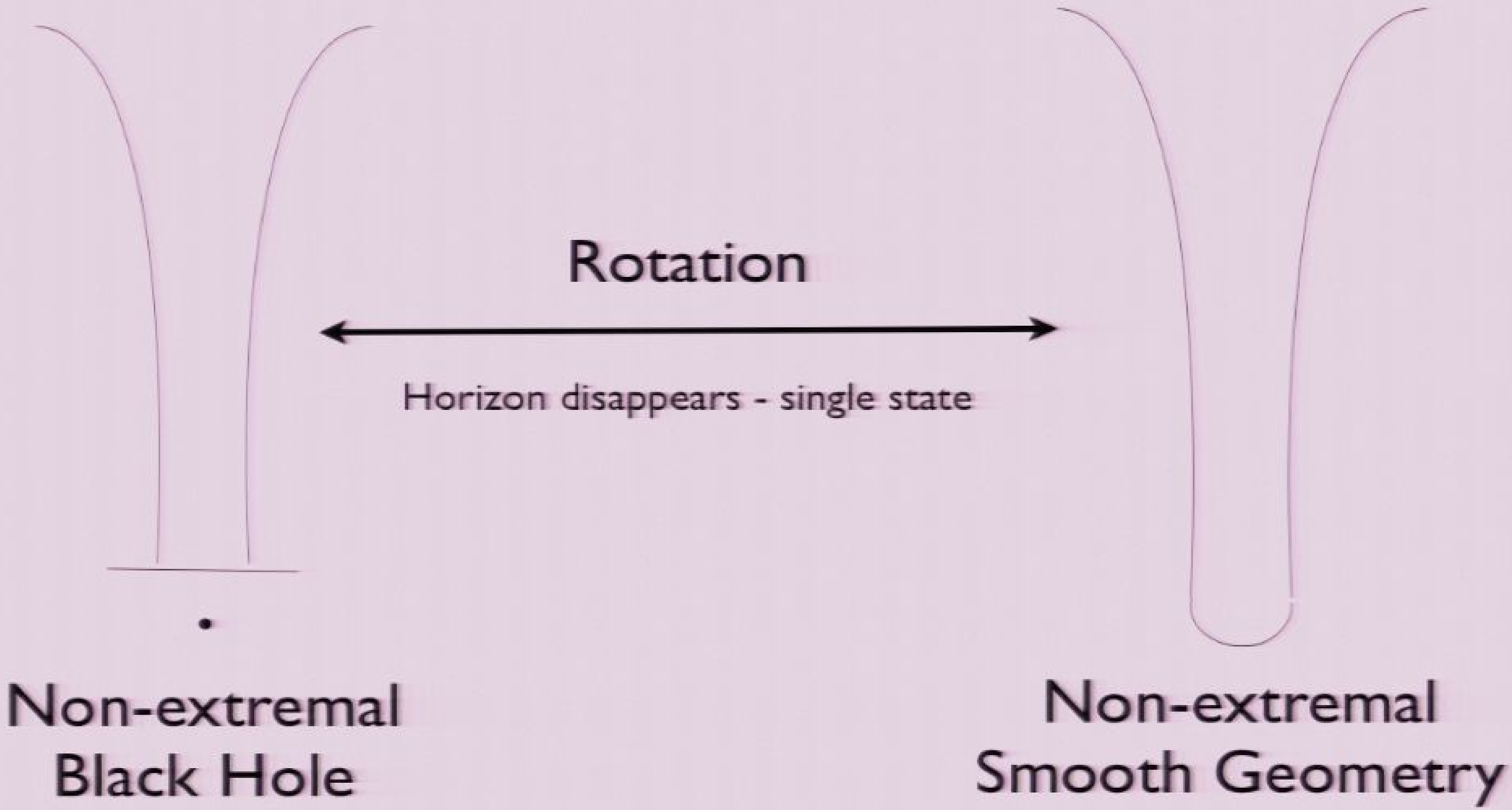
The importance of the S^1 circle

In the limit of infinite R the AdS and flat space split off

In the CFT side the natural energy scale is 1/R

The energy scale of emission on gravity side becomes integral in 1/R for large R.

Non-extremal smooth geometries (hep-th/0504181)



Features of this geometry

No horizon

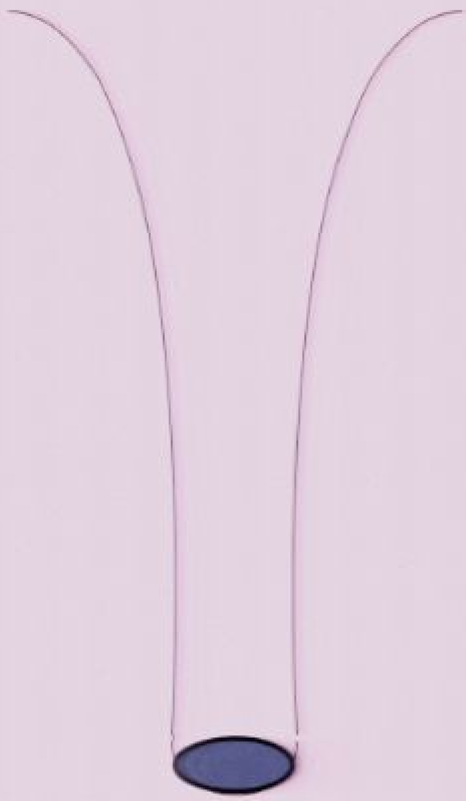
Completely Smooth

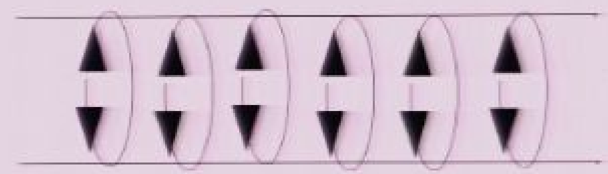
Rotation

Have ergoregion

- No global timelike Killing vector
- Negative energy excitations inside ergoregion

CFT dual to non-extremal smooth geometries





fermionic excitations on left and right sectors

All component strings of same winding number

Mass, Charge, Angular momentum of Grav and CFT match in large R limit

Classical Instability (hep-th/0512277)

Klein-Gordon equation in the smooth background

$$\Box\Psi = 0$$

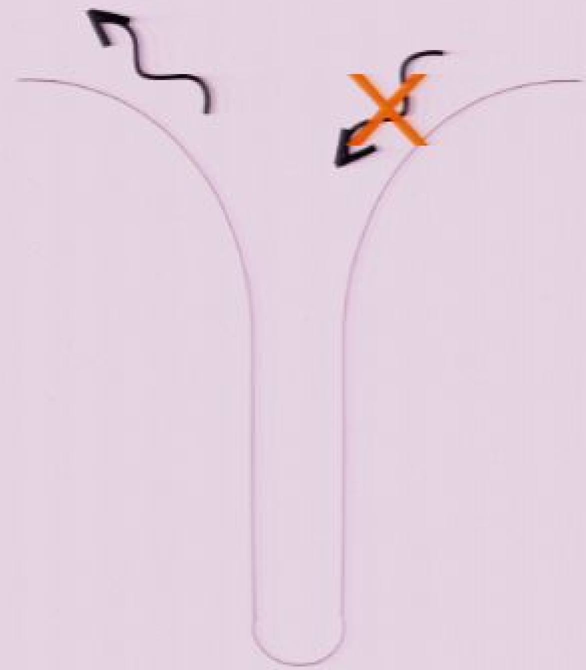
ansatz

$$\Psi = exp(-i\omega t + i\lambda\frac{y}{R} + im_{\psi}\psi + im_{\phi}\phi)\chi(\theta)h(r$$

In the large R limit angular part reduces to laplacian on S^3

The radial equation cannot be solved exactly.

solution in outer region



$$\omega_R = \frac{1}{R}(-l - m_\psi m + m_\phi n - |\lambda + m_\psi n - m_\phi m| - 2(N+1)$$

$$\omega_I = \frac{1}{R}\left[\frac{2\pi}{(l!)^2}\left\{\left(\omega^2 - \frac{\lambda^2}{R^2}\right)\frac{Q_1 Q_5}{4R^2}\right\}^{l+1}[l+1]_N[l+1]_{N+|\zeta|}\right]$$

solution in inner region

Classical Instability (hep-th/0512277)

Klein-Gordon equation in the smooth background

$$\Box\Psi = 0$$

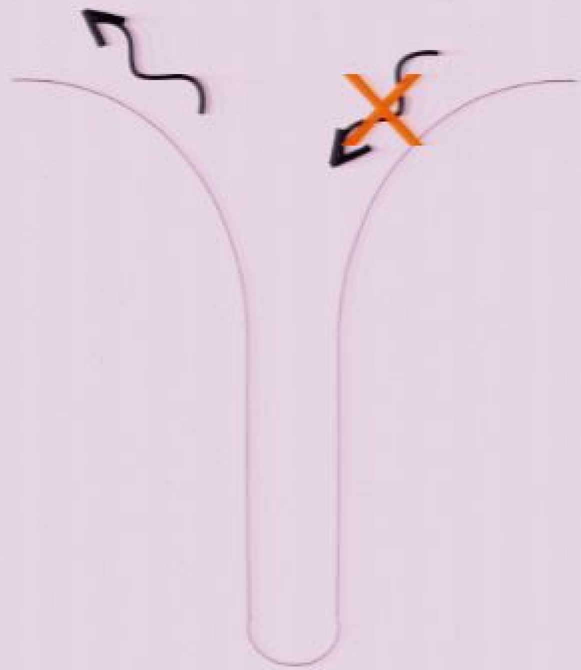
ansatz

$$\Psi = exp(-i\omega t + i\lambda\frac{y}{R} + im_\psi\psi + im_\phi\phi)\chi(\theta)h(r$$

In the large R limit angular part reduces to laplacian on S^3

The radial equation cannot be solved exactly.

solution in outer region

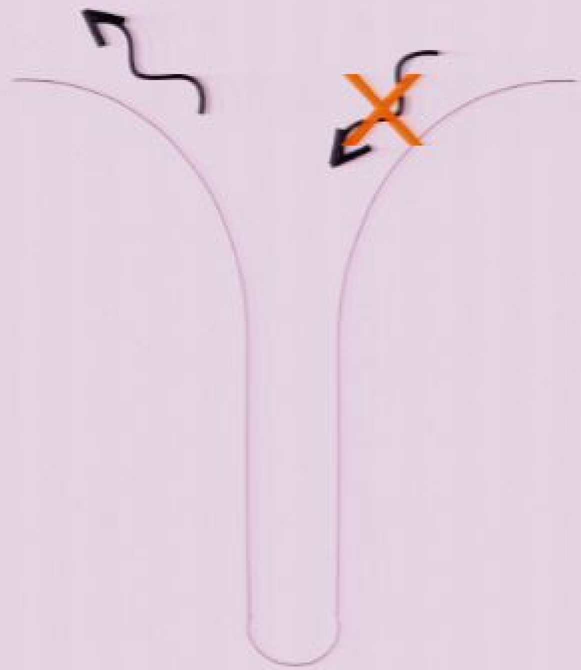


$$\omega_R = \frac{1}{R}(-l - m_\psi m + m_\phi n - |\lambda + m_\psi n - m_\phi m| - 2(N+1)$$

$$\omega_I = \frac{1}{R}\left[\frac{2\pi}{(l!)^2}\left\{\left(\omega^2 - \frac{\lambda^2}{R^2}\right)\frac{Q_1 Q_5}{4R^2}\right\}^{l+1}[l+1]_N[l+1]_{N+|\zeta|}\right]$$

solution in inner region

The radial equation cannot be solved exactly.



solution in outer region

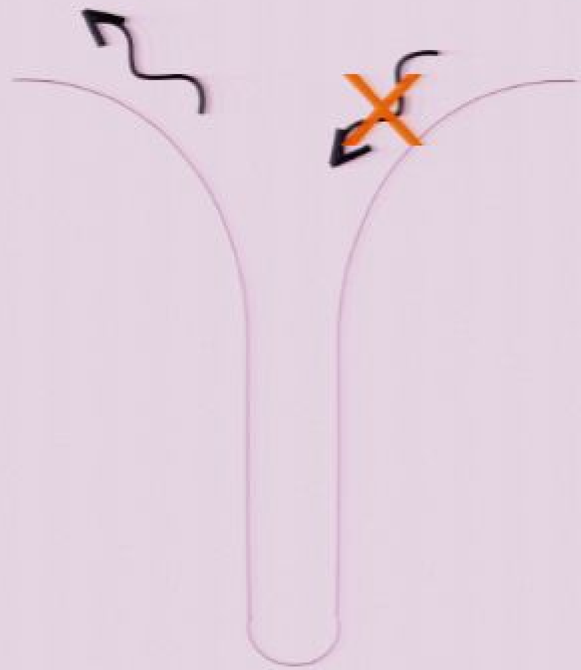
$$\omega_R = \frac{1}{R}(-l - m_\psi m + m_\phi n - \quad - 2(\quad + 1)$$

$$\omega_I = \frac{1}{R}\left[\frac{2\pi}{(l!)^2}\left\{\left(\omega^2 \quad \right)\frac{Q_1 Q_5}{4R^2}\right\}^{l+1} \quad \right]$$

solution in inner region

The radial equation cannot be solved exactly.

solution in outer region



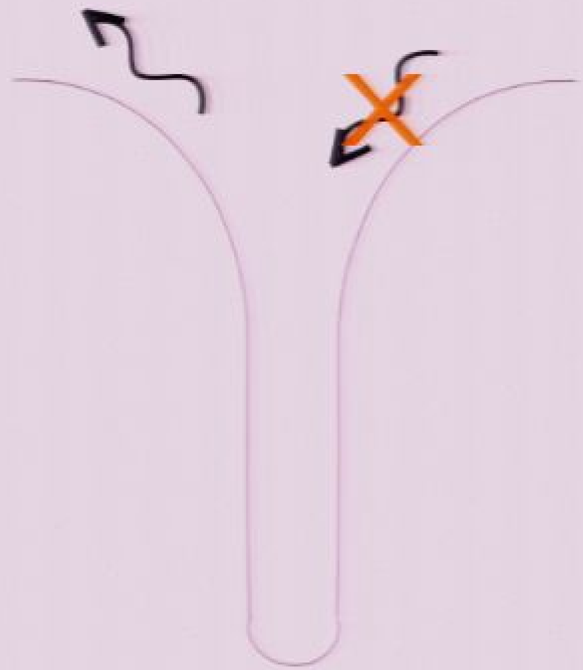
$$\omega_R = \frac{1}{R}(-l - m_\psi m + m_\phi n - |\lambda + m_\psi n - m_\phi m| - 2(N+1)$$

$$\omega_I = \frac{1}{R}\left[\frac{2\pi}{(l!)^2}\left\{\left(\omega^2 - \frac{\lambda^2}{R^2}\right)\frac{Q_1 Q_5}{4R^2}\right\}^{l+1}[l+1]_N[l+1]_{N+|\zeta|}\right]$$

solution in inner region

The radial equation cannot be solved exactly.

solution in outer region



$$\omega_R = \frac{1}{R}(-l - m_\psi m + m_\phi n - \quad \ldots \quad - 2(\quad + 1)$$

$$\omega_I = \frac{1}{R}\left[\frac{2\pi}{(l!)^2}\left\{\left(\omega^2 \quad \ldots \right)\frac{Q_1 Q_5}{4R^2}\right\}^{l+1} \quad \ldots \quad \right]$$

solution in inner region

Interpretation of the wave solution

In the large R limit

flat space and AdS decouple

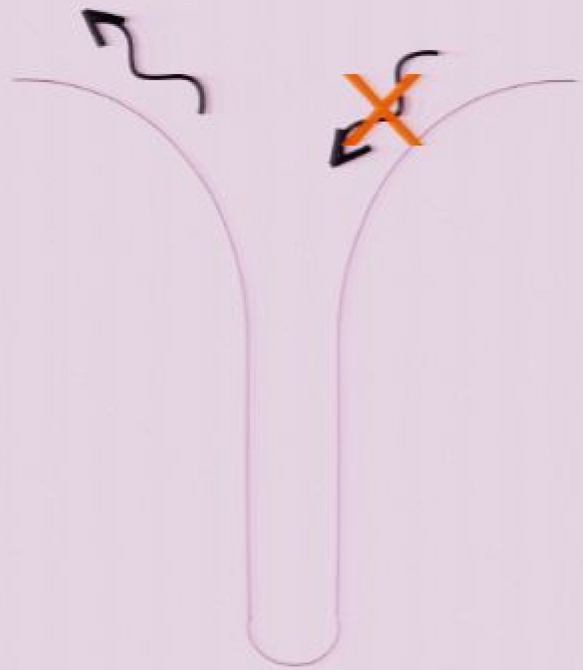
the wave splits off into two parts

the energy of excitations in AdS is

$$\omega_R = \frac{1}{R}(-l - m_\psi m + m_\phi n - |\lambda + m_\psi n - m_\phi m| - 2(N+1))$$

The radial equation cannot be solved exactly.

solution in outer region



$$\omega_R = \frac{1}{R}(-l - m_\psi m + m_\phi n - |\lambda + m_\psi n - m_\phi m| - 2(N+1)$$

$$\omega_I = \frac{1}{R}\left[\frac{2\pi}{(l!)^2}\left\{\left(\omega^2 - \frac{\lambda^2}{R^2}\right)\frac{Q_1 Q_5}{4R^2}\right\}^{l+1}[l+1]_N [l+1]_{N+|\zeta|}\right]$$

solution in inner region

Interpretation of the wave solution

In the large R limit

flat space and AdS decouple

the wave splits off into two parts

the energy of excitations in AdS is

$$\omega_R = \frac{1}{R}(-l - m_\psi m + m_\phi n - |\lambda + m_\psi n - m_\phi m| - 2(N+1))$$

This is something like tunneling of excitations out of a box

However here the box initially had no excitations

Simultaneously excitations produced inside and outside the box

What about energy conservation ?

Classification of solution in large R

$$\Delta M_{ADM} = \frac{1}{2R}(m^2 + n^2 - 1)n_1 n_5$$

$$J_\psi = -m n_1 n_5$$

$$J_\phi = n n_1 n_5$$

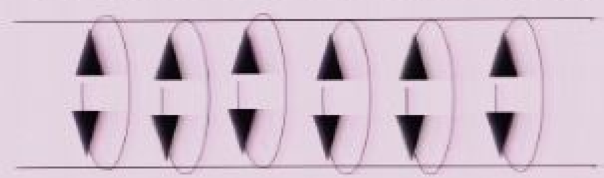
$$n_p = n m n_1 n_5$$

With

$$m = n_L + n_R + 1$$

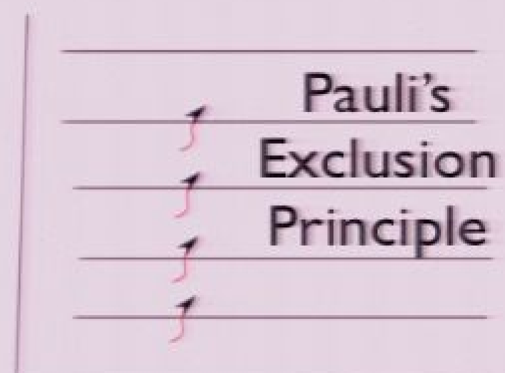
$$n = n_L - n_R$$

2 flavors of n_L and n_R fermion



$$\Delta M_{ADM} = \frac{1}{R}(n_L(n_L + 1) + n_R(n_R + 1))n_1 n_5$$

$$n_p = (n_L(n_L + 1) - n_R(n_R + 1))n_1 n_5$$



Model: n_L left fermions and n_R right of two flavors

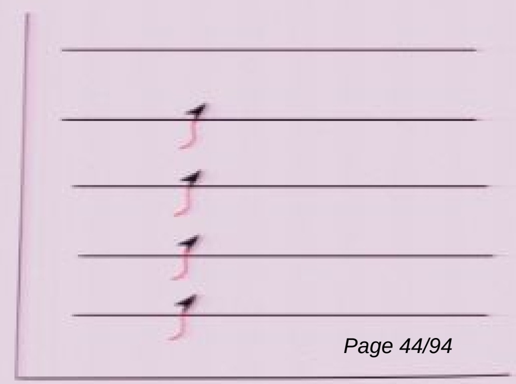
The string has spin half in each direction

$2 \times n_L su(2)_L$

$2 \times n_R su(2)_R$

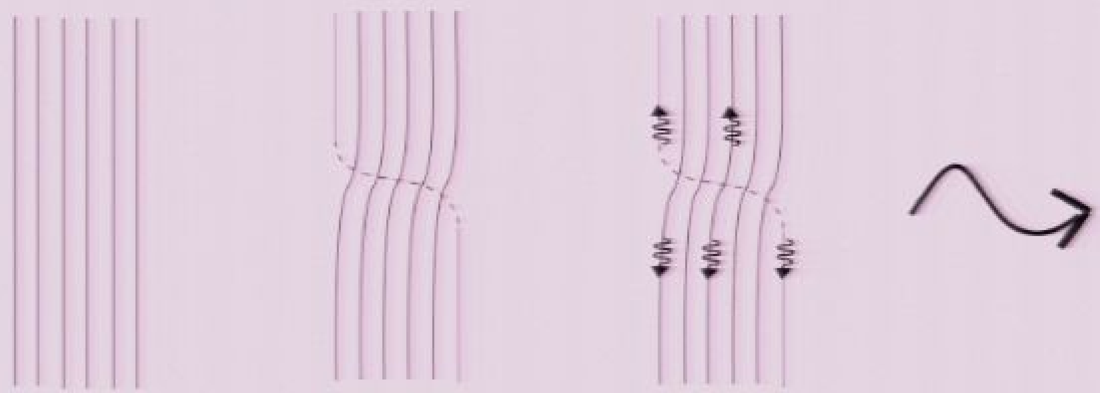
$\times \; n_1 n_5$

$$
\begin{aligned}
ER &= n_1 n_5 (P_L + P_R) = n_1 n_5 (n_L(n_L+1) + n_R(n_R+1)) \\
PR &= n_1 n_5 (P_L - P_R) = n_1 n_5 (n_L - n_R)(n_L + n_R + 1) \\
(J_L, J_R) &= \frac{n_1 n_5}{2}(2n_L + 1, 2n_R + 1)
\end{aligned}
$$



Proposal:

the instability vertex operator



- twists (ℓ+1) strings to one
- annihilates and creates bosons and fermions on the strings
- produces graviton in the bulk

energy, momentum, angular momentum conserved

Instabilities: Explicit example

$n_l=4, n_R=2, \ell=3$

start with $\ell+1=4$ loops

2 flavors, 4 fermions each

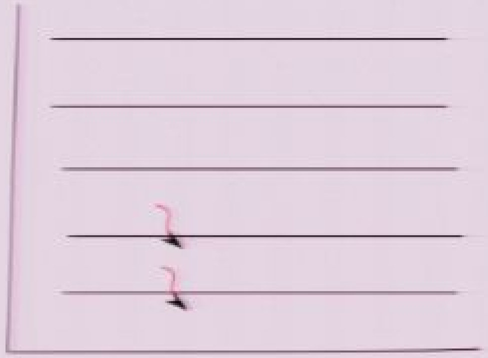
$\times\ 3+1=4$

2 flavors, 2 fermions each

For each flavor in the left moving sector

$$P_L^f = \frac{1}{R}[1+2+3+4]$$
$$= \frac{10}{R}$$

For total left momentum we have $P_L = \dfrac{20}{R}$



For each flavor in the right moving sector

$$P_R^f = \frac{1}{R}[1+2]$$

$$= \frac{3}{R}$$

For total left momentum we have $P_R = \frac{6}{R}$

spin from left moving fermions of one flavor

$$J_L^{f,ferm} = \frac{1}{2} \times 4 = 2$$

base spin of the string

$$J_L^{f,base} = \frac{1}{2}$$

total spin of left movers

$$J_L = \frac{1}{2} + 2 + 2 = \frac{9}{2}$$

spin from right moving fermions of one flavor

$$J_R^{f,ferm} = \frac{1}{2} \times 2 = 1$$

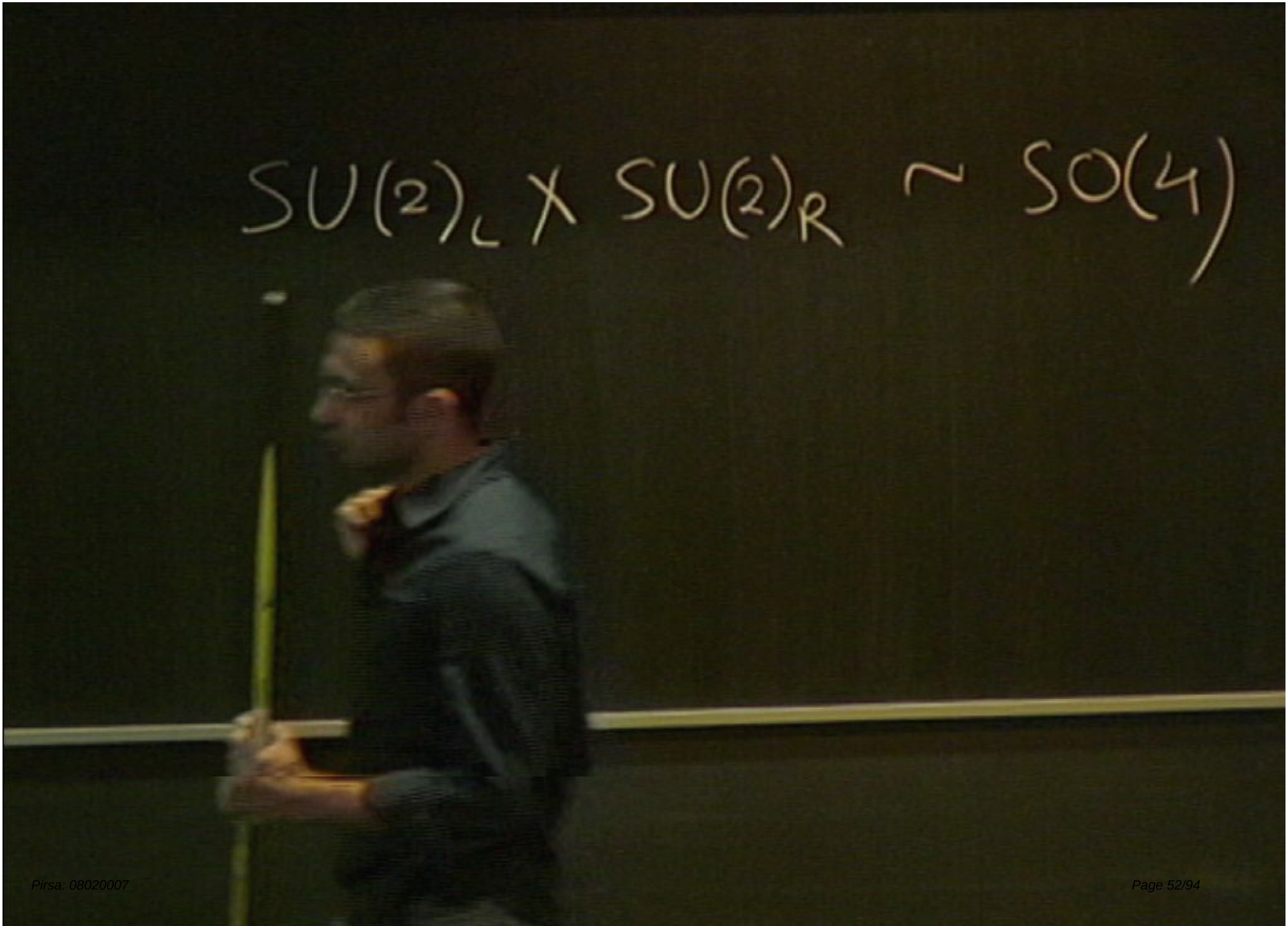
base spin of the string

$$J_R^{f,base} = \frac{1}{2}$$

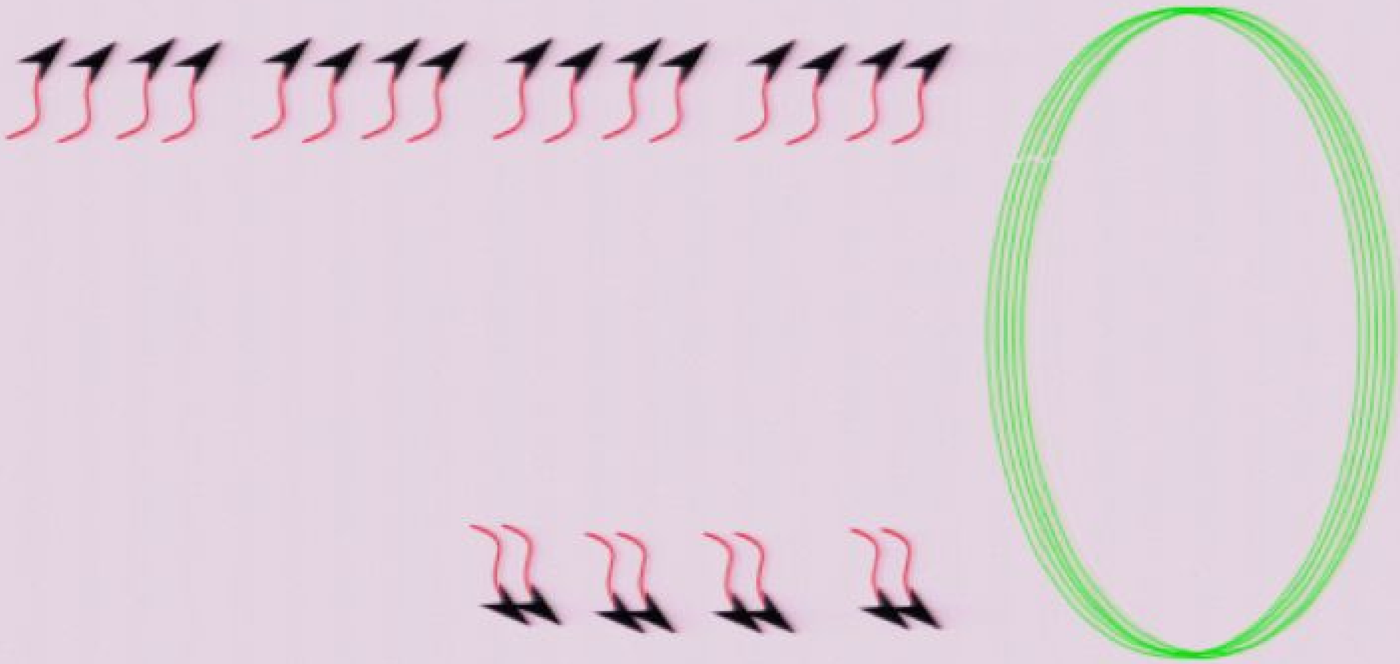
total spin of right movers

$$J_R = \frac{1}{2} + 1 + 1 = \frac{5}{2}$$

$$
\begin{aligned}
E &= P_L + P_R = \frac{20+6}{R} = \frac{26}{R} \\
P &= P_L - P_R = \frac{20-6}{R} = \frac{14}{R} \\
J_\psi &= -(J_R + J_L) = -\frac{5+9}{2} = -7 \\
J_\phi &= -(J_R - J_L) = 2
\end{aligned}
$$


$SU(2)_L \times SU(2)_R \sim SO(4)$

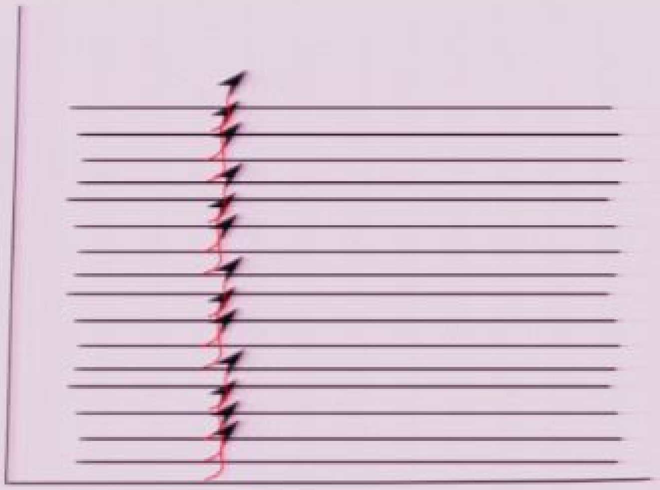
and make a twisted string of length (3+1) R



X 2 flavors

and make a twisted string of length (3+1) R

X 2 flavors



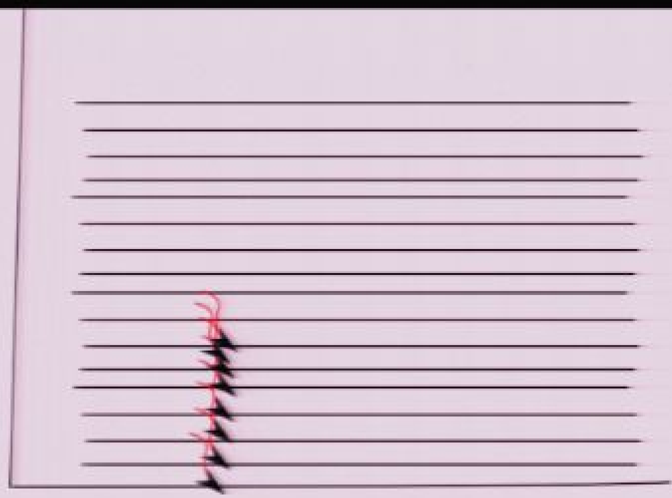
X 2 flavor

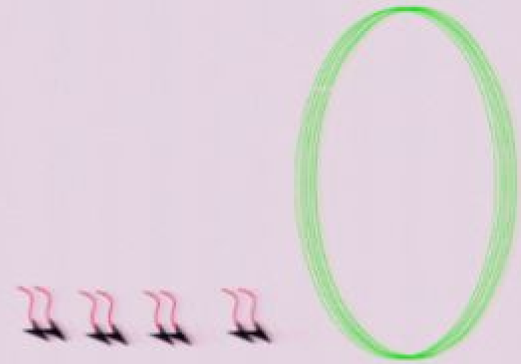
momentum quanta have gone down to $\dfrac{1}{4R}$

For each flavor in the left moving sector

$$P_L^f = \frac{1}{4R}\left[1+2+...+16\right] = \frac{34}{R}$$

total left momentum $$P_L = \frac{68}{R}$$





X 2 flavo

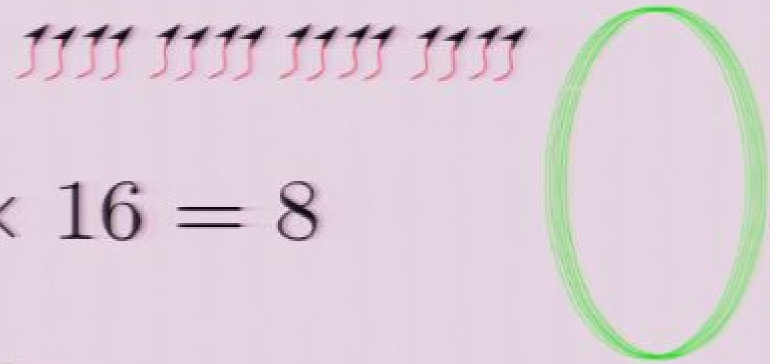
momentum quanta have gone down to $\dfrac{1}{4R}$

For each flavor in the left moving sector

$$P_R^f = \frac{1}{4R}\left[1+2+...+8\right] = \frac{9}{R}$$

total right momentum $P_R = \dfrac{18}{R}$

The spin from left moving fermions
of one flavor



X 2 flavors

$$J_L^{f,ferm} = \frac{1}{2} \times 16 = 8$$

base spin of the string

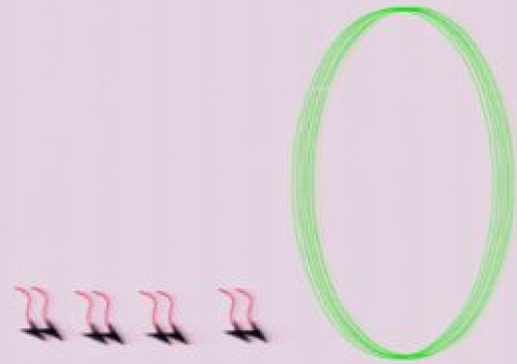
$$J_R^{f,base} = \frac{1}{2}$$

total spin of left movers

$$J_L = \frac{1}{2} + 2 \times 8 = \frac{33}{2}$$

The spin from left moving fermions of one flavor

$$J_R^{f,ferm} = \frac{1}{2} \times 8 = 4$$



X 2 flavors

base spin of the string

$$J_R^{f,base} = \frac{1}{2}$$

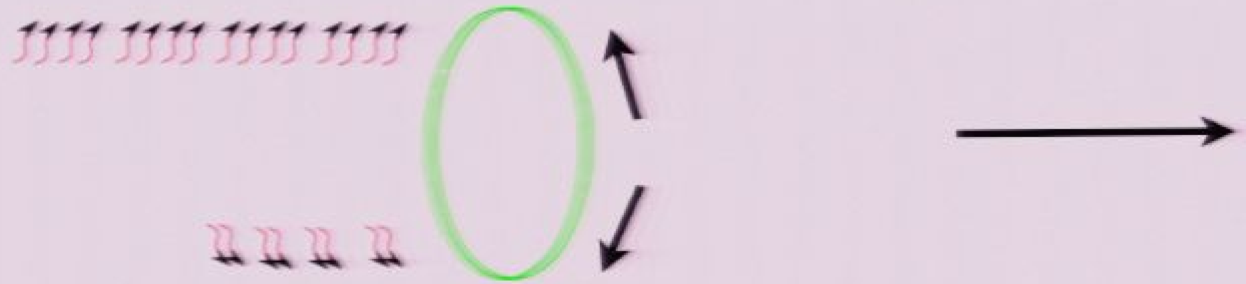
total spin of left movers

$$J_R = \frac{1}{2} + 2 \times 4 = \frac{17}{2}$$

after the twisting we have

X 2 flavors

$$
\begin{aligned}
E &= P_L + P_R = \frac{68+18}{R} = \frac{86}{R} \\
P &= P_L - P_R = \frac{68-18}{R} = \frac{50}{R} \\
J_\psi &= -(J_R + J_L) = -\frac{17+33}{2} = -25 \\
J_\phi &= -(J_R - J_L) = 8
\end{aligned}
$$



Account E=2/R for bosons

$$
\begin{aligned}
E &= \frac{104}{R} \\
P &= \frac{56}{R} \\
J_\psi &= -28 \\
J_\phi &= 8
\end{aligned}
$$

$$
\begin{aligned}
E &= \frac{86}{R} + \frac{2}{R} = \frac{88}{R} \\
P &= \frac{50}{R} \\
J_\psi &= -25 \\
J_\phi &= 8
\end{aligned}
$$

$$
\begin{aligned}
\omega &= \frac{16}{R} \\
\lambda &= \frac{6}{R} \\
m_\psi &= -3 \\
m_\phi &= 0
\end{aligned}
$$

$$\longrightarrow$$

$$\omega = \frac{16}{R}$$

$$\lambda = \frac{6}{R}$$

$$m_\psi = -3$$

$$m_\phi = 0$$

$$m = n_L + n_R + 1 = 7$$

$$n = n_L - n_R = 2$$

$$\omega = -l - m_\psi m + m_\phi n - |-\lambda - m_\psi n + m_\phi m| - 2(N+1)$$

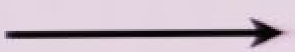
$$16 = -3 - (-3)7 + (0)2 - |-6 - (-3)2 + (0)7| - 2$$

Our model gives agreement with grav. energy

For a general analysis with 2 flavors of n_L left movers and 2 flavors of n_R movers

$$
\begin{aligned}
E &= (l+1)(n_L(n_L+1)+n_R(n_R+1)) \\
P &= (l+1)(n_L(n_L+1)-n_R(n_R+1)) \\
J_\psi &= -(l+1)(n_L+n_R+1) \\
J_\phi &= -(l+1)(n_L-n_R)
\end{aligned}
$$

$$
\begin{aligned}
E &= n_L(n_L(l+1)+1)+n_R(n_R(l+1)+1)+2 \\
P &= n_L(n_L(l+1)+1)-n_R(n_R(l+1)+1) \\
J_\psi &= -(l+1)(n_L+n_R)-1 \\
J_\phi &= (l+1)(n_L-n_R)
\end{aligned}
$$



$$
\begin{aligned}
\omega &= l(n_L+n_R)-2 \\
\lambda &= l(n_L-n_R) \\
m_\psi &= -l \\
m_\phi &= 0
\end{aligned}
$$

Wave left inside is the bound state in AdS

When the number of fermions in each sector is the same before and after wave left behind is in ground state of AdS

Other excited states are left behind if we change the number of fermions in the final state

The two bosons gave a deficit of 2 in the energy and were crucial to preserve the indices.

Width of instability: growth rate

- Earlier result: reproduced Hawking radiation by black holes

    - similar model: fermions and bosons on the string thermally distributed

- Take interaction vertex from those calculations

- Find decay rate for our non-thermal fermions

$$\Gamma_l = \frac{4\pi}{(l!)^2} \left(\frac{Q_1 Q_5}{4R^2} \right)^{l+1} \omega^{2(l+1)}$$

But this is the spontaneous part of decay

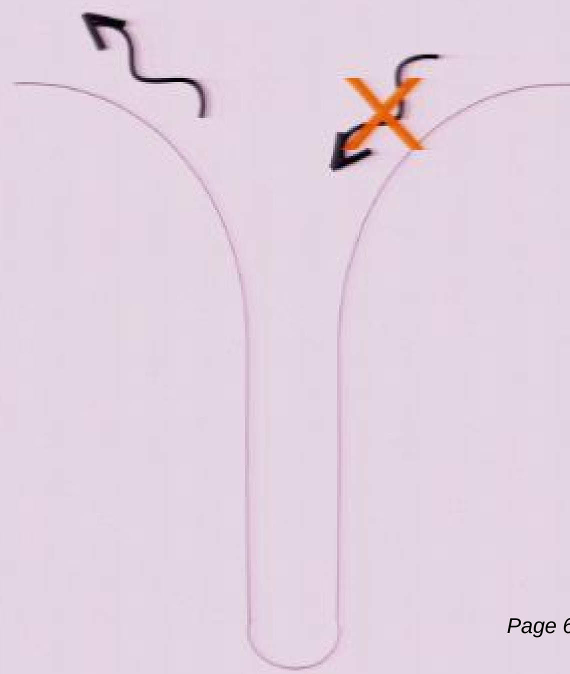
$$\frac{dN}{dt} = \Gamma$$

Stimulated emission would give

$$\frac{dN}{dt} = \Gamma(1 + N)$$

Is it LASER ? No

No mirror

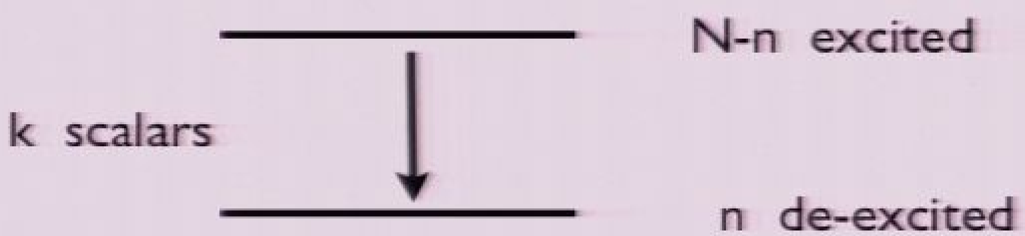


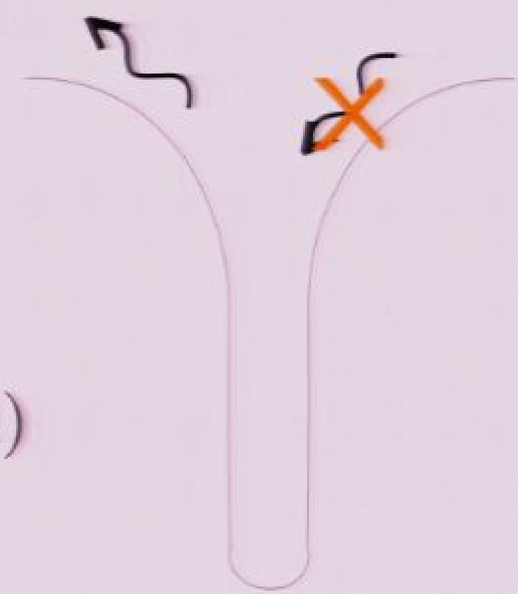
Recall CFT was symmetrized

1+1 (4,4) CFT with target space $(T^4)^N/S^N$

so it's a transition between two BECs

$$H_{int}|n,k\rangle = \alpha\sqrt{N-n}\sqrt{n+1}\sqrt{k+1}|n+1,k+1\rangle + \alpha^*\sqrt{N-n+1}\sqrt{n}\sqrt{k-1}|n-1,k-$$





Scalars escaping: n can only go to n+1

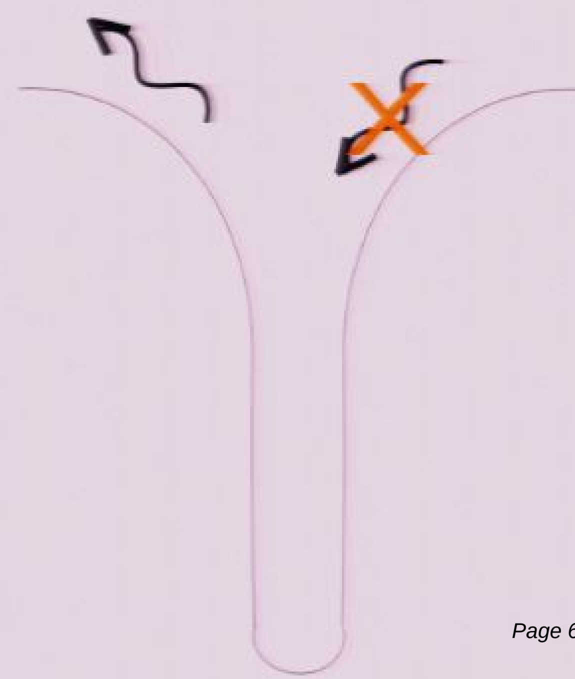
$$\frac{dn}{dt} = |\alpha|^2(N-n)(n+1) \approx |\alpha|^2 N(n+1)$$

But this is the spontaneous part of decay

$$\frac{dN}{dt} = \Gamma$$

Stimulated emission would give

$$\frac{dN}{dt} = \Gamma(1 + N)$$



Is it LASER ?   No

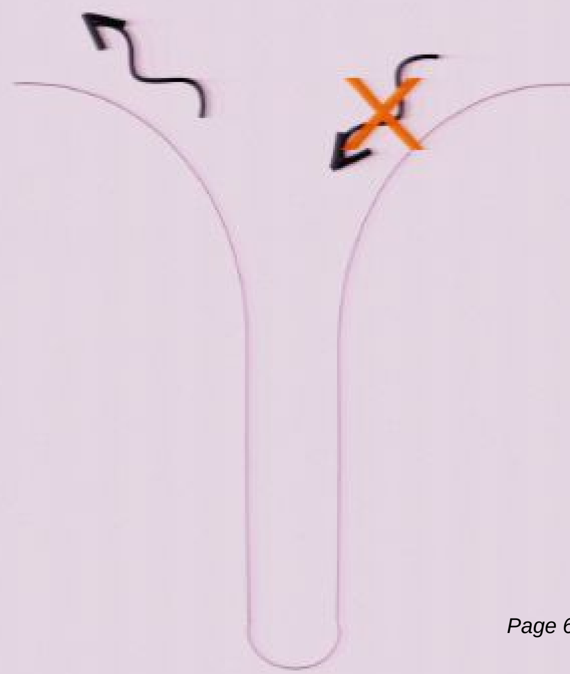
No mirror

But this is the spontaneous part of decay

$$\frac{dN}{dt} = \Gamma$$

Stimulated emission would give

$$\frac{dN}{dt} = \Gamma(1+N)$$



Is it LASER ? No

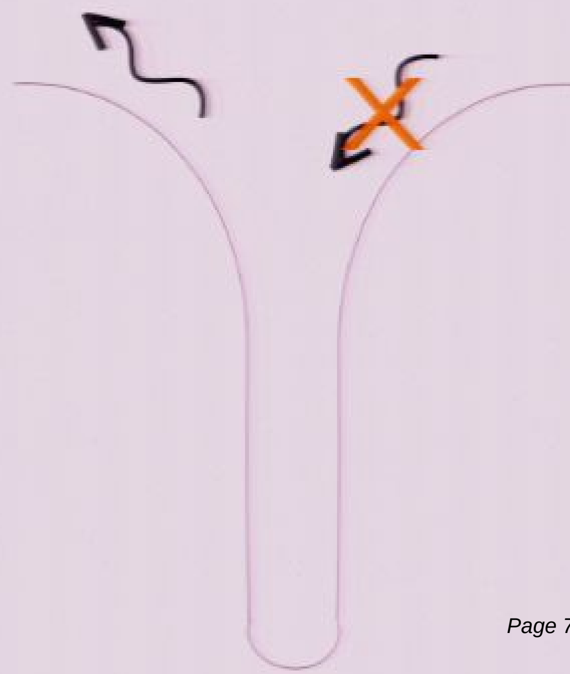
No mirror

But this is the spontaneous part of decay

$$\frac{dN}{dt} = \Gamma$$

Stimulated emission would give

$$\frac{dN}{dt} = \Gamma(1 + N)$$



Is it LASER ?   No

No mirror

- decay of excited state the quanta in the wave grows as

$$\frac{dN}{dt} = \gamma(N+1)$$

- identify spontaneous emission part to the black hole decay rate

- for large N the spontaneous part is negligible and we get

$$N = N_0 e^{\Gamma_l t}$$

- wave grows as $\sqrt{N}$

$$Im(\omega) = \frac{1}{2}\Gamma_l = \frac{2\pi}{(l!)^2}\left(\frac{Q_1 Q_5}{4R^2}\right)^{l+1}\omega^{2(l+1)}$$

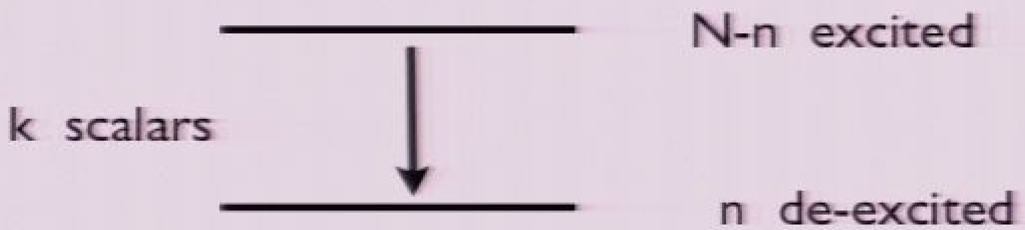
Model agrees with grav. decay width

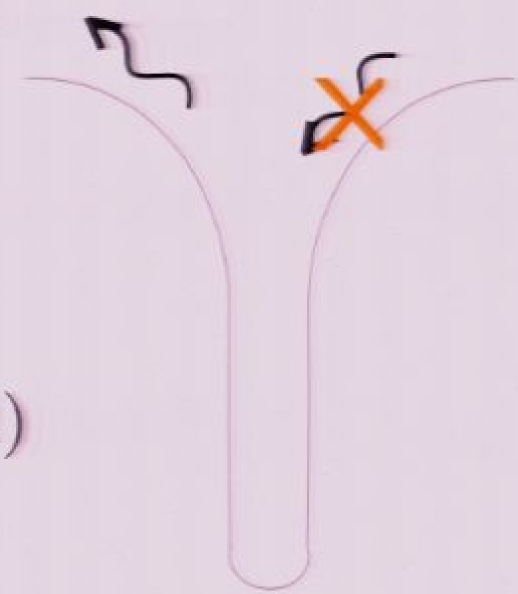
Recall CFT was symmetrized

1+1 (4,4) CFT with target space $(T^4)^N/S^N$

so it's a transition between two BECs

$$H_{int}|n,k\rangle = \alpha\sqrt{N-n}\sqrt{n+1}\sqrt{k+1}|n+1,k+1\rangle + \alpha^*\sqrt{N-n+1}\sqrt{n}\sqrt{k-1}|n-1,k-$$





Scalars escaping: n can only go to n+1

$$\frac{dn}{dt} = |\alpha|^2(N-n)(n+1) \approx |\alpha|^2 N(n+1)$$

- decay of excited state the quanta in the wave grows as

$$\frac{dN}{dt} = \gamma(N+1)$$

- identify spontaneous emission part to the black hole decay rate

- for large N the spontaneous part is negligible and we get

$$N = N_0 e^{\Gamma_l t}$$

- wave grows as $\sqrt{N}$

$$Im(\omega) = \frac{1}{2}\Gamma_l = \frac{2\pi}{(l!)^2}\left(\frac{Q_1 Q_5}{4R^2}\right)^{l+1} \omega^{2(l+1)}$$

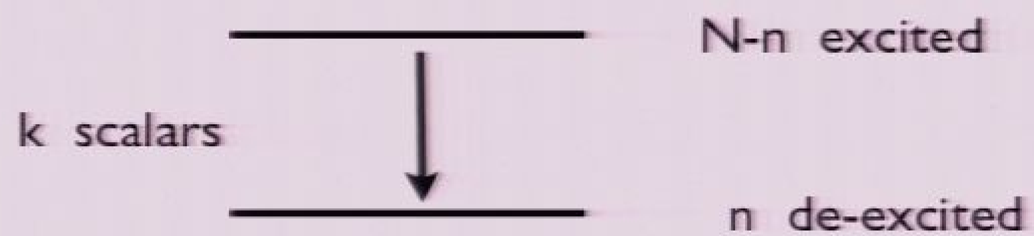
Model agrees with grav. decay width

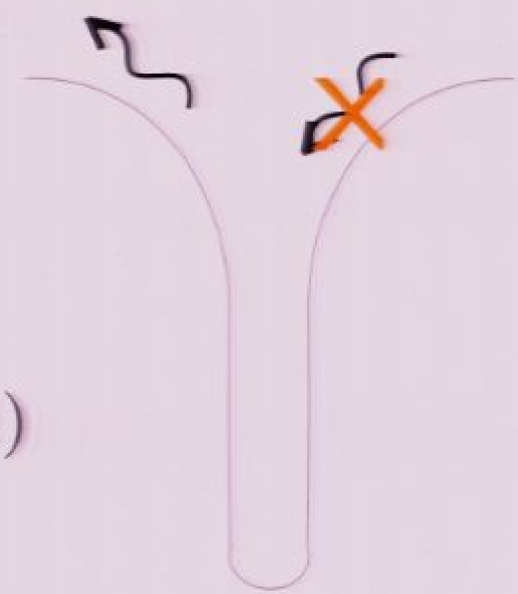
Recall CFT was symmetrized

1+1 (4,4) CFT with target space $(T^4)^N/S^N$

so it's a transition between two BECs

$$H_{int}|n,k\rangle = \alpha\sqrt{N-n}\sqrt{n+1}\sqrt{k+1}|n+1,k+1\rangle + \alpha^*\sqrt{N-n+1}\sqrt{n}\sqrt{k-1}|n-1,k-$$





Scalars escaping: n can only go to n+1

$$\frac{dn}{dt} = |\alpha|^2(N-n)(n+1) \approx |\alpha|^2 N(n+1)$$

- decay of excited state the quanta in the wave grows as

$$\frac{dN}{dt} = \gamma(N+1)$$

- identify spontaneous emission part to the black hole decay rate

- for large N the spontaneous part is negligible and we get

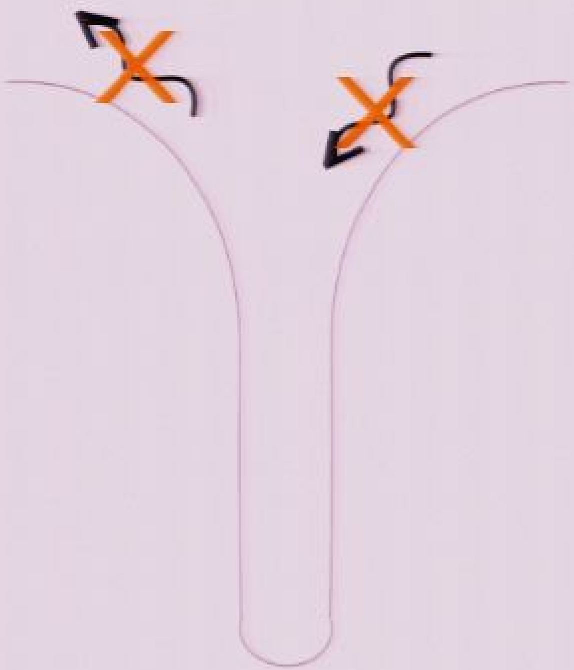
$$N = N_0 e^{\Gamma_l t}$$

- wave grows as $\sqrt{N}$

$$Im(\omega) = \frac{1}{2}\Gamma_l = \frac{2\pi}{(l!)^2}\left(\frac{Q_1 Q_5}{4R^2}\right)^{l+1} \omega^{2(l+1)}$$

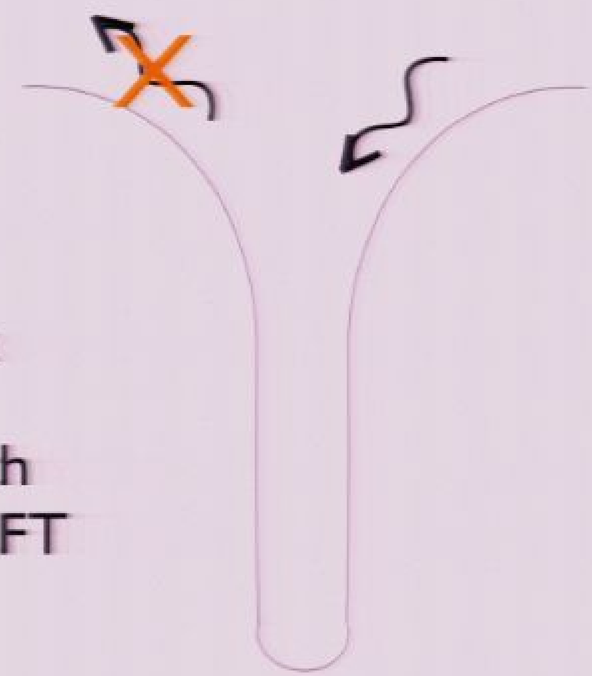
Model agrees with grav. decay width

Additional Ideas



Put mirrors

Instability goes away in gravity and CFT

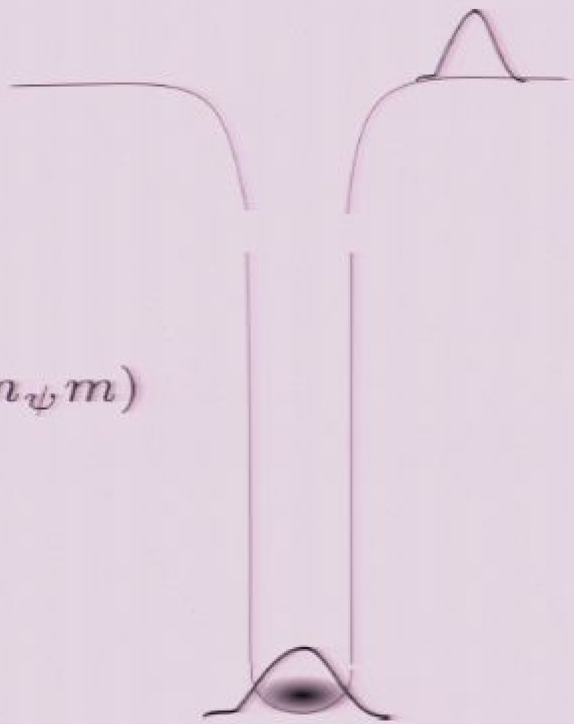


Only ingoing

Exponential Flux

Energy and Width reproduced in CFT

Additional Ideas



$$e^{-i(\omega t - m_\psi m)}$$

The two parts of wave seen as Hawking Pair

Solution grows exponentially

Noether Charge

The energy, angular momentum of the inside solution is equal and opposit[e] to the outside solution

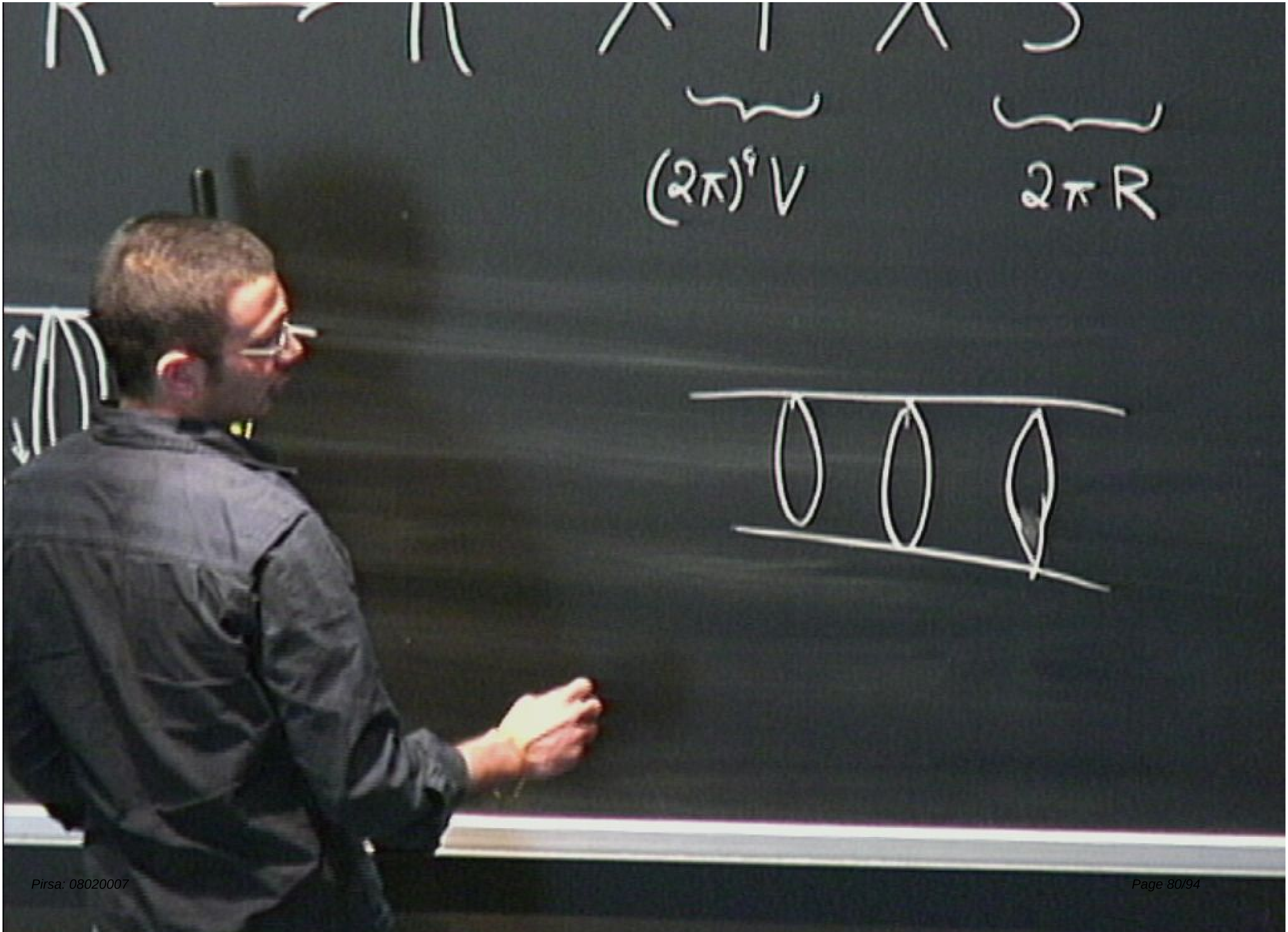
Proposal

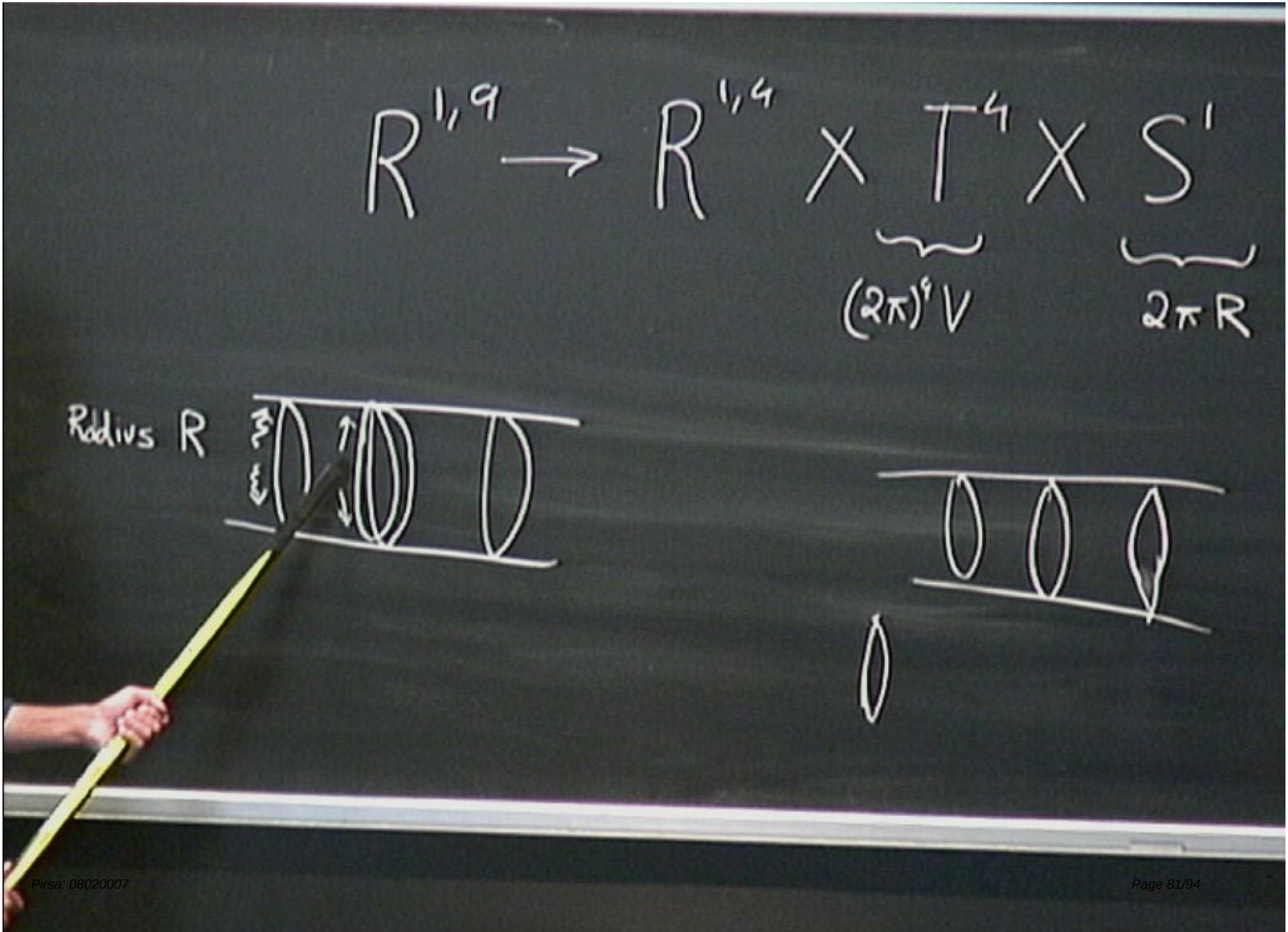
A generic non-extremal fuzzball will still have particle and anti-particle production

The initial state is not special so there will be no stimulated emission, only spontaneous emission

Simple model: Two oppositely rotating non-extrema smooth geometries

The emitted scalar from one absorbed by other give competing absorbing process canceling instability just like the case with mirrors


(2π)^6 V
2πR


R1,9 → R1,4 × T4 × S1
(2π)4 V
2π R
Radius R

Proposal

A generic non-extremal fuzzball will still have particle and anti-particle production

The initial state is not special so there will be no stimulated emission, only spontaneous emission

Simple model: Two oppositely rotating non-extrema smooth geometries

The emitted scalar from one absorbed by other give competing absorbing process canceling instability just like the case with mirrors

Proposal

A generic non-extremal fuzzball will still have particle and anti-particle production

The initial state is not special so there will be no stimulated emission, only spontaneous emission

Simple model: Two oppositely rotating non-extrema smooth geometries

- The emitted scalar from one absorbed by other give competing absorbing process canceling instability just like the case with mirrors

Conclusion

Emission from non-extremal fuzzball found

On the CFT side process same as Hawking Radiation

Hawking pair interpretation

Suggests a non-rotating fuzzball could have ergoregion like regions while having net angular momentum zero

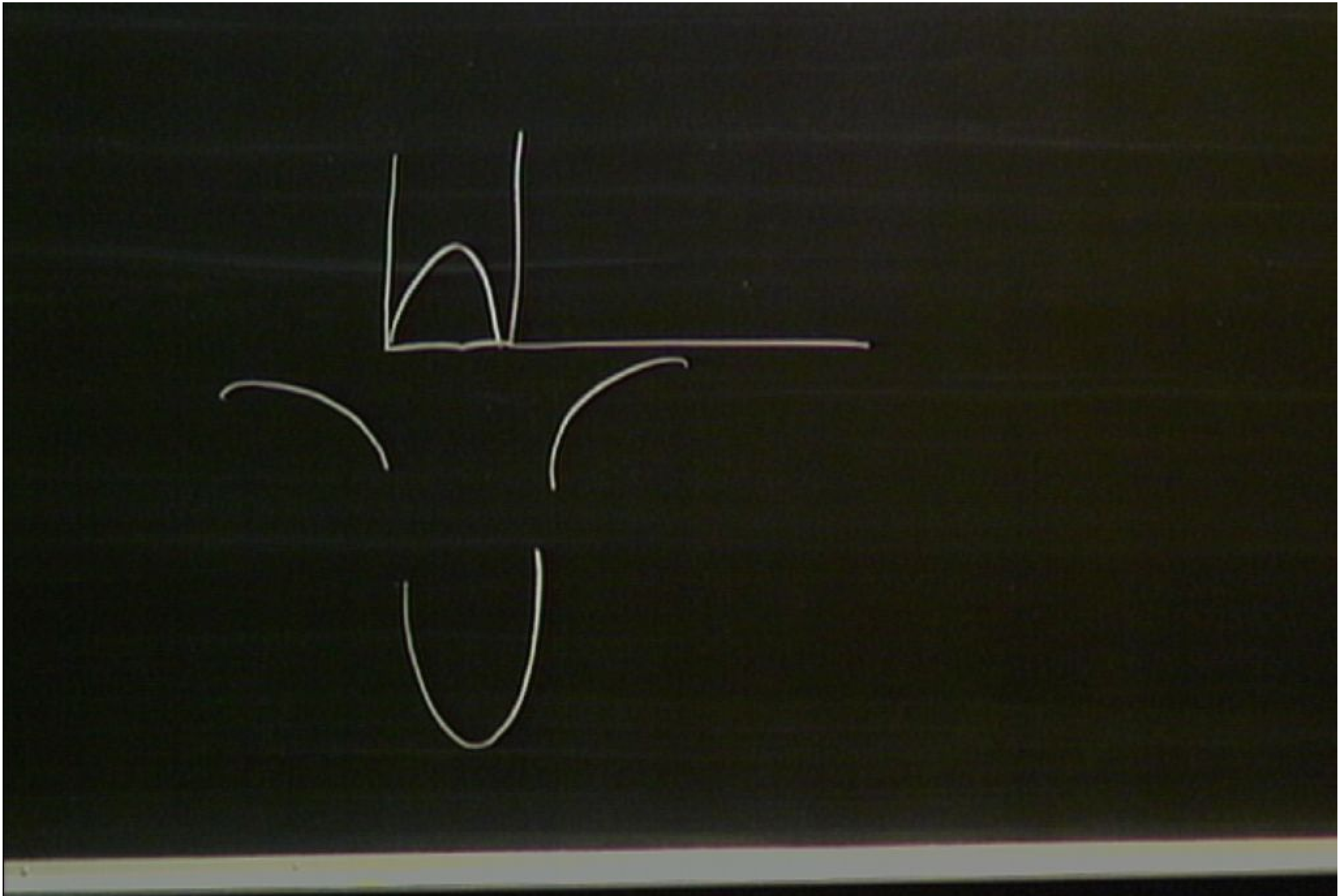
Hawking radiation would then be exactly the process described here

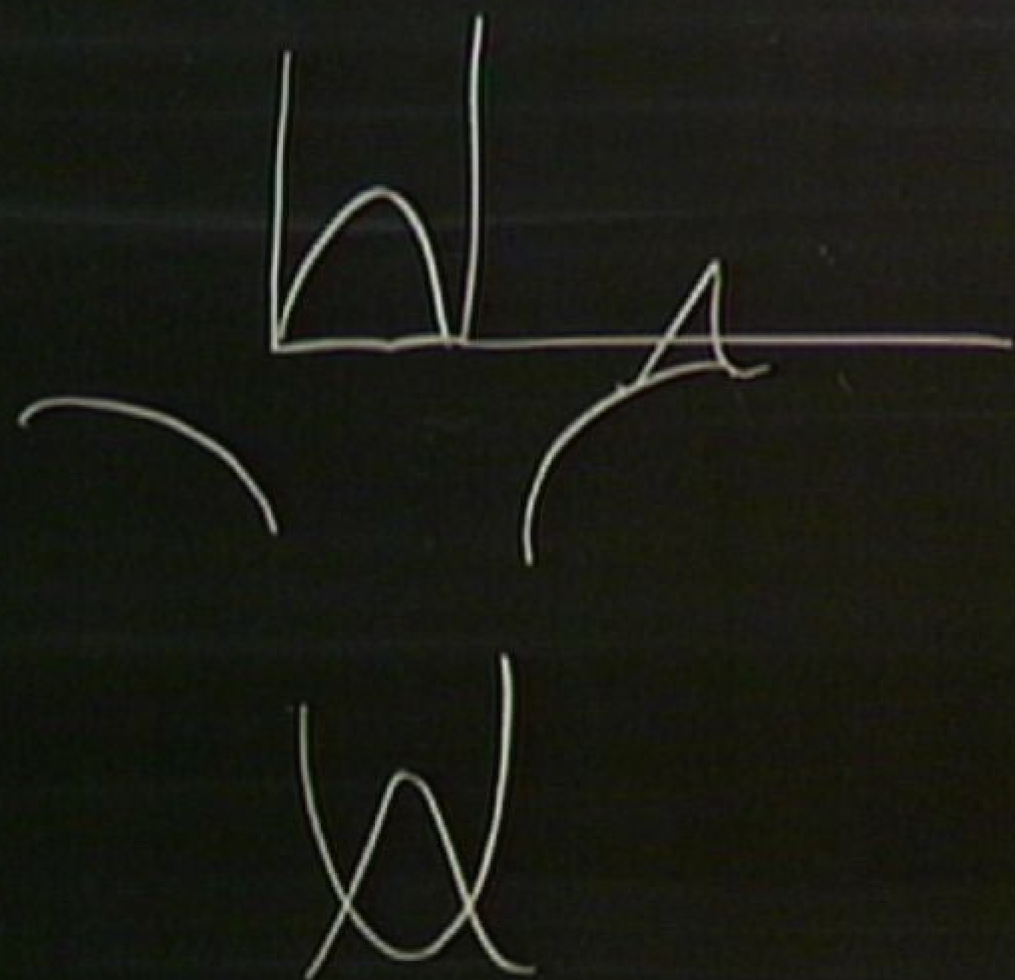
$$SU(2)_L \times SU(2)_R \sim SO($$

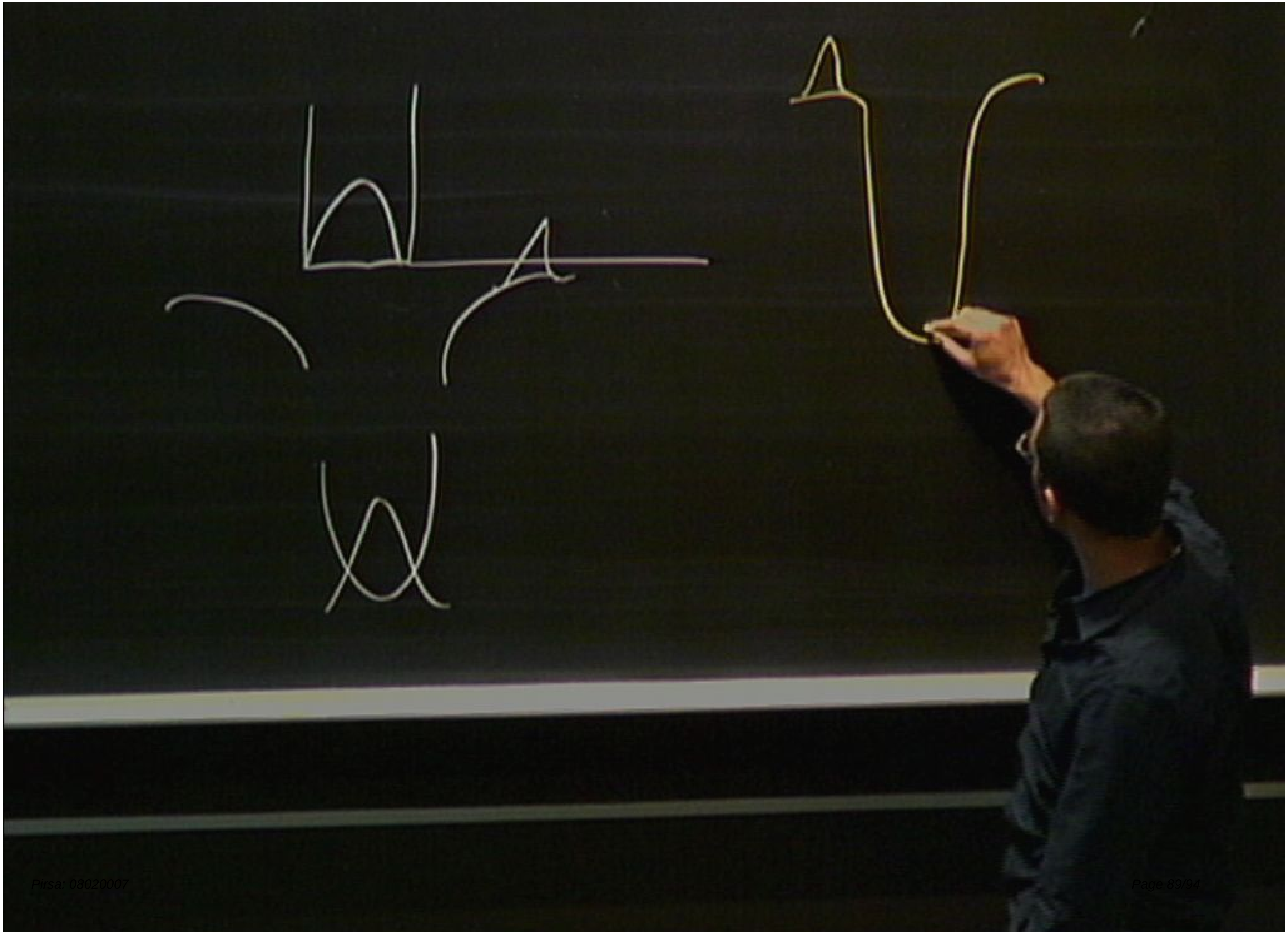
$$\frac{dn}{dt} \propto (N-n)\,n$$

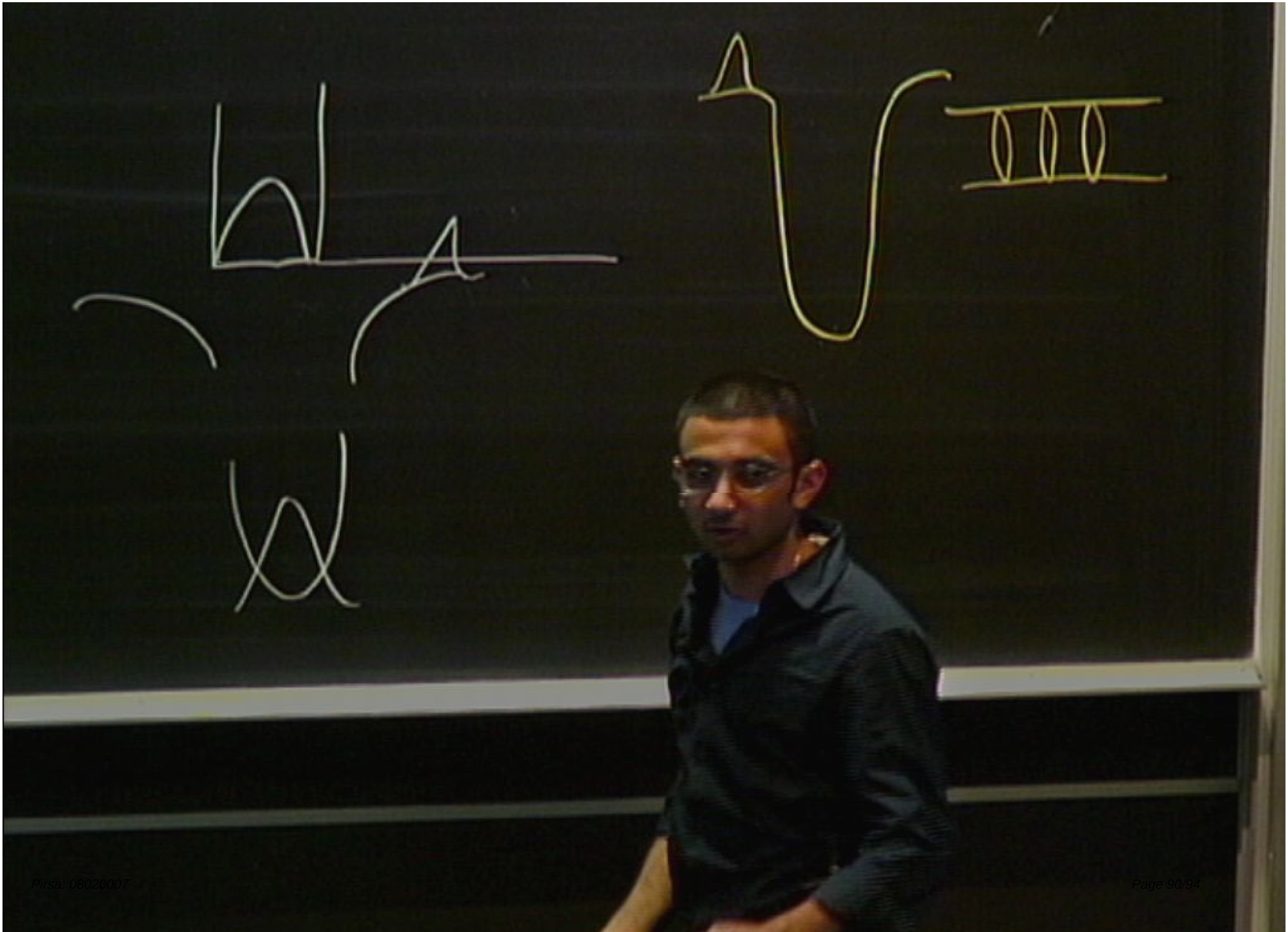
$SU(2)_L \times SU(2)$

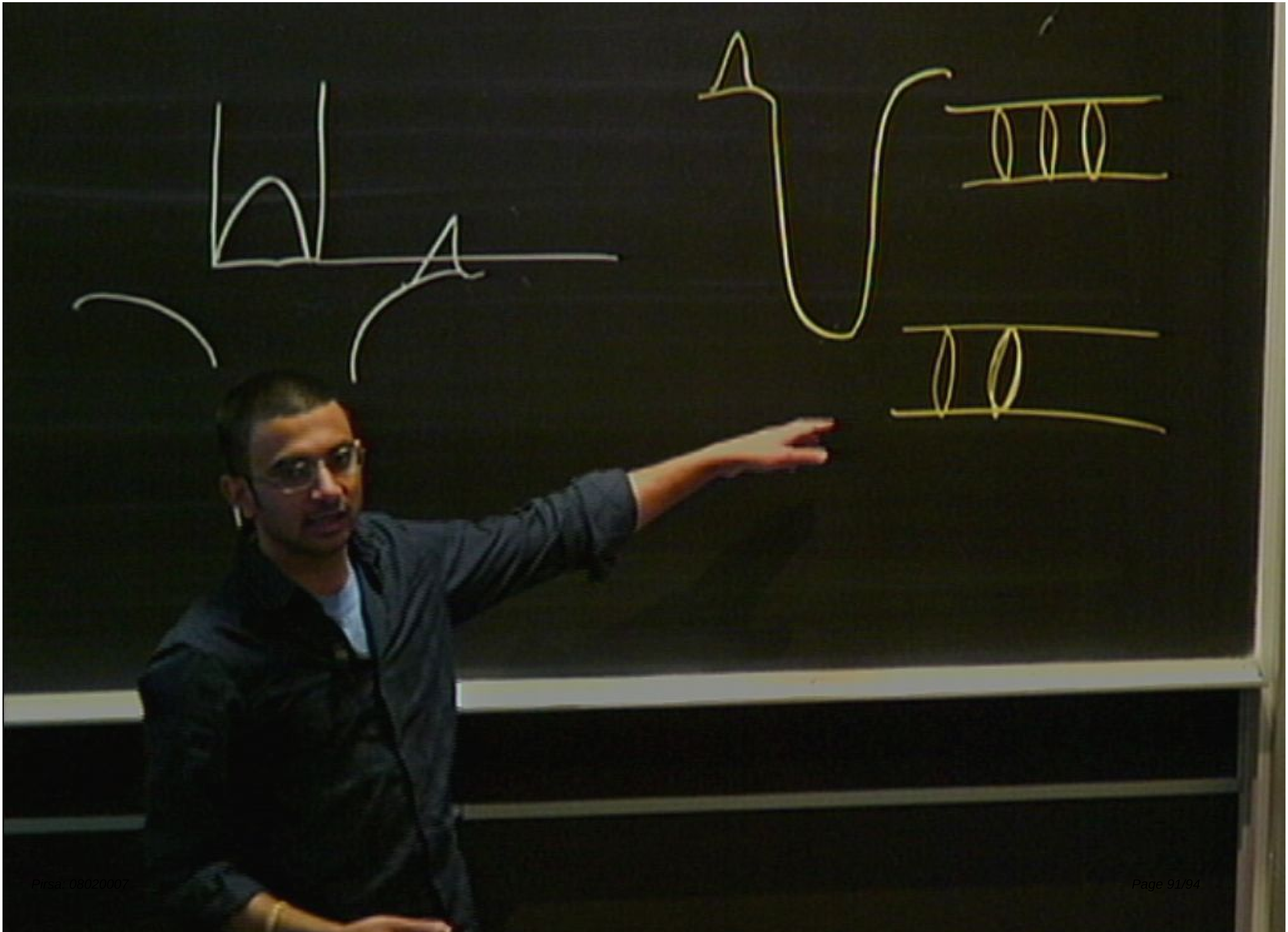
$$\frac{dn}{dt} \propto (N-n)\,n$$

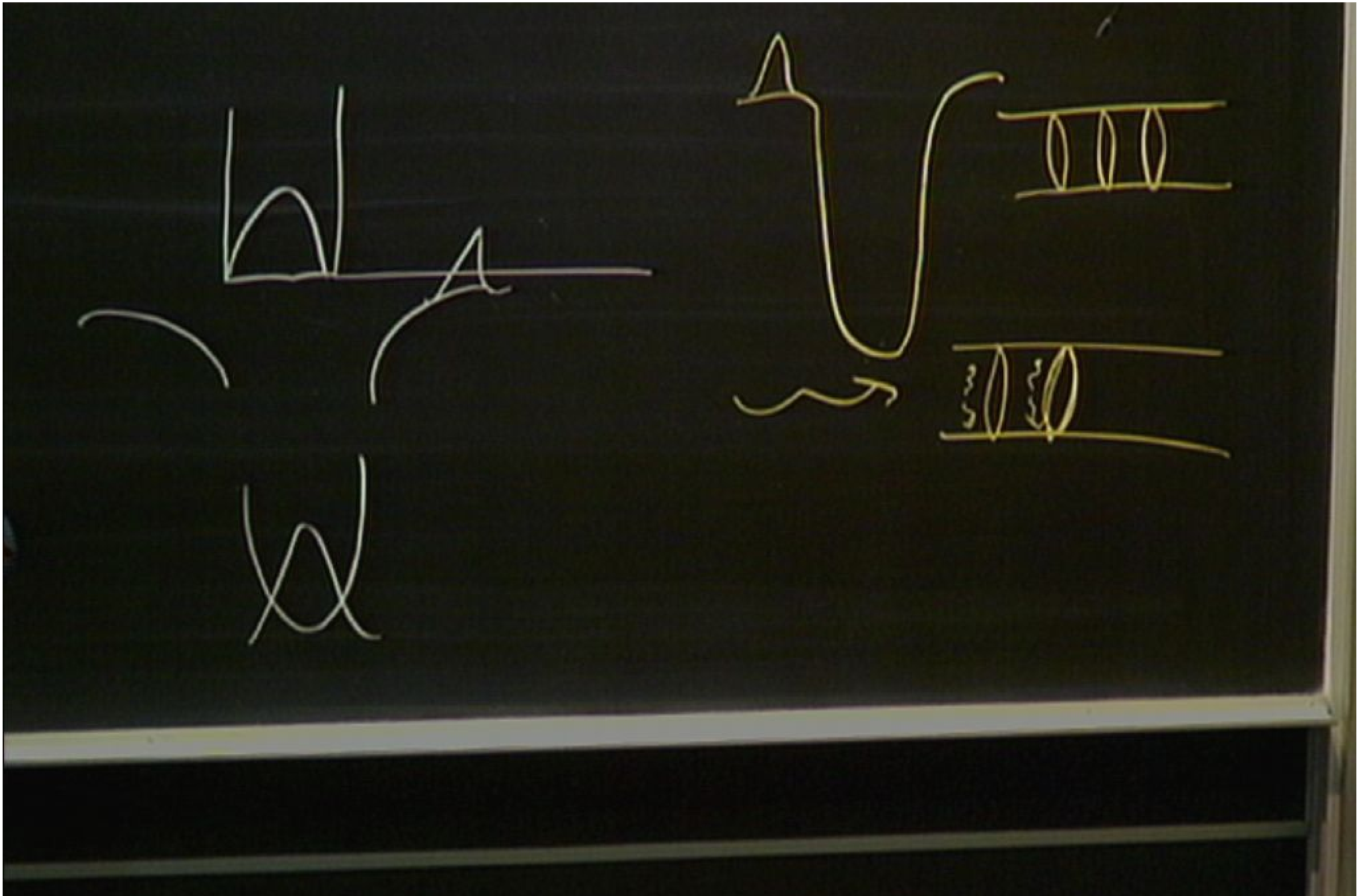


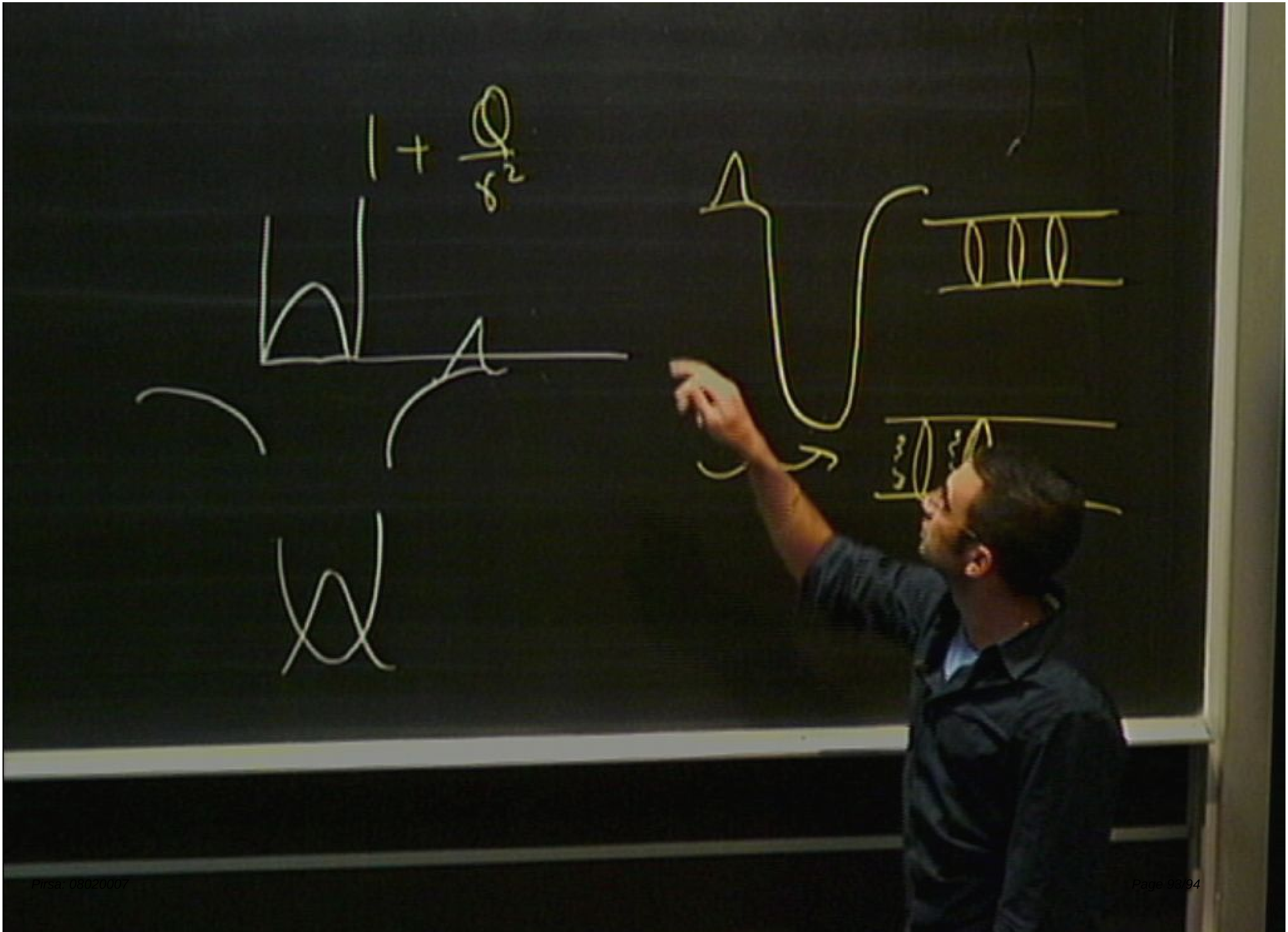


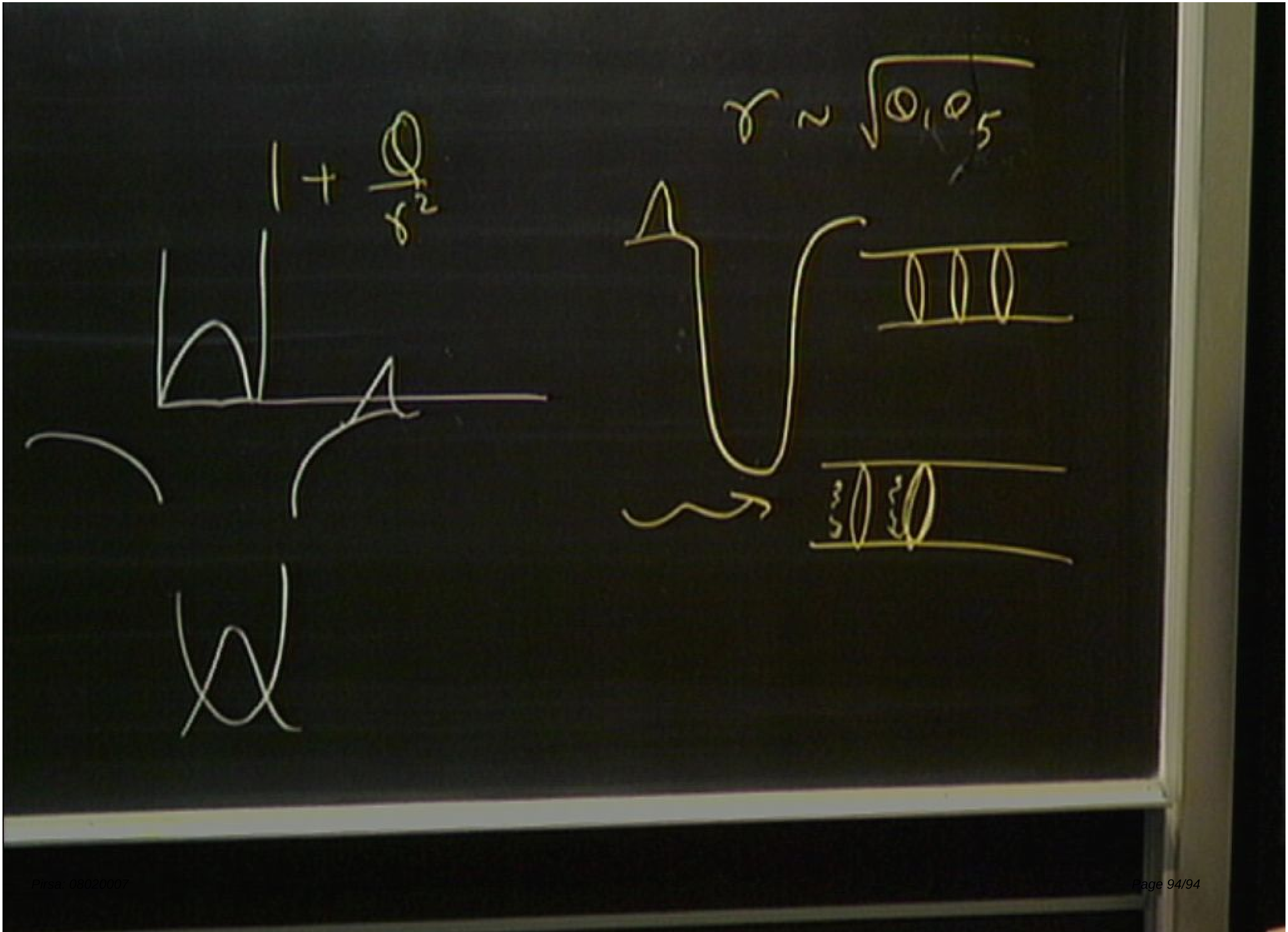









$1 + \frac{Q}{r^2}$


$1 + \frac{Q}{r^2}$
$r \sim \sqrt{Q_1 Q_5}$