Gary Horowitz (UCSB) (ITP 6-7-01) Fate of the Black String Instability

(1993)

Gregory & Ia Flame

P-branes are not (i.e., black strings and extended black holes are stable)

Ordinary black holes

K. Maceda & G.H.

Instability

Black String

Fate of the
Quantum 

Classical 

Expect block string will break up into black holes 

String of black hole 

Entropy

provided \( r_0 > l \) 

\[ \text{Solutions to 5D R} = 0 \]

4D Schwarzschild x S' 

Simplest example:
Symmetry breaking

Like spontaneous

\[ \begin{align*}
\text{Black string} & \quad \text{できない}
\end{align*} \]

They settle down to new broken up into black holes.

Black strings do not

- Unstable D-brane configuration
- BPS states of D3-branes
- Near extremal D3-branes
- D-brane - monopoles
- Discussions of BH on

AdS/CFT correspondence
- Density of states from
- BH in matrix theory
- BH in matrix theory

The idea that black

Strings \[ \rightarrow \] BH has been

used in many string disc.
Area theorem

Event horizons: $A \geq 0$

Fundamental property of $J$

$S = \frac{4\pi}{G}$

where $A = \frac{p}{\nu}$

Null geodesics

The divergence of $J$

are:

& \frac{\nu}{p} \leq 1

S-corded.

$z = \frac{\nu}{p} \leq 1$

Spherical perturbation

Start with $4D$ scalaron $S$.

The simplest case

for $p$-branes. But consider

Applying to all black

punch off in infinite time.

is unlikely, they can

Two arguments that

finite time.

cannot punch off in

Proof that horizons

Il present.
with known evolution.
Plus scalar, get contradiction.
Surface are 4D gravity.
Induced 3gs on \( z = 0 \).

\[
\begin{align*}
&\text{form a long neck:} \\
&\text{The horizon cannot}
\end{align*}
\]

Can horizon pinch off in infinite time?

If \( \psi \rightarrow -\infty \) in finite time,

\[
\frac{\gamma_p}{\Theta P} \Rightarrow 0
\]

\[
\frac{\gamma_p}{\Theta P} \Rightarrow 0
\]

Shear:

\[
\frac{\gamma_p}{\Theta P} = \frac{1}{\Theta^2}
\]

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Given by Raychaudhuri Eq.

Change of \( \Theta \) along horizon.
is essentially static. At late times, the solution is a very slow decay:

\[ a(t) \sim e^{-(t_A - t)^2 / \sigma^2} \]

\[ \sigma^2 = \frac{4m}{3} \]

is very restricted, e.g. decay which is possible remain finite, the type of horizon could not pinch off holes. So true event

horizon forms surrounding both black holes. Usually find a black holes very close looks like two spherical forms a short neck:

If horizon tries to
Perturbation has a non-trivial static $\Phi$. Predict $\Phi \times \epsilon$ with $\lambda \sim$.

Old solns when $L \sim R$. New solns join onto. If you vary $L$ keeping $\Phi (M/l)$ fixed, expect $R_o \sim 1$.

$S > S_0 \Rightarrow$ n.e. soln.

$(4)$ $S_{tot} \times \epsilon$

$mM A \sim \phi, \phi$ constant on horizon and

$\phi \sim C \sim 0$ exponentially fast at $\infty$.

$(2)$ Approaches trans. inv. soln.

$(1)$ $Q \sim A \max \phi \sim Q(1)$

Expect $\phi$ solns. $x \sim 1$.
in finite \( A \). These curves cannot \( \rightarrow \) of curves \( R(\lambda) \). Length of any \( s \) at \( \lambda = 0 \). Get family weak energy condition. Choose of any spacetime satisfying Thm: Consider event horizon.

odd mother, etc.

spaces, higher dim, can generalize to non-spherical.

(Found by Gregory & LaFlamme)

This is true.
Speculations
and
New Directions

1) Finding the new solns
2) Numerical work is underway and analytically may be hard
3) Implications for string
   theory remain to be investigated

Final Comments
to scallering camp!|!ded! what are the quantum string loop Corrections

Consider time dependent

More basic problems

(1) de Sitter space

(2) Cosmology

(3) Space-time inside BH

(4) Space like singularities

(e.g. Big bang)

Applications

String theory

time dependence in

Need to understand
Recover a semi-classical spacetime from dual CFT? How does one require $X = 0$ but nonsingular metric on worldsheet. But light cones of $q^n$ are different from $\mathbb{R}^4$. Expand $q^n = \eta_{+n} + \ldots$. Approaches require static spacetime (Riemann surfaces, modular spaces) usual technology.
\[
\frac{\partial^2 \phi}{\partial t^2} = \frac{\partial^2 \phi}{\partial x^2}
\]
So \( L = \frac{1}{b} \) \( l = \frac{c}{b} \) \( \phi = \frac{c}{L} \)

Find \( \phi, g, y, \Gamma \), \( L = \frac{c}{L} \)

(1) Compactifying on \( S^1/Z_2 \)
(2) Recover bosonic string by

(3) Planck tension membranes

(4) Recover bosonic string by

\( g_{\mu\nu}, F = \frac{c}{L^3} \)

(2) Massless fields

(1) 77 dimensions

\[ (\text{7, Susskind G.H.}) \]

\[ \text{Bosonic M Theory} \]

What is the fate of the closed string? Tachyon?
Fate of the Black String Instability

Kaluza-Klein vacuum is unstable (Witten)

$R^3$ can decay to space with "hole"

Can take $S^{1/2}$ (Fanger & Horava)

Boundary of space becomes worm hole

This description only valid for $r > l_p$. For $r \leq l_p$, expect tachyons to appear. (Analogy: tachyons in bosonic string is remnant of this instability when $r > 0$)

Absence if there are periodic fermions at infinity.

Probability for decay $e^{-\alpha r^2}$ of $R^3$ ball of size $r$. Tachyon in bosonic string is stable in this instability when $r > 0$.
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Comes up in $4+1$ GR
Closed string tachyon

4 old calculations of
nothing

Suggested by bubbles of

May be stable with $\gamma^2=0$

Final fate of $\mathbb{R}^{2,1}\times S^2$ is to be stable. What is Expect $2D$ flat space

Such a theory exist?

with $SO(2,1)$ symmetry. Does
is described by $4+1$ CFT

AdS$_4 \times S^7$

Boundary conditions

Bosonic M theory with

(NEW)

(OLD)

CFT with $SO(8)$ symmetry
by $4+1$ conformal field theory

Boundary conditions is described

\underline{AdS/CFT Prediction}