
BH Dynamics

in

AdS/CFT

- work in progress w/
A. Lawrence, S. Shenker, D. Wenren
+ A. Maloney (...)
- G. Horowitz, A. Lawrence, E.S '09
inside horizon in AdS/CFT
- Emparan '99

Outline

- Setup
- Moduli space & effect of ~~SUSY~~ compactification
- Wilson lines, electric fluxes, 'long strings', matrix dynamics, hair
- Fireball candidates & bounds
- More general comments

AMPS '12

Hitchcock '56



The Man Who Knew Too Much (1956)

Top 5000

PG 120 min - [Thriller](#) - [1 June 1956 \(USA\)](#)



Your rating: ★★★★★★★★ -/10

Ratings: 7.5/10 from 27,108 users

Reviews: 168 user | 58 critic

A family vacationing in Morocco accidentally stumble on to an assassination plot and the conspirators are determined to prevent them from interfering.

Director: [Alfred Hitchcock](#)

Writers: [John Michael Hayes](#) (screenplay), [Charles Bennett](#) (based on a story by), [2 more credits](#) »

Stars: [James Stewart](#), [Doris Day](#), [Brenda de Banzie](#) | [See full cast and crew](#)

An old problem
'34

The Man Who Knew Too Much



Directed by [Alfred Hitchcock](#)

AMPS '12 used a thought experiment
to make a prediction for theory

Firewall: $M_{\text{susy}} \gg T_{\text{BH}}$

in particular $\frac{\text{Signal}}{\text{Noise}} \sim \frac{M_{\text{FW}}}{T_{\text{BH}}} \gg 1$

To settle this we need to control
BH dynamics (e.g. in AdS/CFT)
Well enough to detect this
Signal

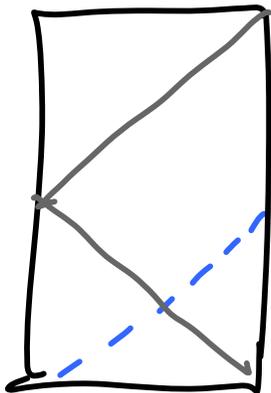
A relatively simple case where the dual QFT has a protected probe of the fate of the BH interior is

Emparan '99 Howitz Lawrence '09

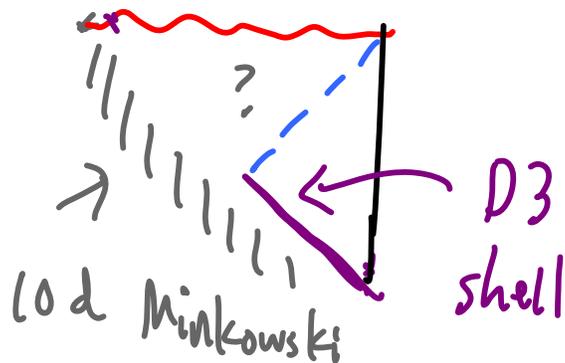
classical metric

$$ds^2 \Big|_{\mu=0} = \frac{r^2}{R^2} (-d\Upsilon^2 + \underbrace{\Upsilon^2 d\sigma^2}_{\mathbb{H}_3/\mathbb{Z}}) + \frac{R^2}{r^2} dr^2 + R^2 d\Omega^2$$

Classically this is an orbifold of a patch of the Poincare patch, freely acting except at $\Upsilon=0$ singularity



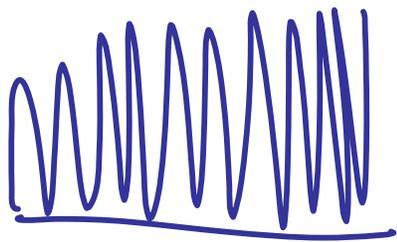
form naturally:



Dual QFT : $N = 4$ $U(N_c)$ SYM

on $-d\tau^2 + \tau^2 d\sigma^2$

Before compactifying, QFT on H_3



$\frac{1}{l_s}$ gap

} not normalizable

Dual QFT : $N=4$ SYM on

$$-d\tau^2 + \tau^2 d\sigma^2$$

$\leftarrow \underbrace{\quad}_{\mathbb{H}_3/\mathcal{I}}$

Compact \Rightarrow

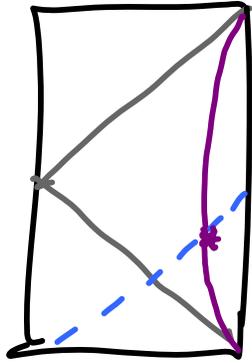
• Classical moduli space $\supset (\mathbb{R}^6 \times T^{b_1})^N / S_N$
actually $\exists N^2$ -dim'l space of flat connections

• Moduli are dynamical QM. variables (below a gap to QFT modes on \mathbb{H}_3), not superselection parameters. Part of $N \times N$ matrix

• BH decays via brane nucleation

• ~~SUSY~~ $\leftarrow H = \frac{da}{d\tau} = \frac{1}{\tau} = \frac{1}{l_{\Sigma}}$

Horizon Locus



M_W

$$r_h \gamma_h = R^2$$

$$\phi_h = \frac{\sqrt{\lambda}}{\gamma_h}$$

under $U(N+1) \rightarrow U(N) \times U(1)$

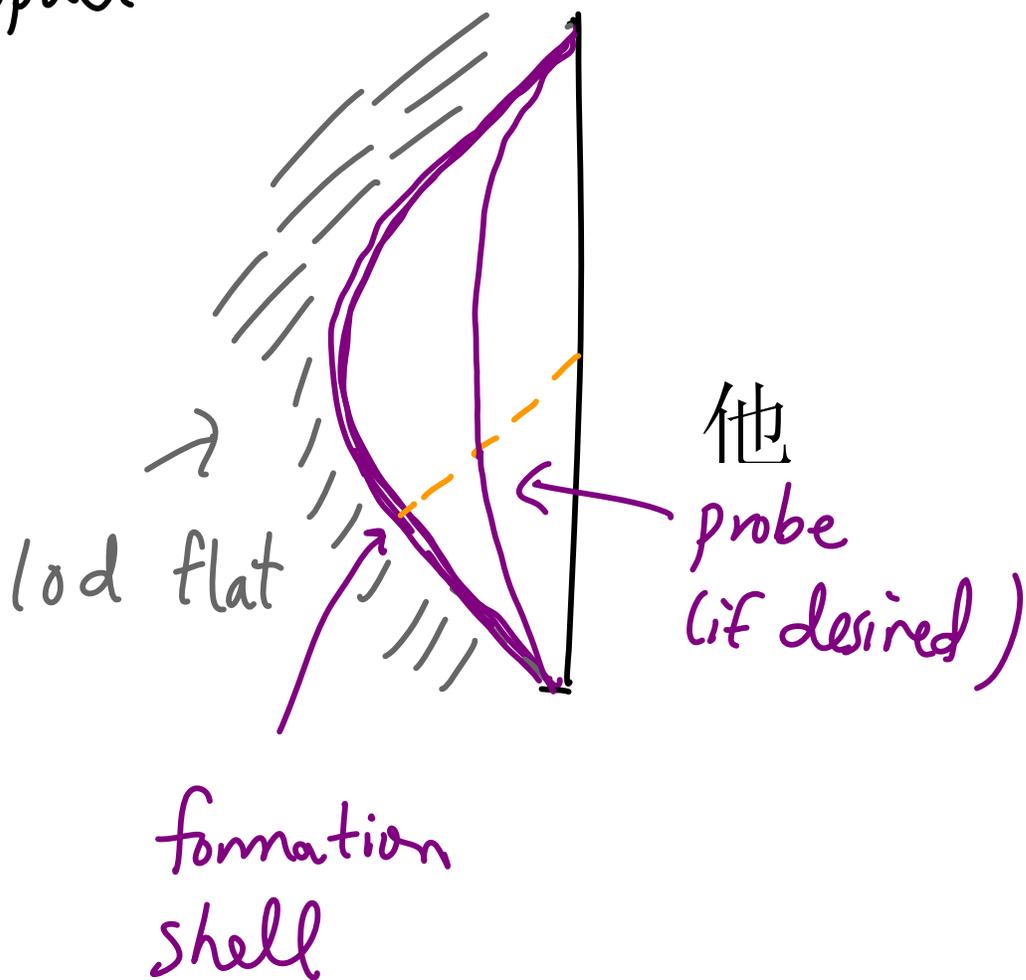
Before compactifying,

\mathcal{F} exact moduli space with protected (uncorrected) metric

$$S_{\text{un}} = \int dt r^3 d^3 \sigma \sqrt{\tilde{g}} \left\{ \underset{\substack{\uparrow \\ \lambda}}{(\partial\phi)^2} + \dots \right\}$$

where $\phi = \langle \phi \rangle + \delta\phi$
 \uparrow parameter

Noncompact



→ Compactify on

$$\Sigma = \left. \begin{array}{l} \cdot T_{\text{susy}}^3 \text{ periodic b.c.} \\ \cdot T_{\text{susy}}^3 \text{ anti-periodic} \\ \quad \text{(Scherk-Schwarz)} \end{array} \right\} \begin{array}{l} \text{QFT} \\ + \\ \text{GR} \\ \text{side} \end{array}$$

$$\cdot \text{our } 1\text{H}_3/\mathcal{T} \left. \right\} \begin{array}{l} \text{QFT} \\ \text{side} \end{array}$$

→ ϕ dynamical and interacts
w/ whole matrix, but initially
very heavy & weakly coupled

$$\mathcal{L}_{\text{eff}} = \frac{\text{Vol}}{g_s} \cdot \frac{\dot{\phi}^2}{2} + \dots = \frac{1}{2} m v^2$$

uncertainty $\Delta\phi \Delta\dot{\phi} \gtrsim \frac{g_{YM}^2}{Vol}$

Minimal uncertainty wavepacket

$$\Delta\phi \sim \frac{g_{YM}}{l_\Sigma} = \frac{g_{YM}}{|r|} \ll \frac{\sqrt{\lambda}}{r}$$

$$\Delta\phi \ll \phi_{horizon}$$

T_{susy}^3 : v^2 term protected

$T_{susy}^3 \sim 1\text{Hz}/r$: ~~susy~~ injected at
 scale $\frac{1}{l_\Sigma} = \frac{1}{|r|} \ll m_W, m_{FW}$

~~SUSY~~ in W loops $\begin{matrix} \text{---} \bigcirc \text{---} + \text{---} \bigcirc \text{---} \\ + \dots \end{matrix}$

Ψ_{initial} peaked at $\begin{pmatrix} \phi_{11} & 0 & \dots & 0 \\ \hline 0 & & & \\ \vdots & & & \\ 0 & & \Phi & \end{pmatrix}$
 $\Phi_{(N-1) \times (N-1)}$

v^0, v^2 terms cancel
 in SUSY case to all orders,

residual ~~SUSY~~ $\propto \frac{\lambda^n}{(l_\epsilon \Phi)^{3n}} \ll 1$ at horizon

$$\int \frac{d\tilde{\omega} \cdot g_{\tilde{m}\tilde{n}}^2 N}{\tilde{\omega}^2 + \phi^2 + \frac{1}{l_\epsilon^2}} \quad \xrightarrow{\omega \rightarrow 0} \quad \int \frac{d\tilde{\omega} \cdot g_{\tilde{m}\tilde{n}}^2 N}{\tilde{\omega}^2 + \phi^2 + \omega^2} \quad \xrightarrow{\omega \rightarrow \infty}$$

$$\rightarrow \phi^2 \times \frac{1}{l_\epsilon^2} \int \frac{d\tilde{\omega}}{(\tilde{\omega}^2 + \phi^2)^2} \sim \frac{1}{l_\epsilon^2 \phi} \quad \text{marginal at horizon}$$

Matrix dynamics

- Where & when does the probe dissolve into the YM matrix? $\phi_* \stackrel{?}{\gtrsim} \phi_h$

Usual matrix Q.M. : dim'l analysis

\Rightarrow powers of $\frac{\lambda^{\frac{1}{3}}}{\phi}$ where $\lambda_{QM} = \frac{\lambda}{l_\Sigma^3}$

(std in D0-brane matrix theory BFSS Joe P '99)

suggests $\phi_* l_\Sigma \sim \lambda^{\frac{1}{3}} \ll \sqrt{\lambda} \leftarrow$ horizon
is where perturbation theory breaks down

- Full problem \approx

$$\int (\partial \underline{\Phi})^2 + \text{Tr} \left(\underset{\substack{\uparrow \\ \text{holonomies}}}{U^T \underline{\Phi} U} \right) + \dots$$

N^2 classically
Itzykson/Zuber...

Compactification \rightarrow Topological sectors

In Scherk-Schwarz $\times \mathbb{H}_3/\Gamma$,
the system has a new
instability to condense
electric flux loops:

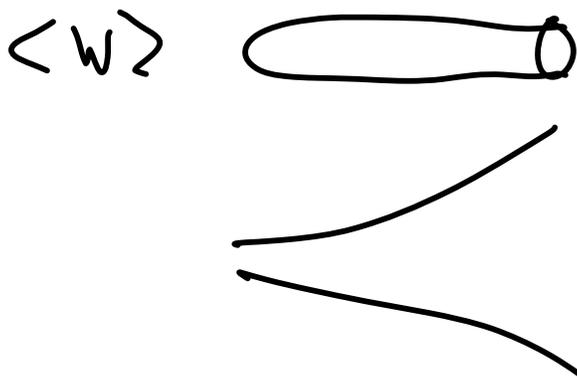
$$\langle W_k = P e^{i \oint d\sigma A^\sigma(\sigma, \sigma_\pm, \tau)} \rangle$$

In T^3_{susy} case, this is dual
to winding string tachyon condensation

APS, ... Horowitz McGreevy ES ...

$N=4$ SYM / S^1
Scherk-Schwarz

GR \Rightarrow QFT
confines



$\langle W \rangle \neq 0$

- on H^3/\mathbb{Z} , a gap of $\sim \frac{1}{l_s}$ would correspond to horizon according to UV/IR $\frac{1}{l_s} = \frac{1}{R} \left(\frac{r}{R} \right) \Rightarrow r l_s = R^2$

$$m_W^2 = - \underbrace{\text{tension}^2}_{\text{worldsheet Casimir}} + L^2 \text{tension}^2$$

At weak coupling, explicit gauge theory computation (Gross/Pisanki/Yaffe '81... Polchinski '91) exhibits this effect for electric

flux tubes. $A_{||} = \begin{pmatrix} \theta_1 & & & \\ & \theta_2 & & \\ & & \ddots & \\ 0 & & & \theta_N \end{pmatrix}$
 gauge choice

Integrate out $A_{\perp}, \Phi \rightarrow$

$$\text{potential} \propto \sum (\theta_a - \theta_b)^2 (2\pi - |\theta_a - \theta_b|)^2$$

$$m_{\theta} \sim \frac{\lambda_n^{\frac{1}{2}}}{l_s}$$

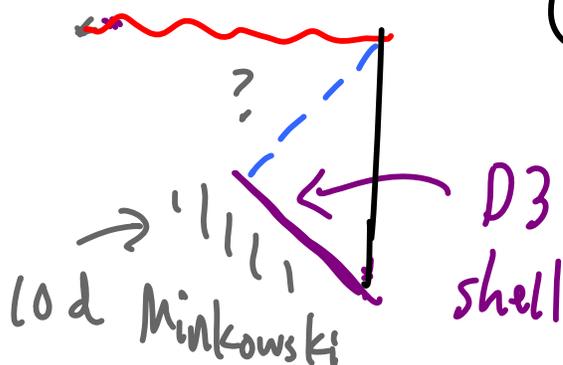
wilson lines driven $\rightarrow \theta_a = \theta_0$

(e.g. can work in static frame)



Induces confinement

Consider formation shell around r_f
 $(r_f \phi_f = \sqrt{\lambda})$



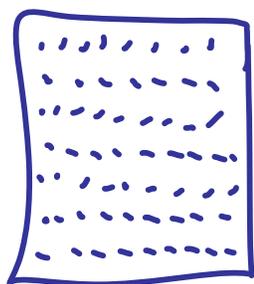
distributed on $\mathbb{R}^6 \rightarrow$ weakly
interacting at low energy \Rightarrow



$$\Theta_a \rightarrow \Theta_0$$

Close enough to extremality,
the entropy count favors

"long strings" with $(Z_N)^{b_1}$



τb_1

Symmetric Wilson

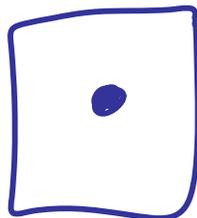
lines

Maldacena Susskind ...
D1-D5

Banks et al
BFSS BH

The potential $\rightarrow \langle W \rangle \neq 0$

\Rightarrow instead



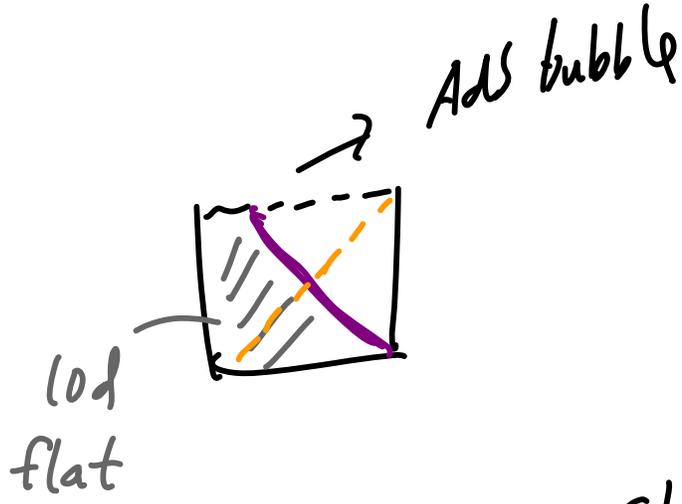
Is this enough to destroy (or
fail to create) the inside?

- Initially, the scales are low...

Causality & Confinement

S^1_{SUSY}

Horowitz/ES



The transition proceeds via stringy winding tachyon condensation



timescale bounded by causality

* For compact $(H_1) / \Gamma$, QFT bound on spreading stops at $l_s \dots$

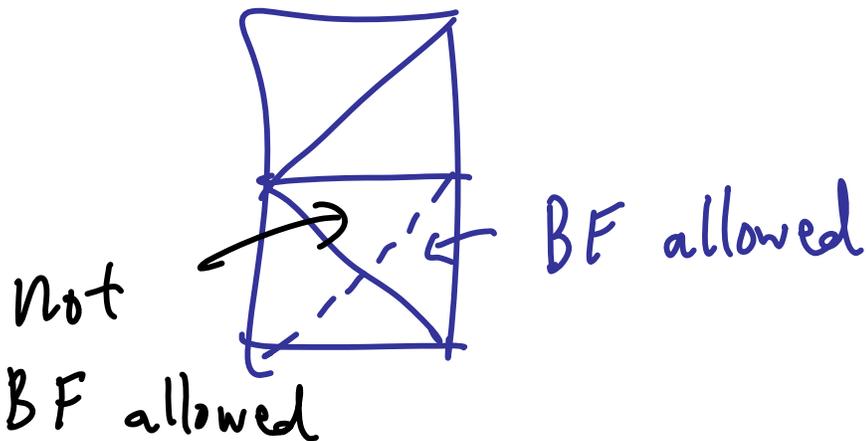
Another aspect of the problem is scalar hair

compact
Reall Santos et al
Maloney et al

inside $\mu = 0$
in + out $\mu < 0$

BF bound
N/A inside

(e.g. after
some
evaporation)



Solutions Bessel ftns, grows exponentially
but $\Phi_{\text{hair}} \sim \Phi_0 e^{\frac{\Delta T}{R}}$ not
metric + A_4 large at horizon

So far

- SUSY protects v^2 , v^0 against large quantum corrections

$\phi_{||}$ joins the matrix further
in could \rightarrow exclusion

- Potential for larger ~~SUSY~~
via $\langle W \rangle$: Wilson lines clump
 \neq long strings

Que Sera Sera ...

General Comments

- S^2 horizon: \mathcal{I} breaks
SUSY, FW would at
a higher scale
- Some cases (Fermi Seasickness)
where GR smooth but
branes are (perturbatively)
unstable to flying up throat
- Reverse-engineer FW in
some case?



home > what is burning man > ten principles

Ten Principles of Burning Man

Burning Man Founder Larry Harvey wrote the Ten Principles in 2004 as guidelines for the newly-formed [Regionals Network](#). They were crafted not as a dictate of how people should be and act, but as a reflection of the community's ethos and culture as it had organically developed since the event's inception.

Radical Inclusion

Anyone may be a part of Burning Man. We welcome and respect the stranger. No prerequisites exist for participation in our community.

Gifting

Burning Man is devoted to acts of gift giving. The value of a gift is unconditional. Gifting does not contemplate a return or an exchange for something of equal value.

Decommodification

In order to preserve the spirit of gifting, our community seeks to create social environments that are unmediated by commercial sponsorships, transactions, or advertising. We stand ready to protect our culture from such exploitation. We resist the substitution of consumption for participatory experience.

Radical Self-reliance

Burning Man encourages the individual to discover, exercise and rely on his or her inner resources.

Radical Self-expression

Radical self-expression arises from the unique gifts of the individual. No one other than the individual or a collaborating group can determine its content. It is offered as a gift to others. In this spirit, the giver should respect the rights and liberties of the recipient.

Communal Effort

Our community values creative cooperation and collaboration. We strive to produce, promote and protect social networks, public spaces, works of art, and methods of communication that support such interaction.

Civic Responsibility

We value civil society. Community members who organize events should assume responsibility for public welfare and endeavor to communicate civic responsibilities to participants. They must also assume responsibility for conducting events in accordance with local, state and federal laws.

Leaving No Trace

Our community respects the environment. We are committed to leaving no physical trace of our activities wherever we gather. We clean up after ourselves and endeavor, whenever possible, to leave such places in a better state than when we found them.

Participation

Our community is committed to a radically participatory ethic. We believe that transformative change, whether in the individual or in society, can occur only through the medium of deeply personal participation. We achieve being through doing. Everyone is invited to work. Everyone is invited to play. We make the world real through actions that open the heart.

Immediacy

Immediate experience is, in many ways, the most important touchstone of value in our culture. We seek to overcome barriers that stand between us and a recognition of our inner selves, the reality of those around us, participation in society, and contact with a natural world exceeding human powers. No idea can substitute for this experience. ↩

