Title: Remarks on cosmic censorship and its possible violations

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Abstract:

On Cosmic Censorship and its potential violations

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Quantum Black Holes in the Sky?

Perimeter Institute – Nov 2017

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Quantum Gravity in the sky?

How does one get there?

Cosmic censorship

A conjecture about *highest-energy physics*

Starting from low-energy densities,

can we, *within a* ***quick***, ***classical*** *time-scale*,

get to explore Quantum Gravity?

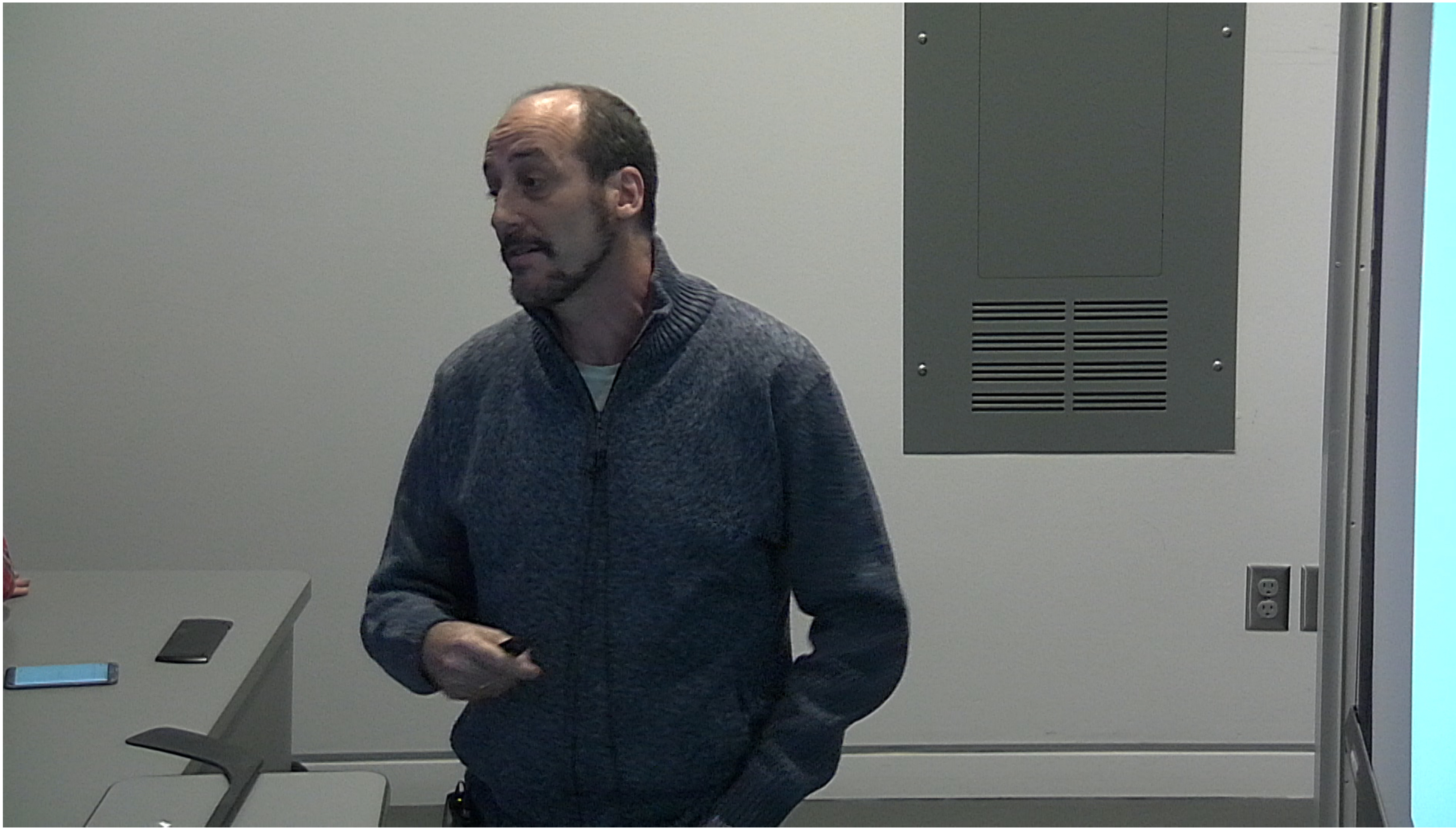
If cosmic censorship is violated,

predictability (within GR) is lost

May learn new physics

Naked Planck-scale energy densities easily form

but in long, quantum timescales



Classical timescale

$$t_M^{(cl)} \sim \frac{GM}{c^3} = M$$

Collapse time

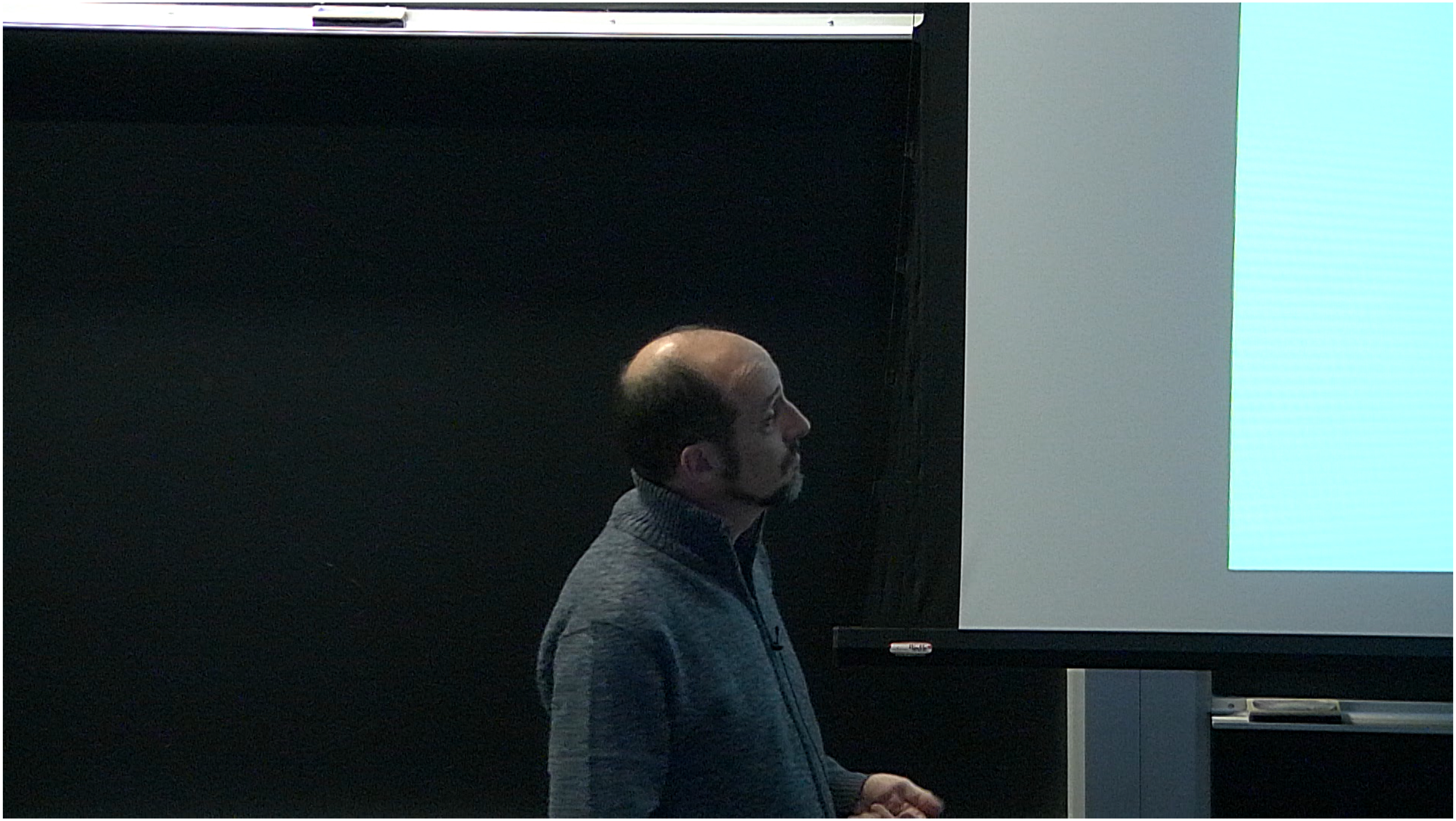
Quantum timescale

$$t_M^{(qu)} \sim t_{Pl}\left(\frac{M}{M_{Pl}}\right)^3 \sim M\left(\frac{M}{M_{Pl}}\right)^2 \gg t_M^{(cl)}$$

Hawking evaporation time & Page time

Firewall formation time (?)

If this quantum time-scale is required to reach quantum gravity, then forget it...



Quantum timescale?

$$t_M^{(sc)} \sim M \log \frac{M}{M_{Pl}} \gtrsim \; t_M^{(cl)}$$

Scrambling time

Fuzzball tunneling time

Echo time

Does not appear to involve Planckian curvatures

Seems to require large non-locality

There exist a few well-established violations of cosmic censorship

Naked singularities of arbitrarily high curvature form within the classical time scale of the system

Critical collapse

Black string instability

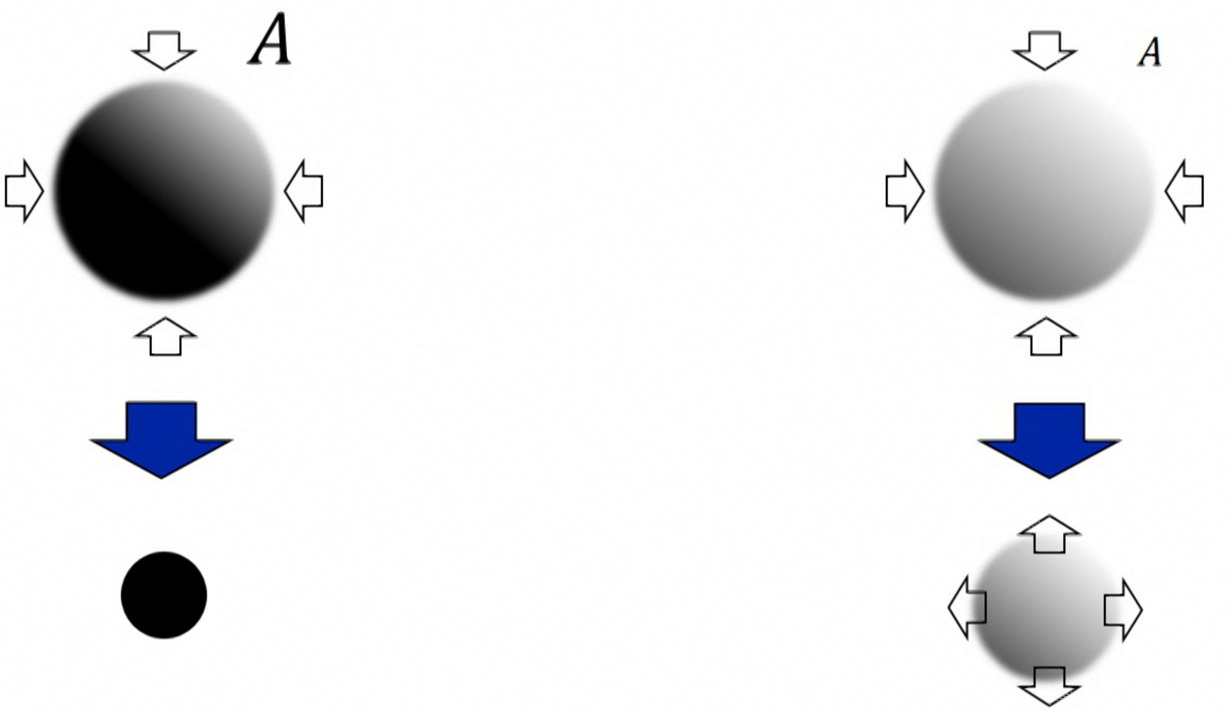
Do these examples suggest a useful window for exploring quantum gravity?

(even at a very theoretical level)

Critical collapse

Choptuik 1993

Change initial amplitude A



Physically, for a small range of values around A_{crit} there forms a Planck-sized object, with naked Planckian curvature

Quantum gravity becomes observable

Is this a useful violation of CC?

Often disregarded since it requires fine-tuning

Fine-tuning of initial conditions

$\Rightarrow$ reaching Planckian scales requires purposeful action

- It *is* possible—the job of experimentalists is to do fine-tuning

- It won't happen spontaneously in Nature – not in the sky

  (or only extremely rarely)

But anyway it is not very useful for studying quantum gravity

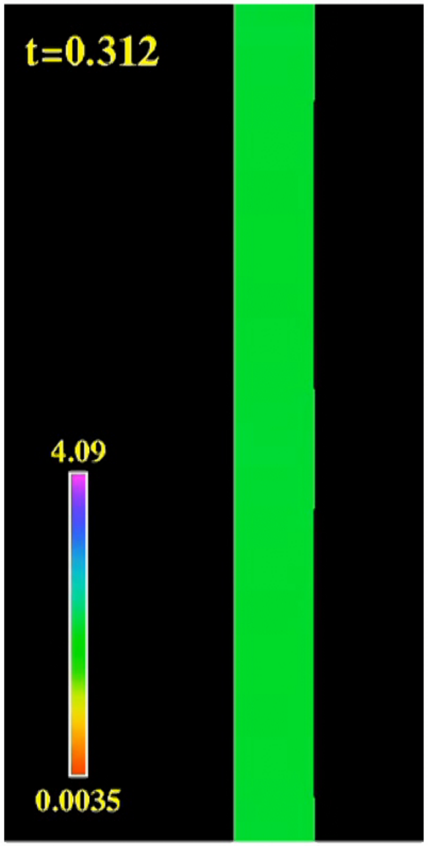
Too small fraction of initial energy goes into singularity

Evolution across singularity is almost entirely predictable

Planck-size “black hole” is likely to evaporate into a few Planckian-energy quanta

Similar to endpoint of Hawking evaporation (but without info-loss issues)

Black string instability

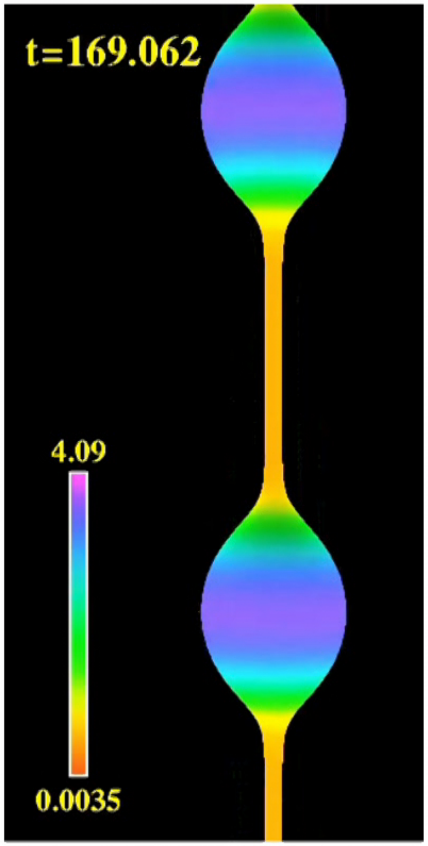


Gregory+Laflamme 1993

Lehner+Pretorius 2010

Evolution of unstable 5D black string

Black string instability



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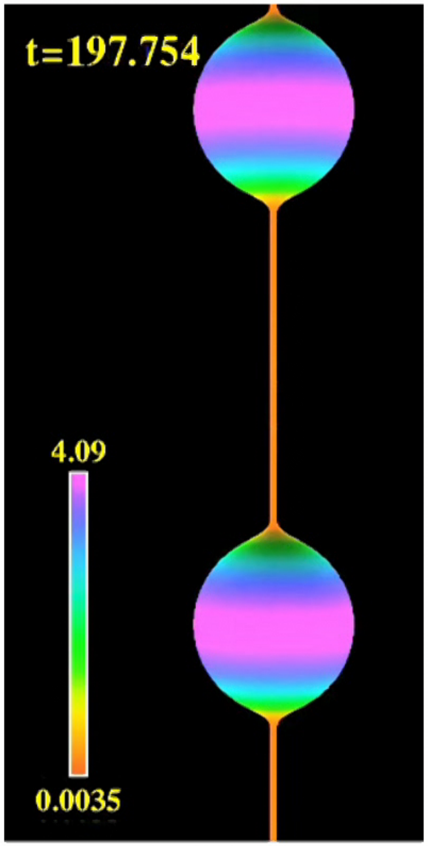

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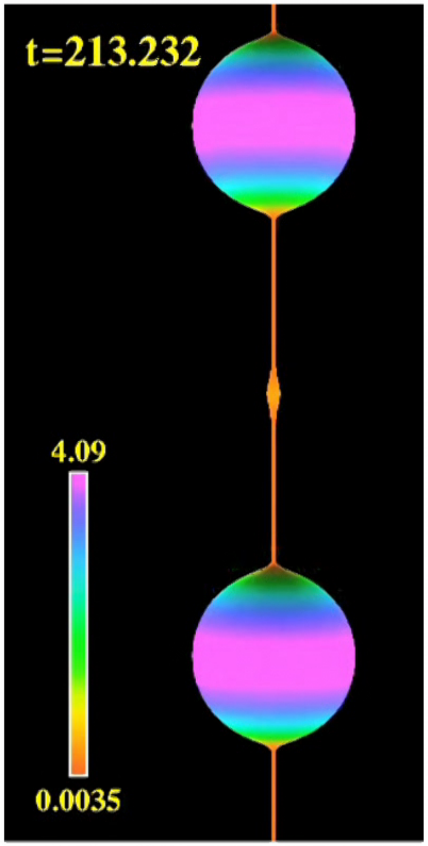

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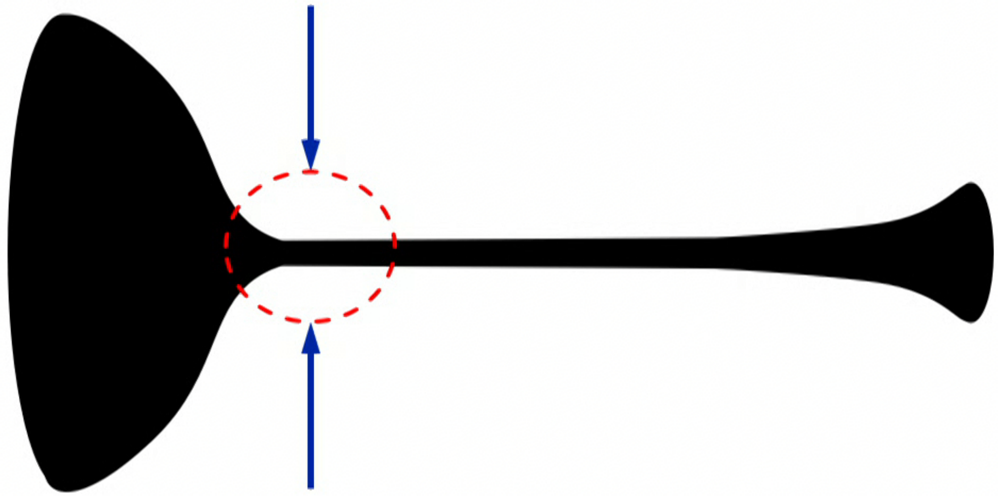
Evolution of unstable 5D black string

Naked arbitrarily large curvatures form within the classical timescale of the system



No fine-tuning is needed

Is this useful?

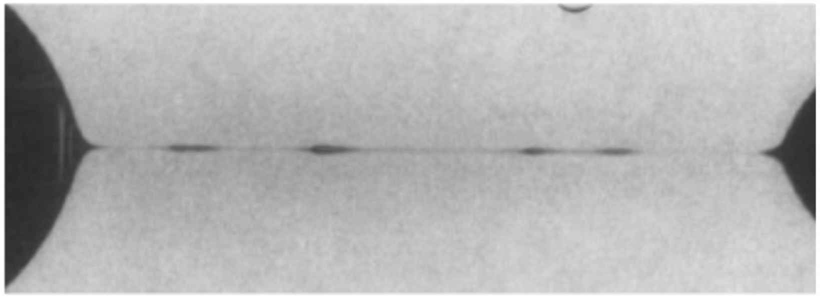
How strong is the loss of predictability?

A model for black string breakup

RE w/ J Rocha & U Miyamoto

Breakup of fluid jets

Eggers 1993, 1995



Glycerol

FLUID JET BREAKUP

When surface tension becomes too large

molecular dynamics enters

thin neck evaporates

Subsequent evolution is quickly described by hydrodynamics

BLACK STRING BREAKUP

When surface gravity becomes too large

quantum gravity/string theory enters

thin neck evaporates

Subsequent evolution is quickly described by classical gravity

Proposal

Breakup controlled by same physics

as at

endpoint of Hawking evaporation

Singularity only occupies a
Planck-sized region
of space and time

Only a Planck-size mass is
radiated

Quantum gravity is just a little pixie dust to effect breakup

Almost all is described (***predictable***) by classical GR attractors

If this is correct,

Cosmic Censorship is violated in the

mildest way

during black string break up

A strength-index s for CC violations

$$M_{sing} \sim M \left(\frac{M_{Pl}}{M} \right)^{1-s}$$

$s = 1$: very strong, maximal violation

$s = 0$: very mild, minimal violation

A strength-index $\boldsymbol{s}$ for CC violations

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$s = 1$: very strong, maximal violation

$s = 0$: very mild, minimal violation

Forming **naked singularities**

with $s > 0$

could violate **entropy bounds**

$s = 0$ is harmless / useless

(black string, critical collapse)

Cosmic Censorship violations

with $s > 0$

could be forbidden by **Thermodynamics**

There seems to be little chance of reaching observable quantum gravity within classical timescales $t_M^{(cl)} \sim M$

Fuzzballs may form in $t_M^{(sc)} \sim M \log \frac{M}{M_{Pl}}$

But fuzzballs don’t seem to reveal much quantum gravity

Cosmic censorship of quantum gravity

A perfect conspiracy?