ANEC and String Theory

Sunny Itzhaki

Based on 1808.02259

and work in progress

ANEC and String Theory

Outline:

- Why we like the Averaged Null Energy Condition (ANEC) so much.

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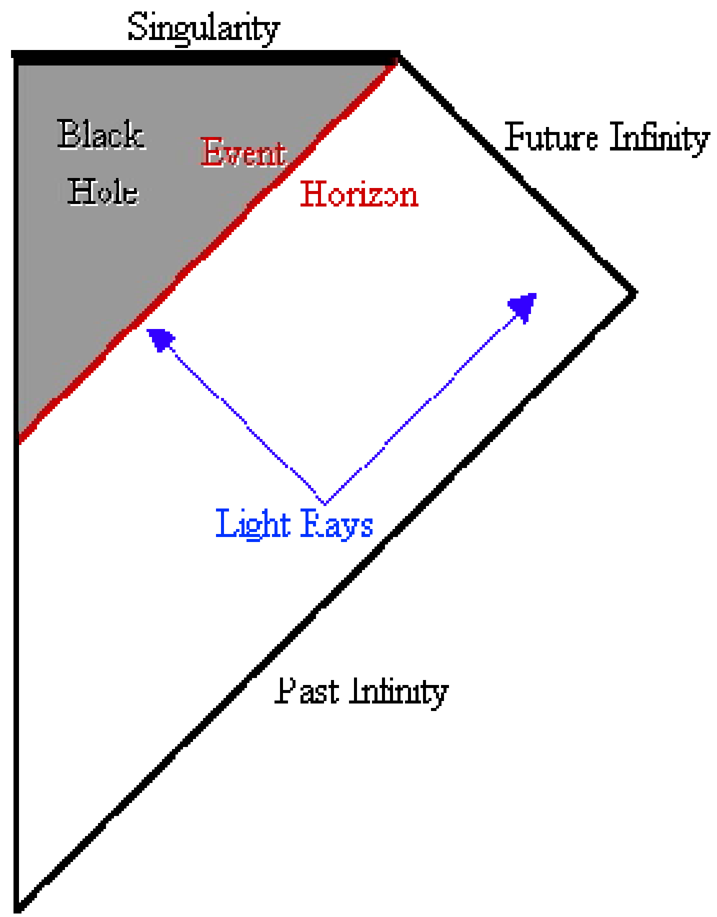
- Why we are certain it is correct.
- What string theory has to say about that.

In GR the BH horizon is smooth



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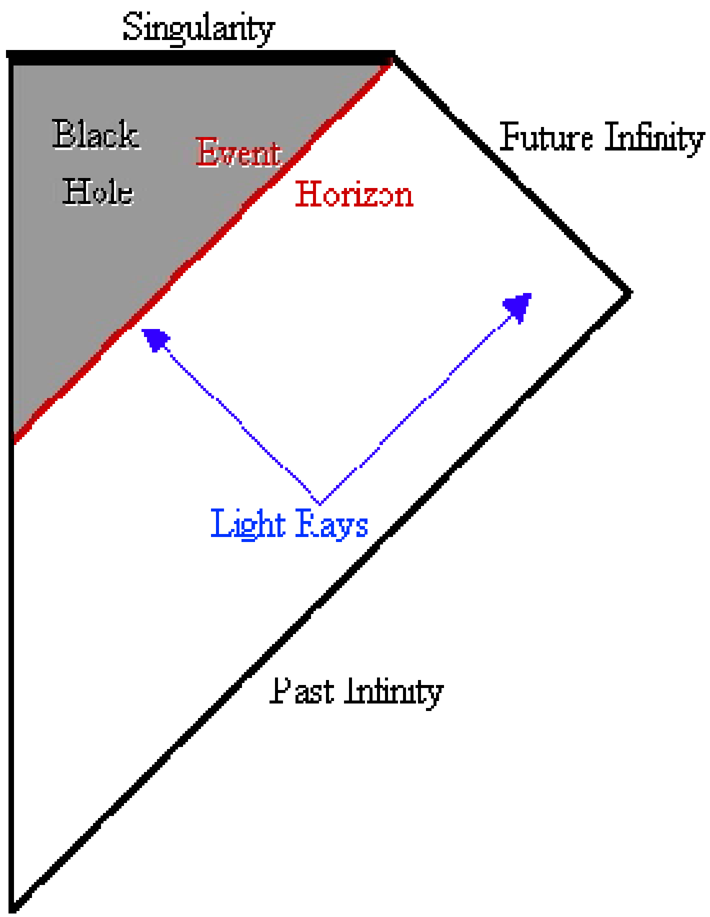

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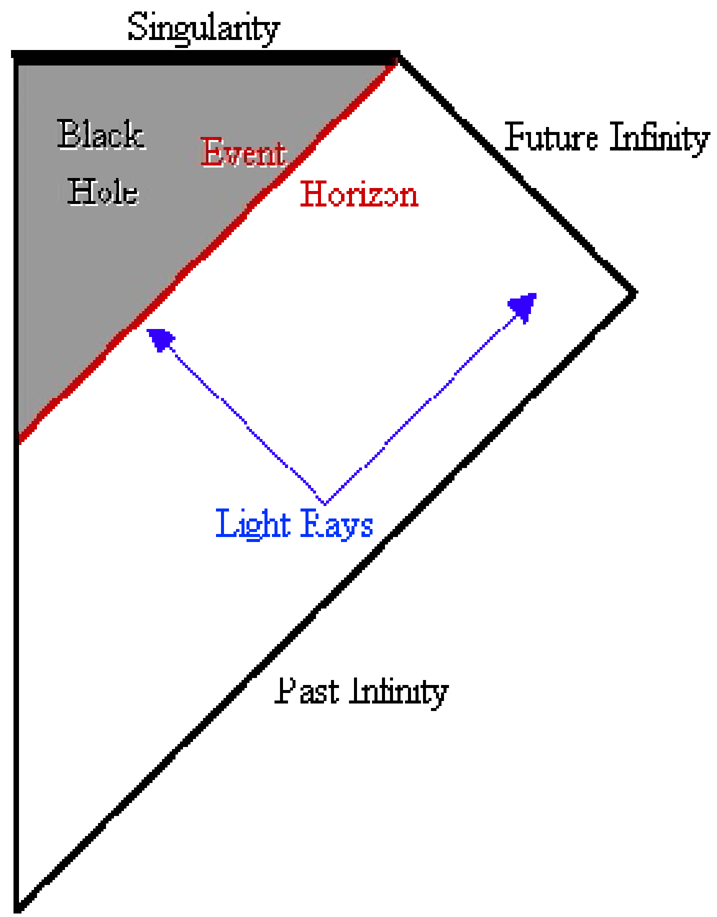

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Energy conditions:

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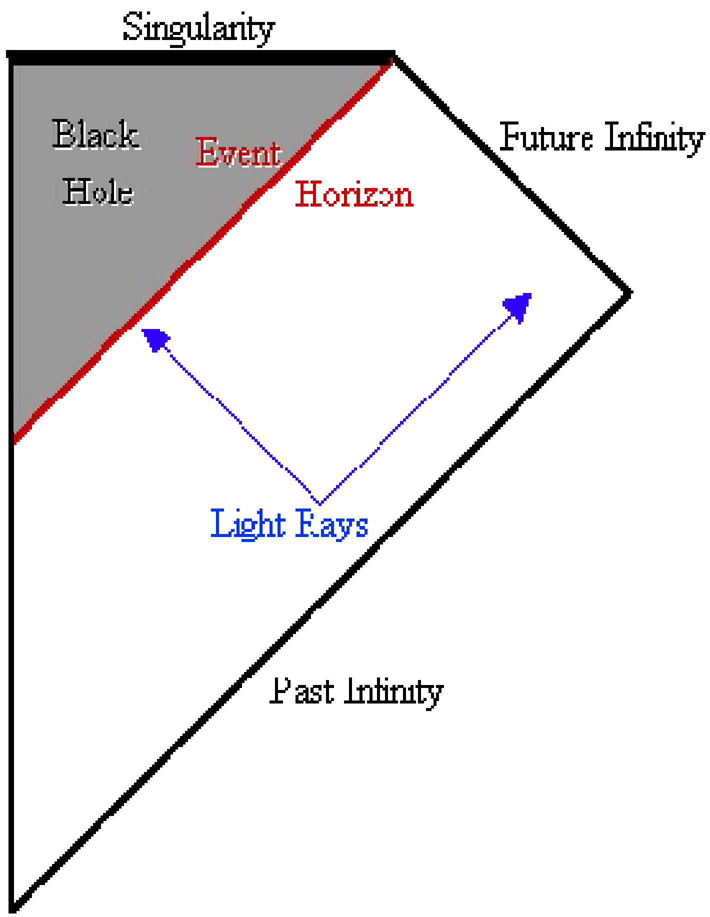

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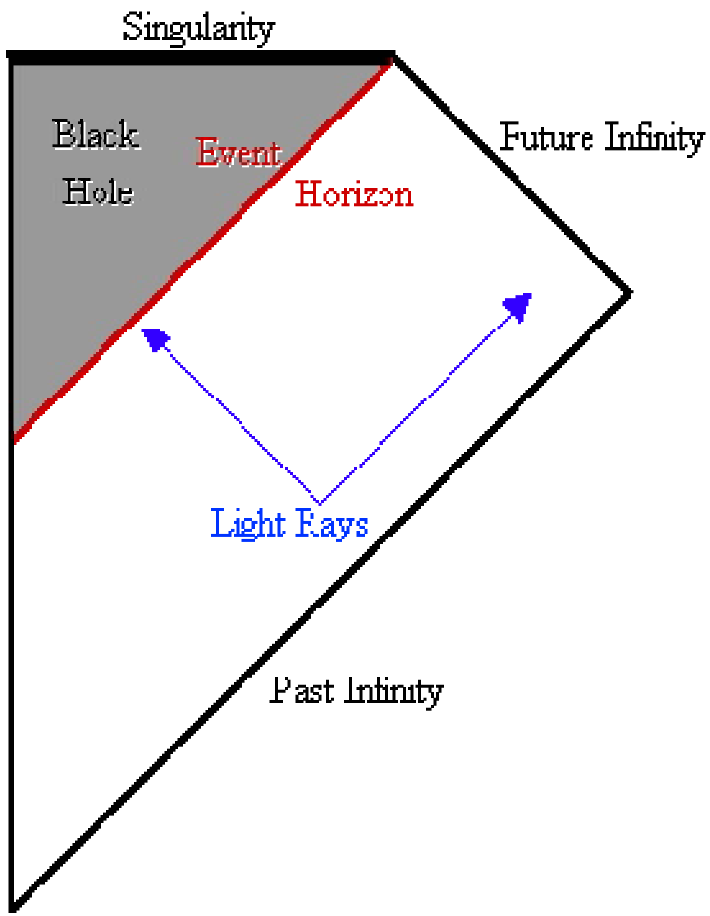
2- Null



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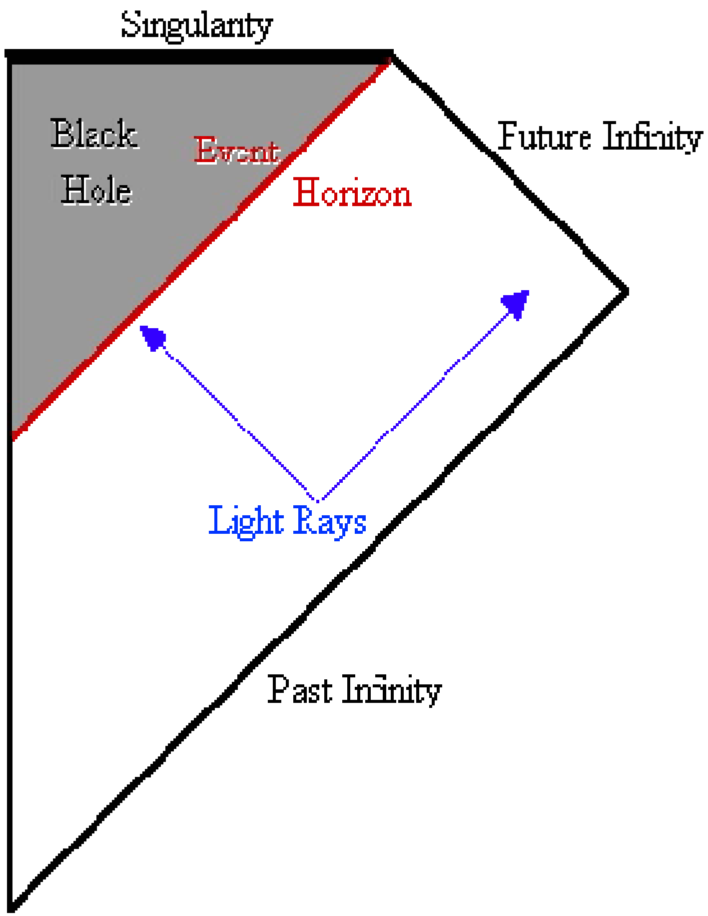
Energy conditions:

1- Weak X

2- Null X (at the quantum level)

3- ANEC (Averaged null energy condition)



A bit on ANEC

1. Once it was found that in QFT it is easy to violate

   the null energy condition: $\langle \Psi | T_{uu} | \Psi \rangle < 0$

   It was quickly realized that in fact the ANEC is sufficient for most of the GR needs [Borde, 87].

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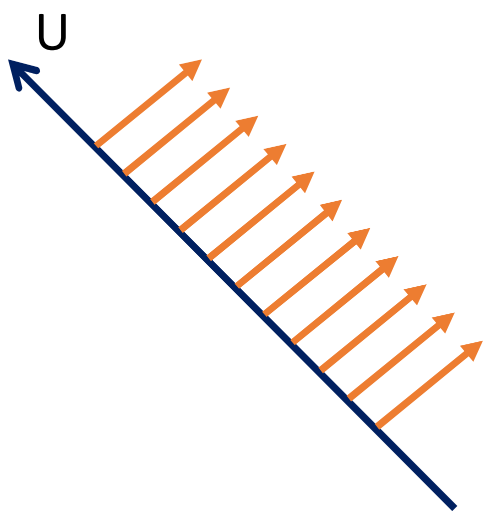
2. Definition: $$\int_\gamma du T_{uu} \geq 0$$



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3. Classical examples (that we'll not discuss too much):

Focusing theorems, no traversable wormhole, topo. censorship etc.

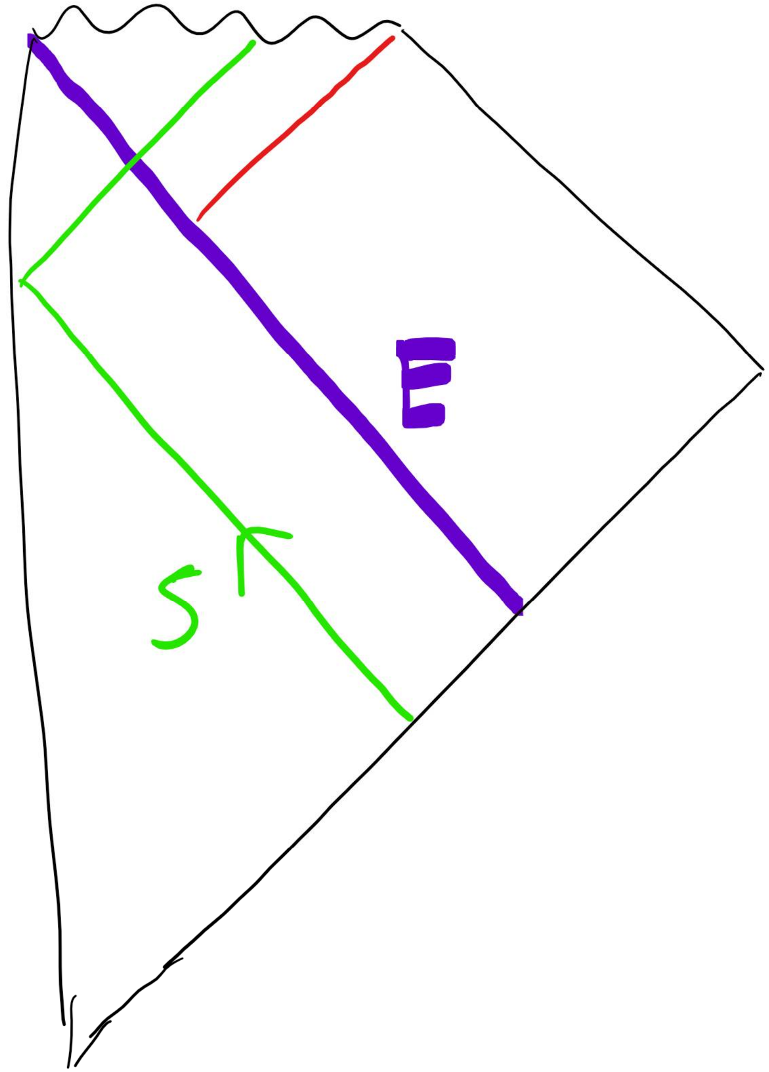
<u>A bit on ANEC</u>

3. An example:

Firewall is not enough

A firewall (red line) cannot prevent

from all the info. to reach the singularity.



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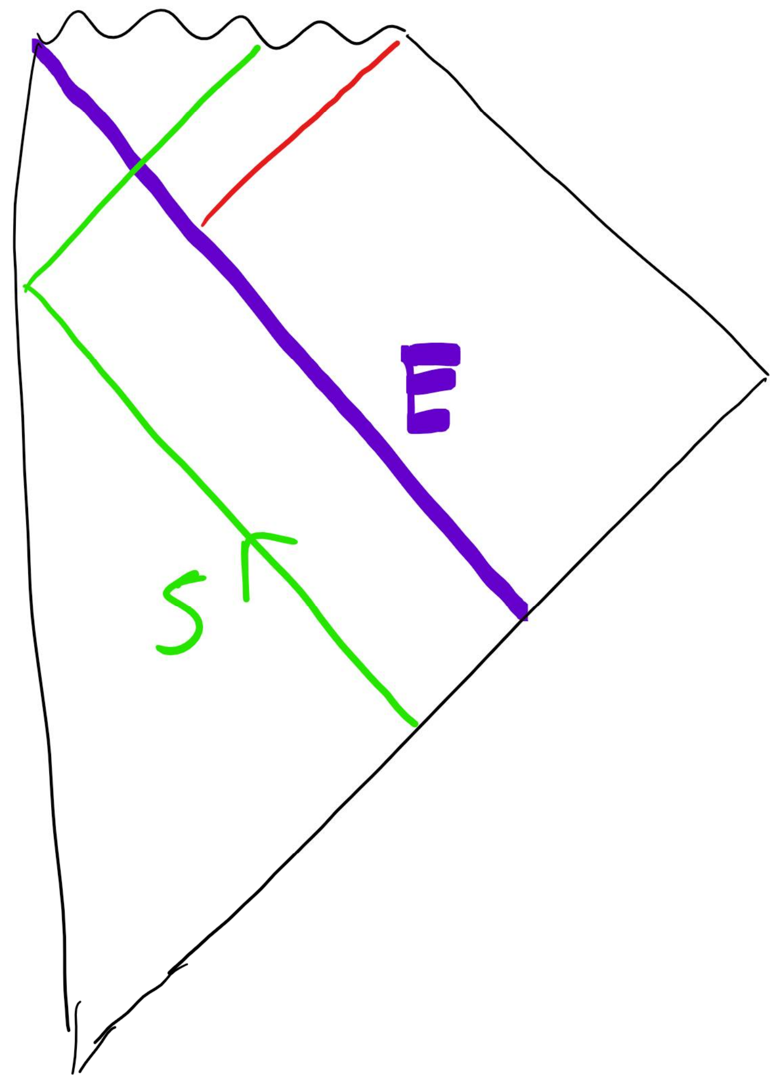

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4. In QFT ANEC was proved in various methods:

- Quantum Information Theory [Faulkner, Leigh, Parrikar and Wang, 1605.08072]

- Causality [Hartman, Kundu, and Tajdini, 1610.05308]

- Holography [Kelly, Wall 1408.3566]

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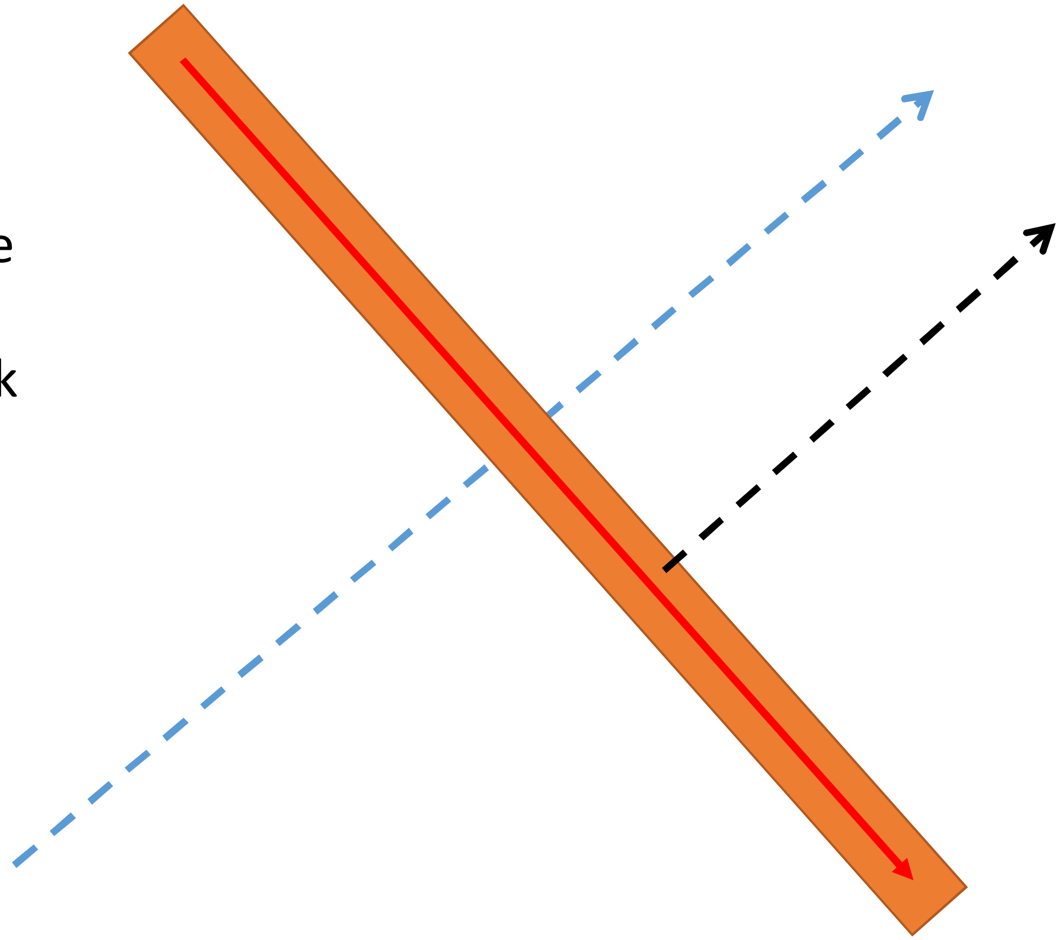
If the flux is negative

then the shift is back

in time.



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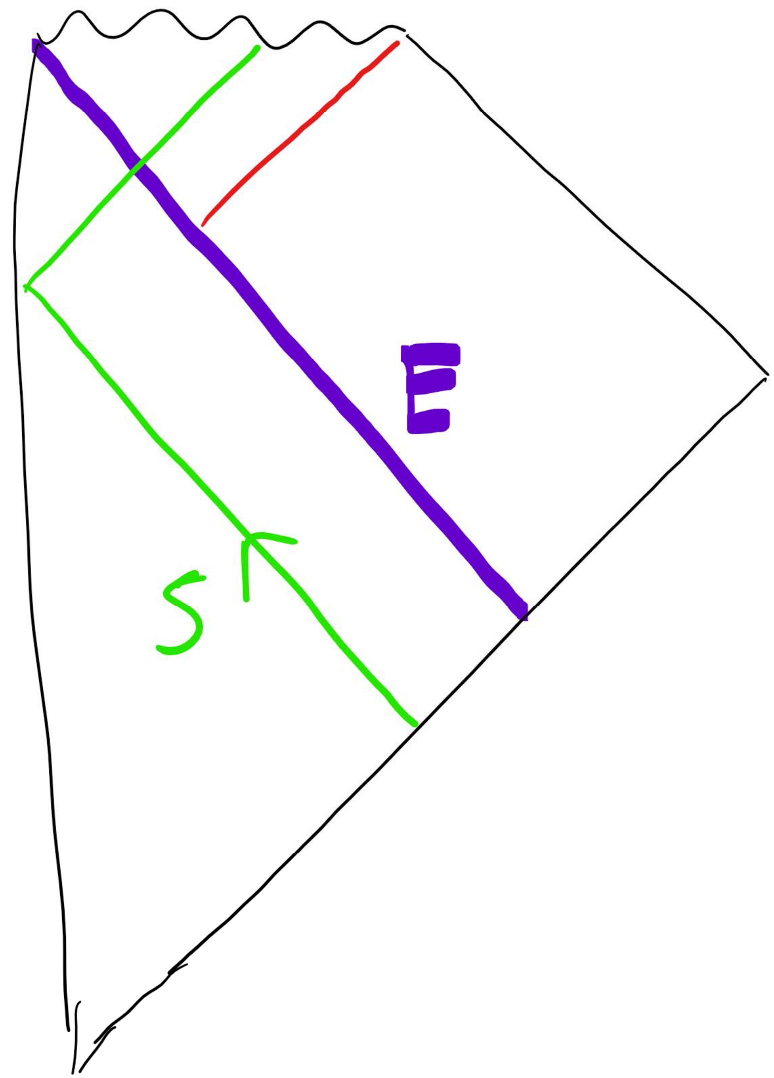

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the larger the region is the easier is to distinguish between two states

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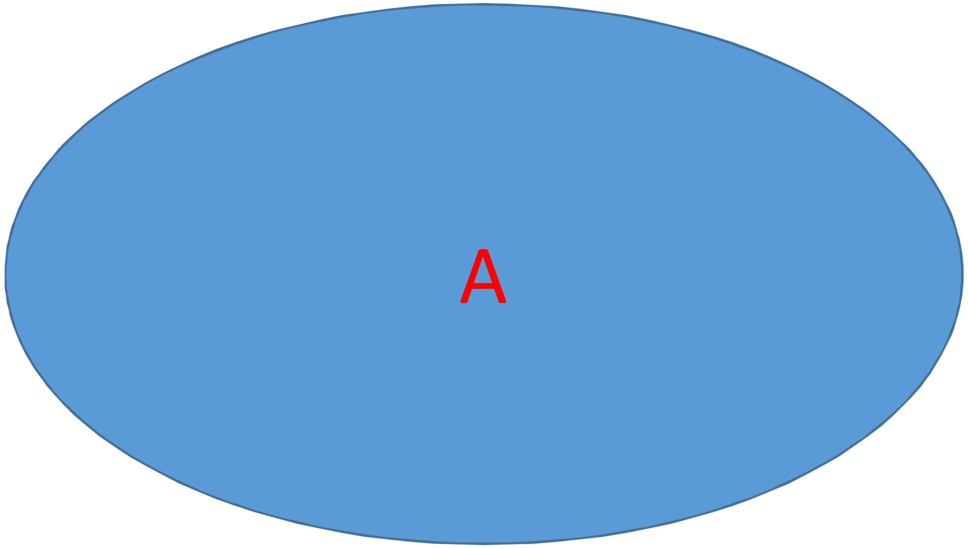

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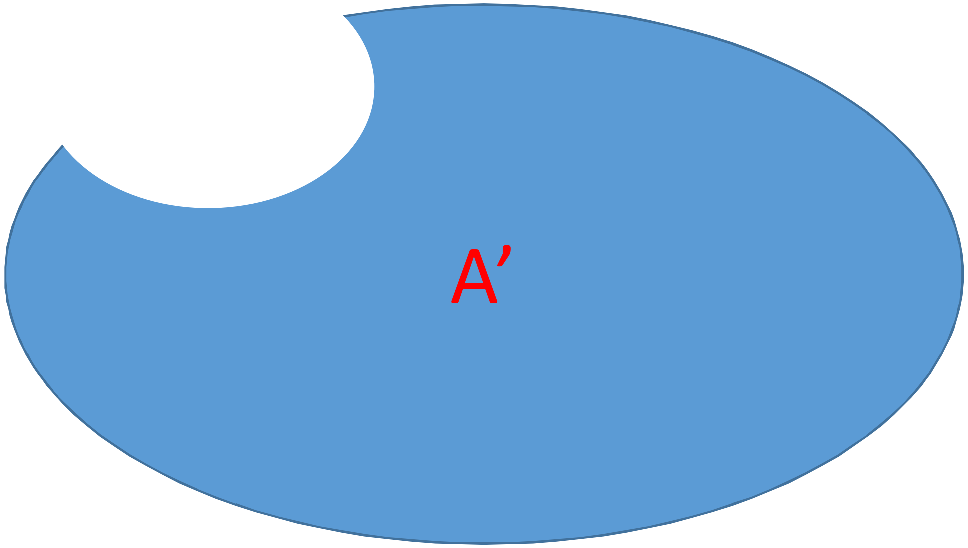

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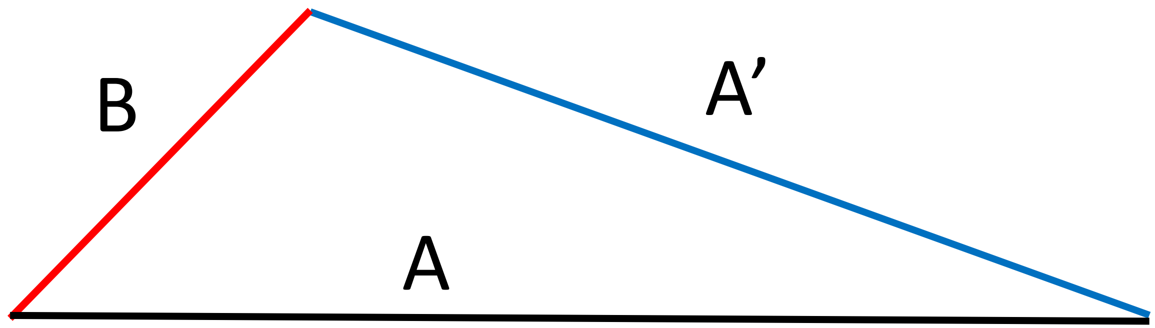

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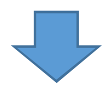

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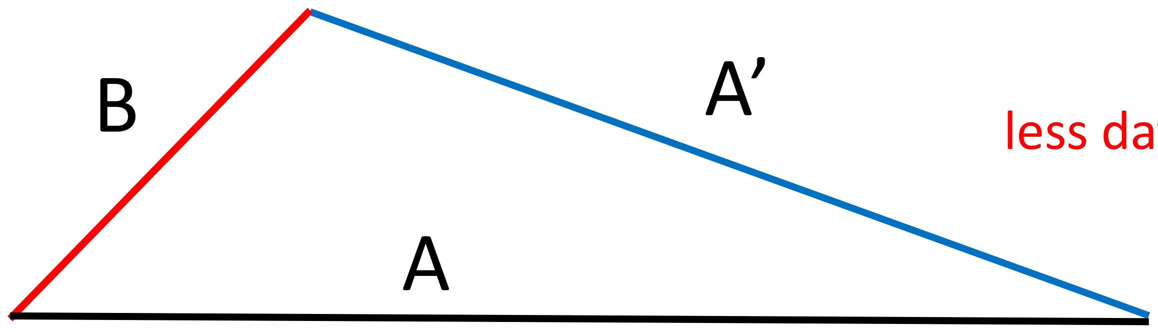

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Tracing B gives the ANEC

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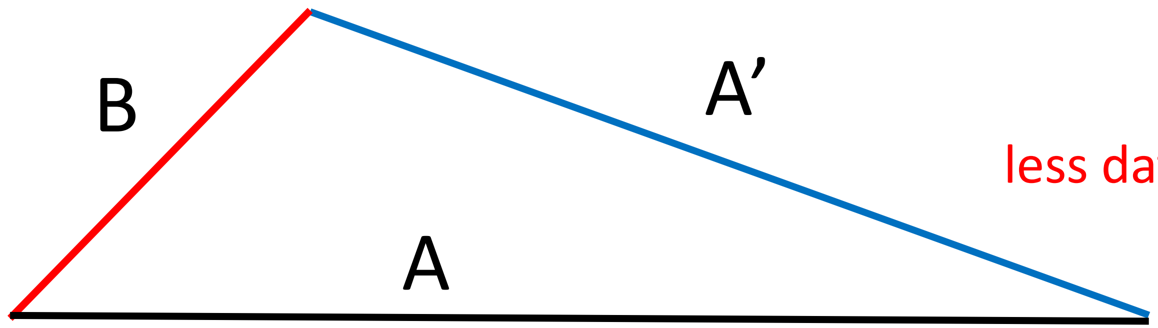

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All assume locality, but string theory is a non local theory.

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- The region behind the horizon of SL(2)/U(1) BH is filled with these objects.

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field $\partial_+\partial_- r = 0$ $\Longrightarrow$ $r = r_+ + r_-$ only with a non standard energy

momentum tensor $T_{++} = -(\partial_+ r)^2 + Q\partial_+^2 r$

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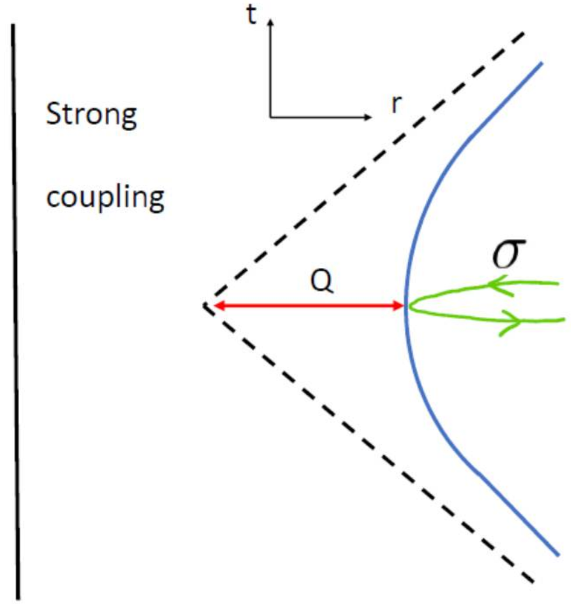

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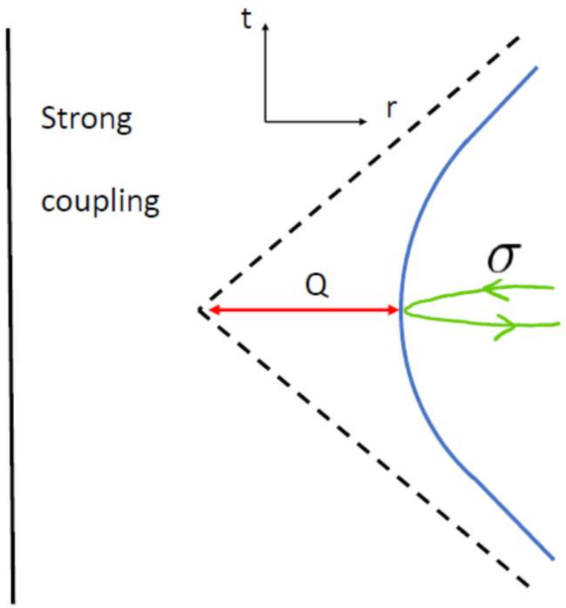

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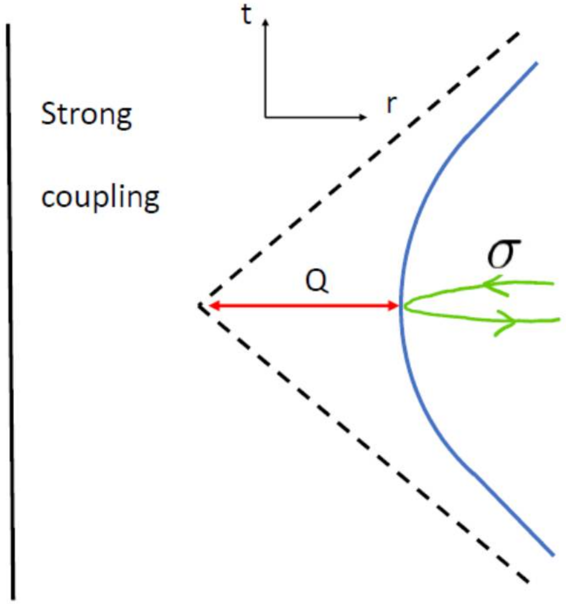

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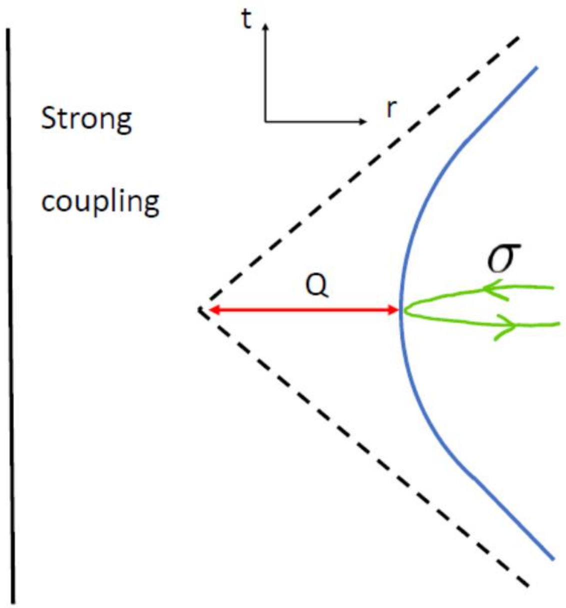

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- The length scale is tiny, of the order of .

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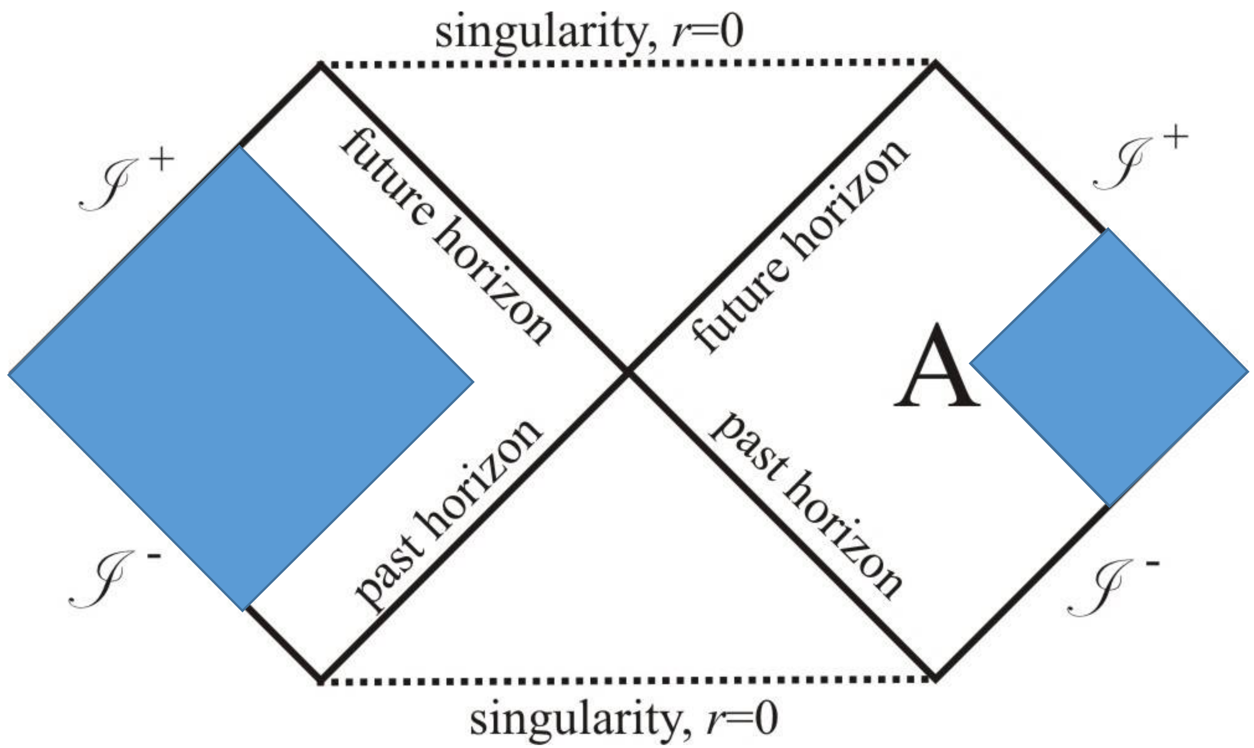

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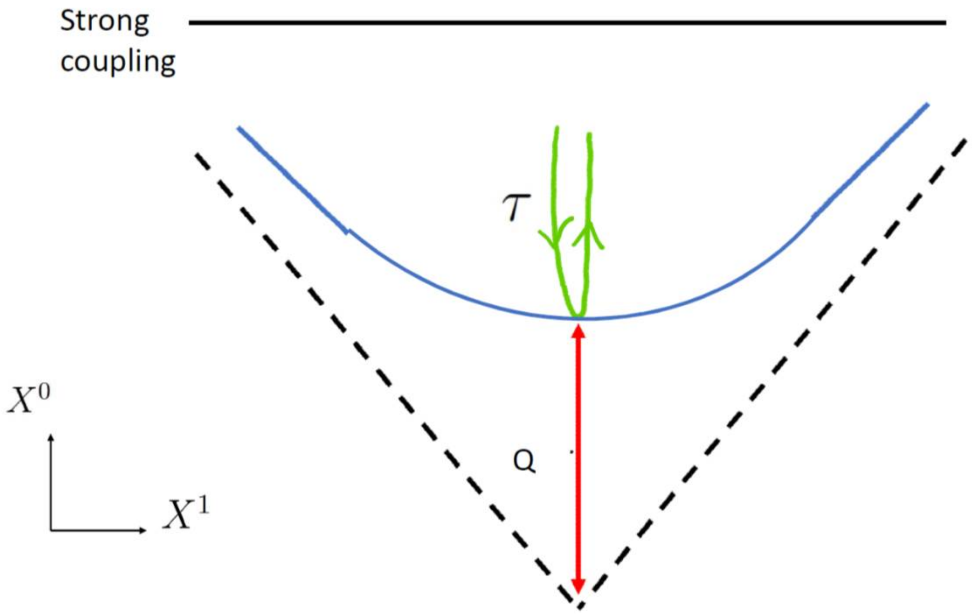
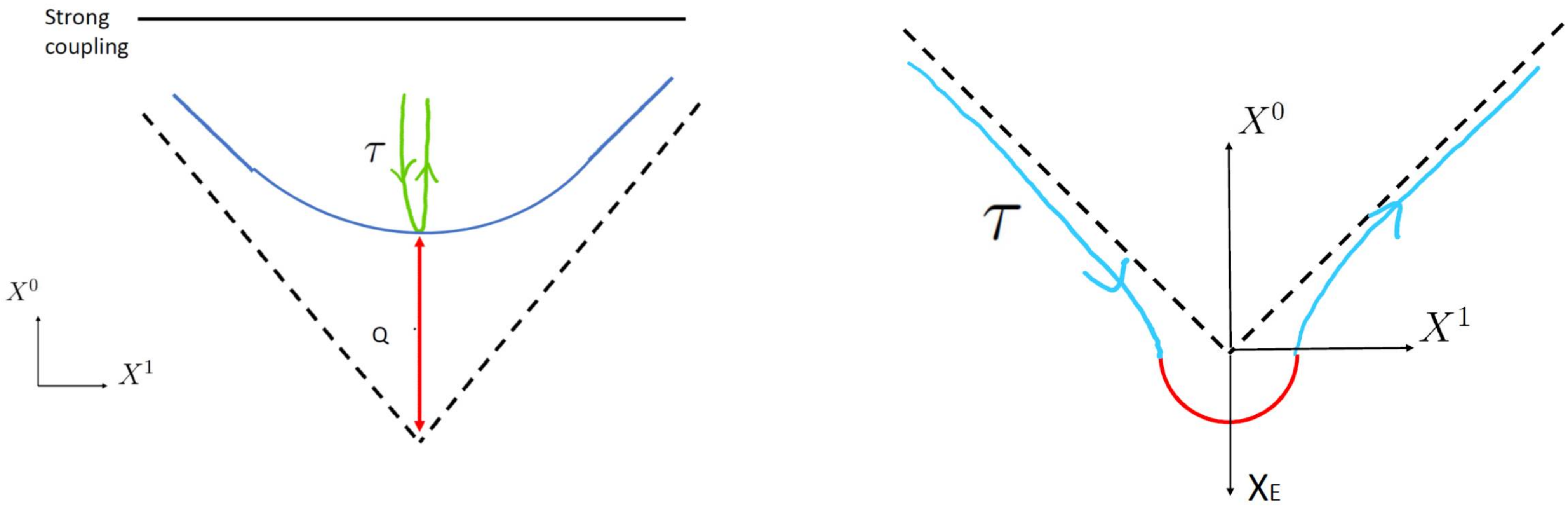


Comparison to the Schwinger mechanism



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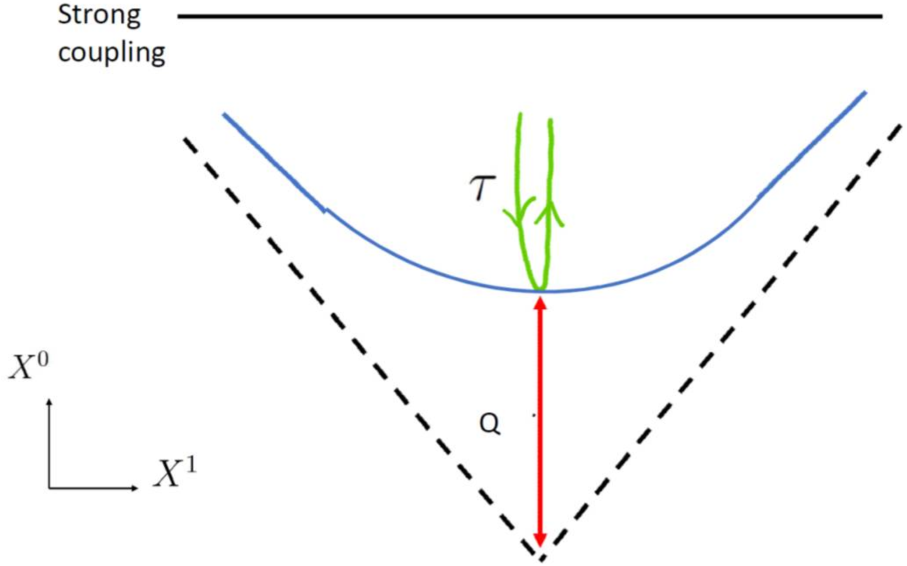

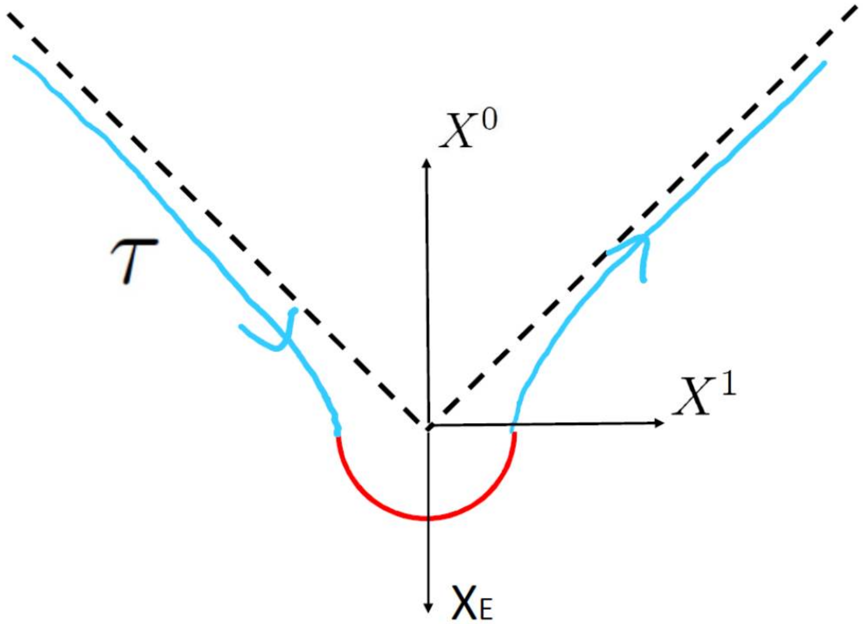

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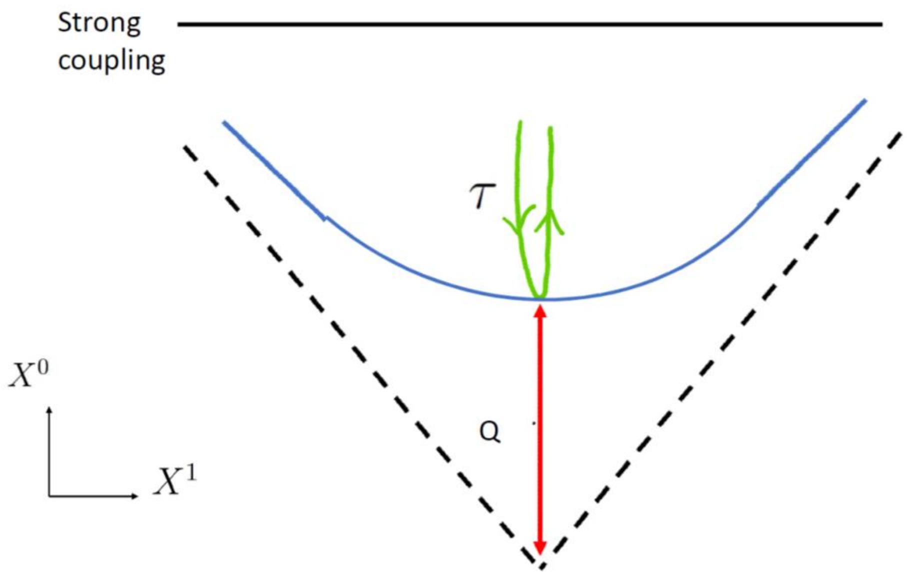

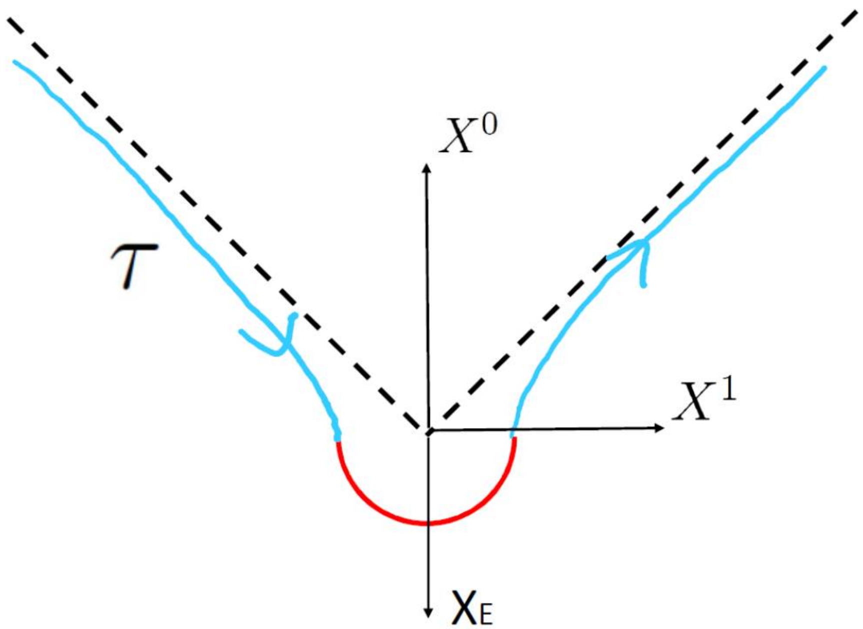

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- Tip is moving faster than light.
- Now we have a tachyon at the tip $m^2 = -Q^2$.

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In details: the string energy momentum tensor is

$$T^{\mu\nu}(x) = \frac{1}{2\pi\alpha'} \int d\sigma\, d\tau \left(\dot{X}^{\mu}\dot{X}^{\nu} - X'^{\mu}X'^{\nu}\right) \delta(x - X(\sigma,\tau))$$

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which in our case gives

$$T^{00} = \frac{1}{2\pi\alpha'} \frac{-4\cosh\left(\frac{x-x_0}{Q}\right) + 4e^{\frac{t-t_0}{Q}}}{\sqrt{-1 + \left(2e^{\frac{t-t_0}{Q}} - \cosh\left(\frac{x-x_0}{Q}\right)\right)^2}} \qquad \ldots$$

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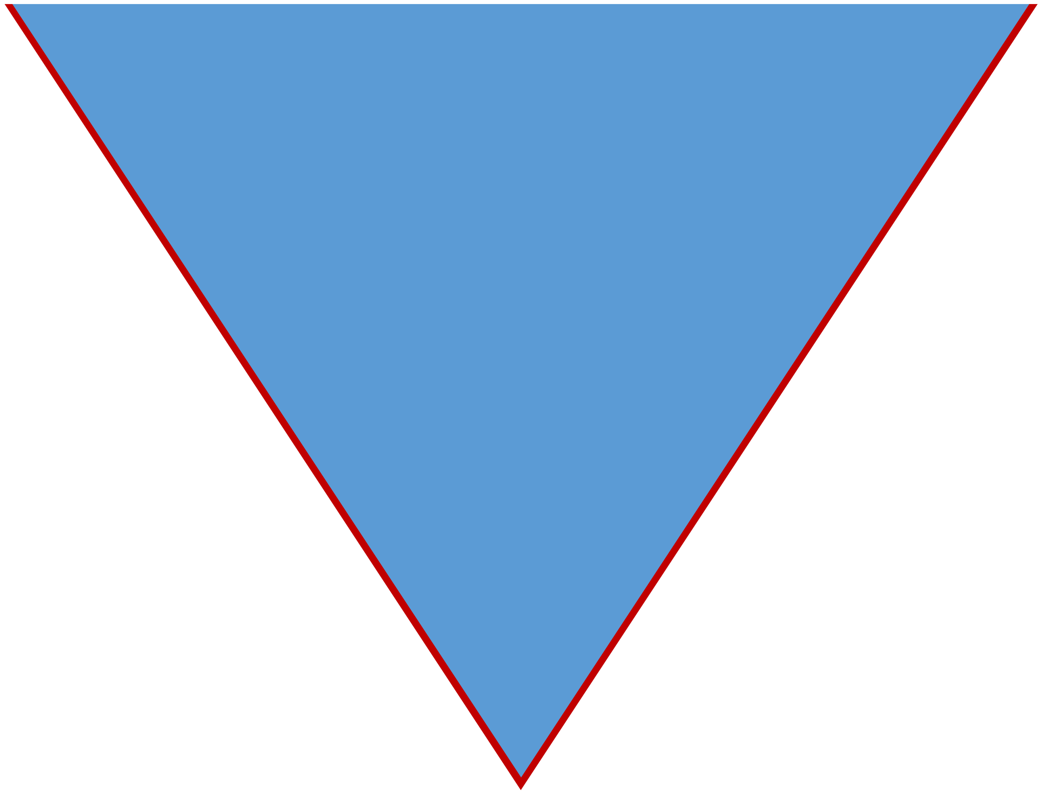

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$$T_{uu} < 0$$

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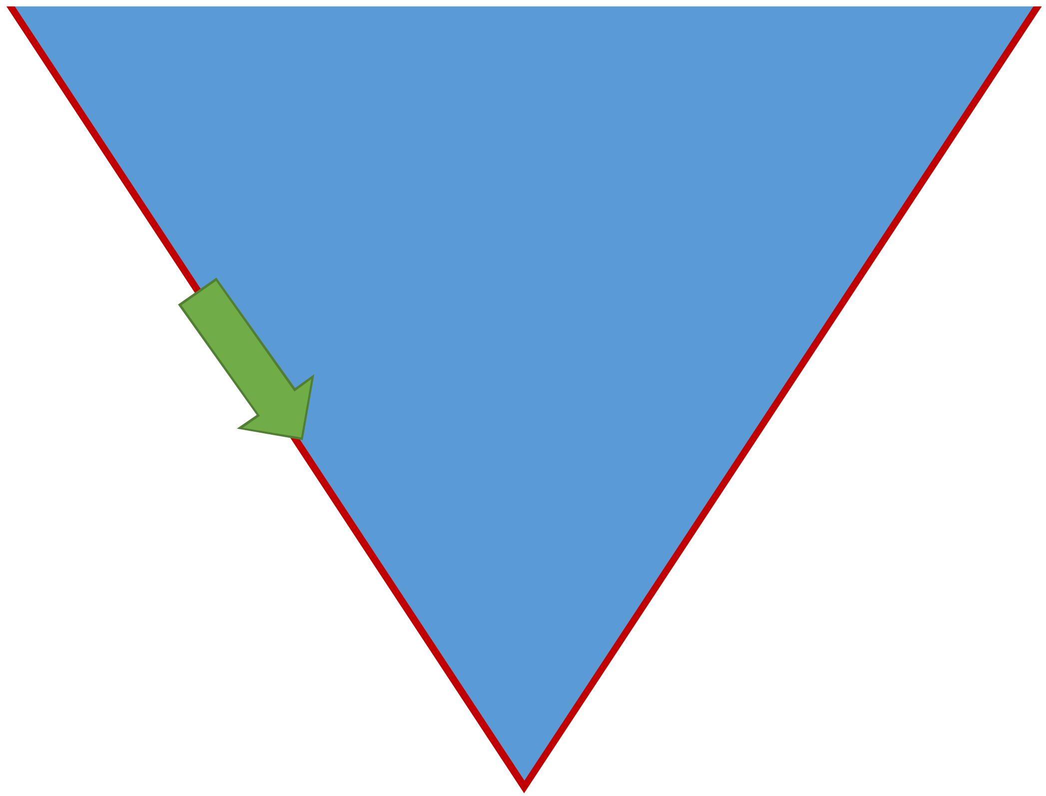
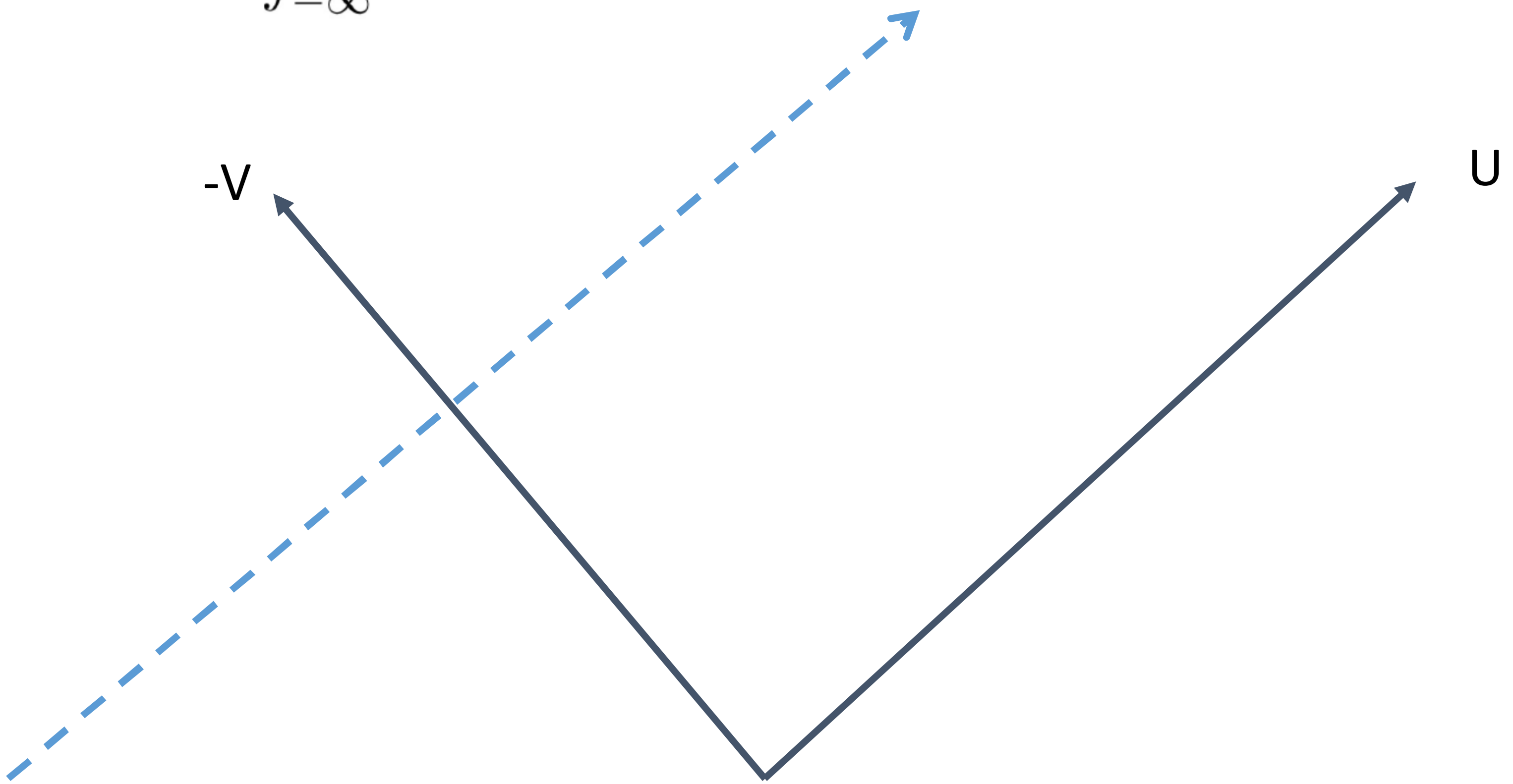


Same with ANEC

$$\int_{-\infty}^{\infty} du\, T_{uu} = (v - Q\log(4)) < 0$$



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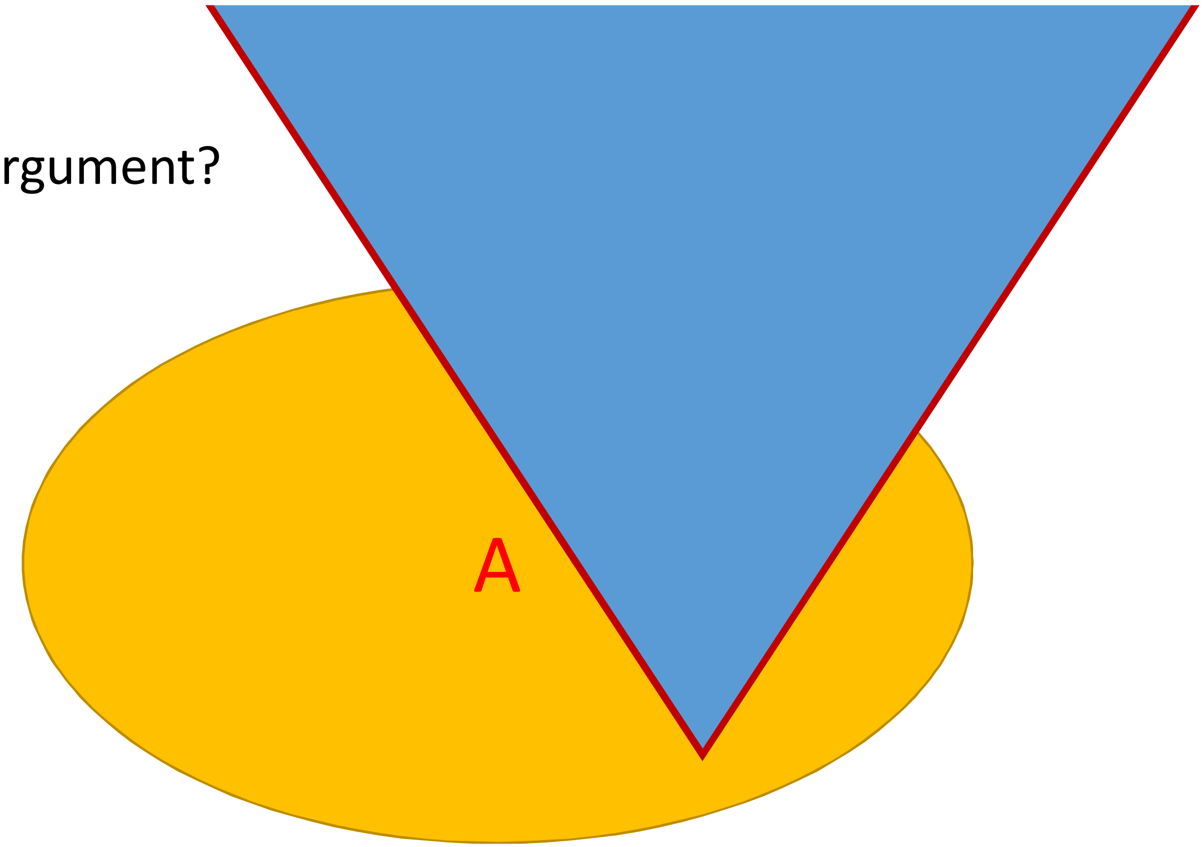

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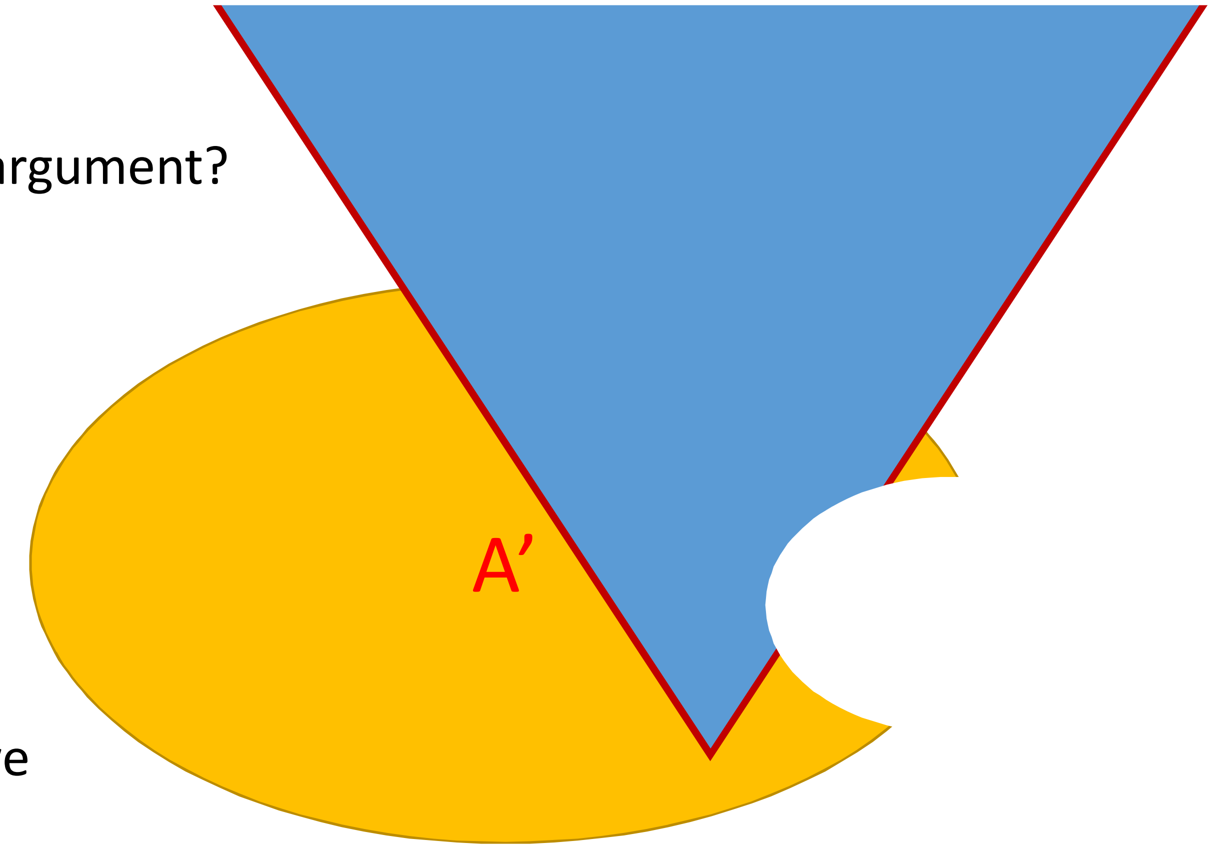

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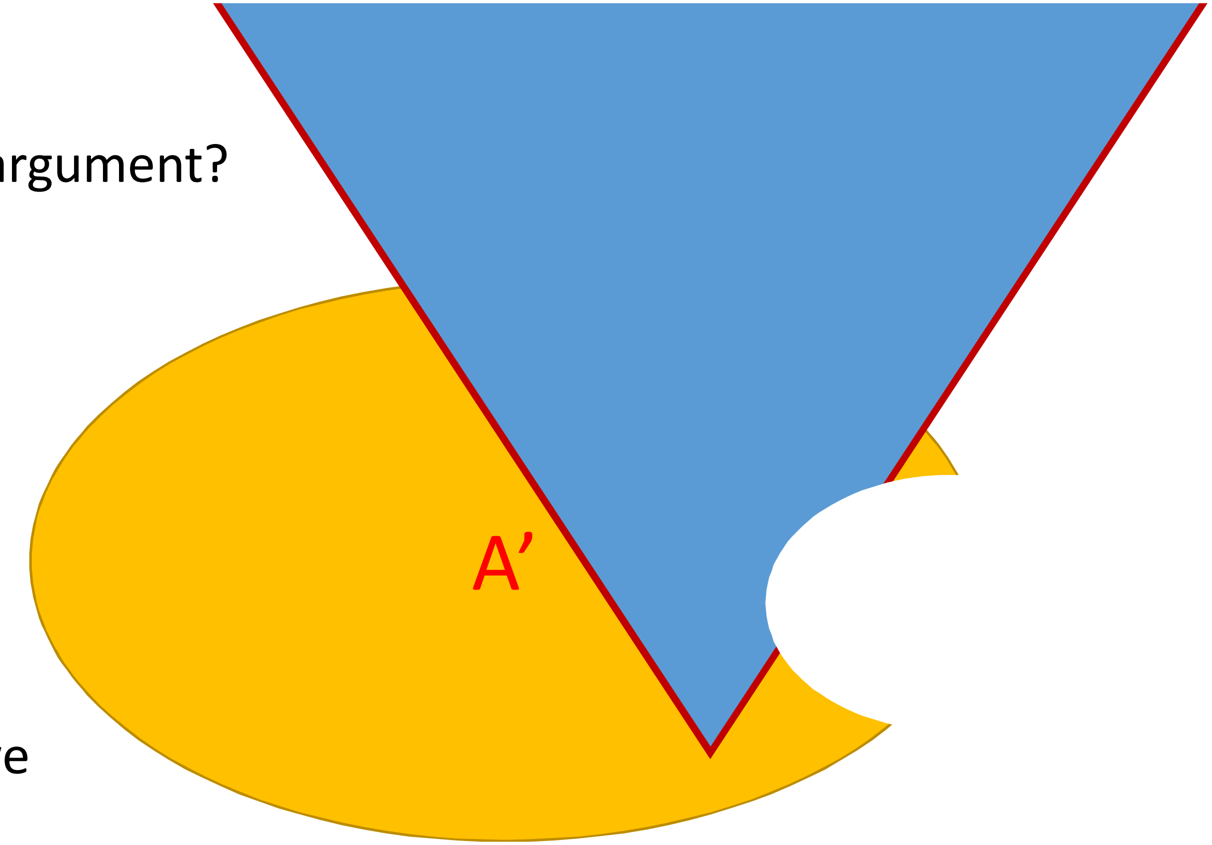

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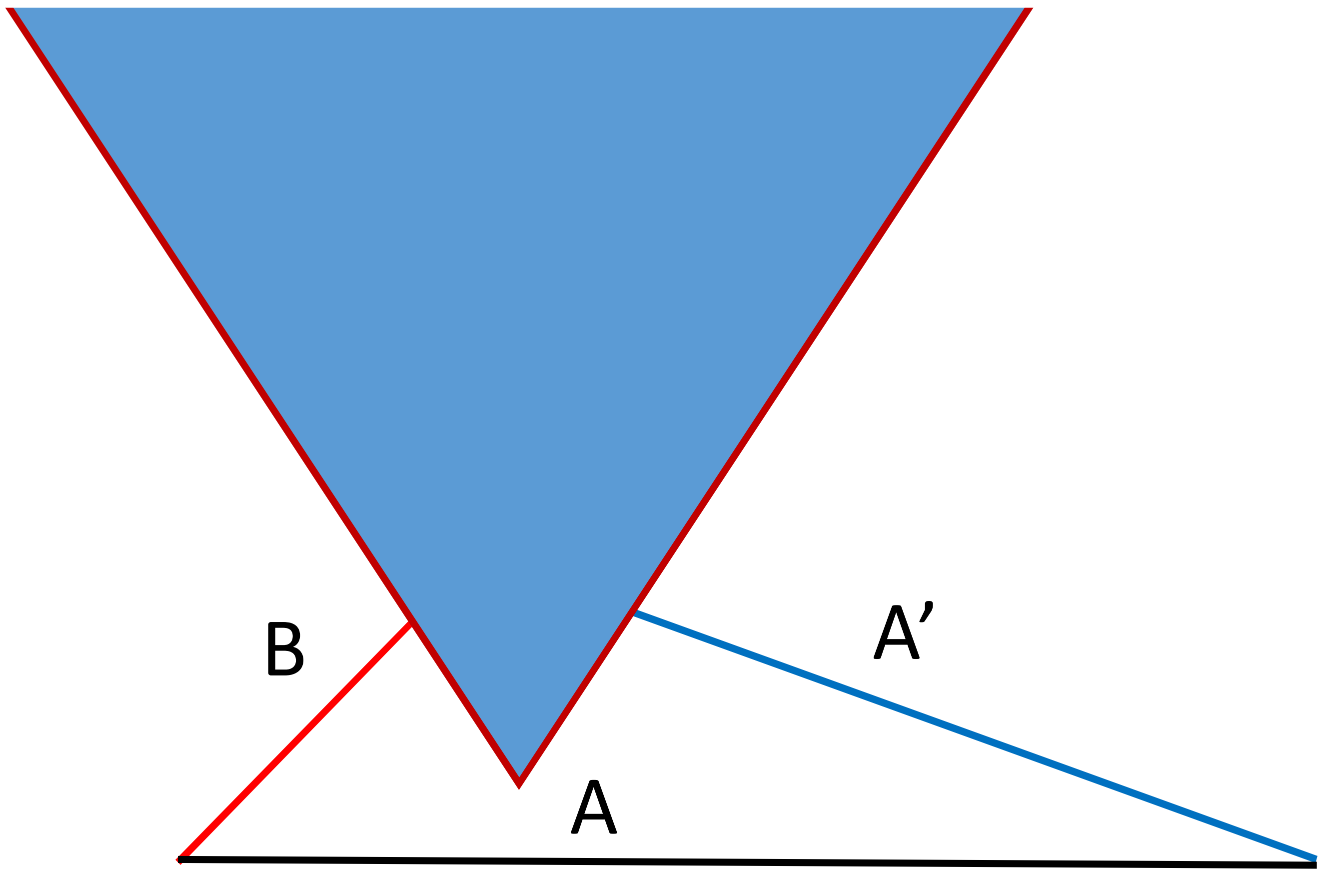
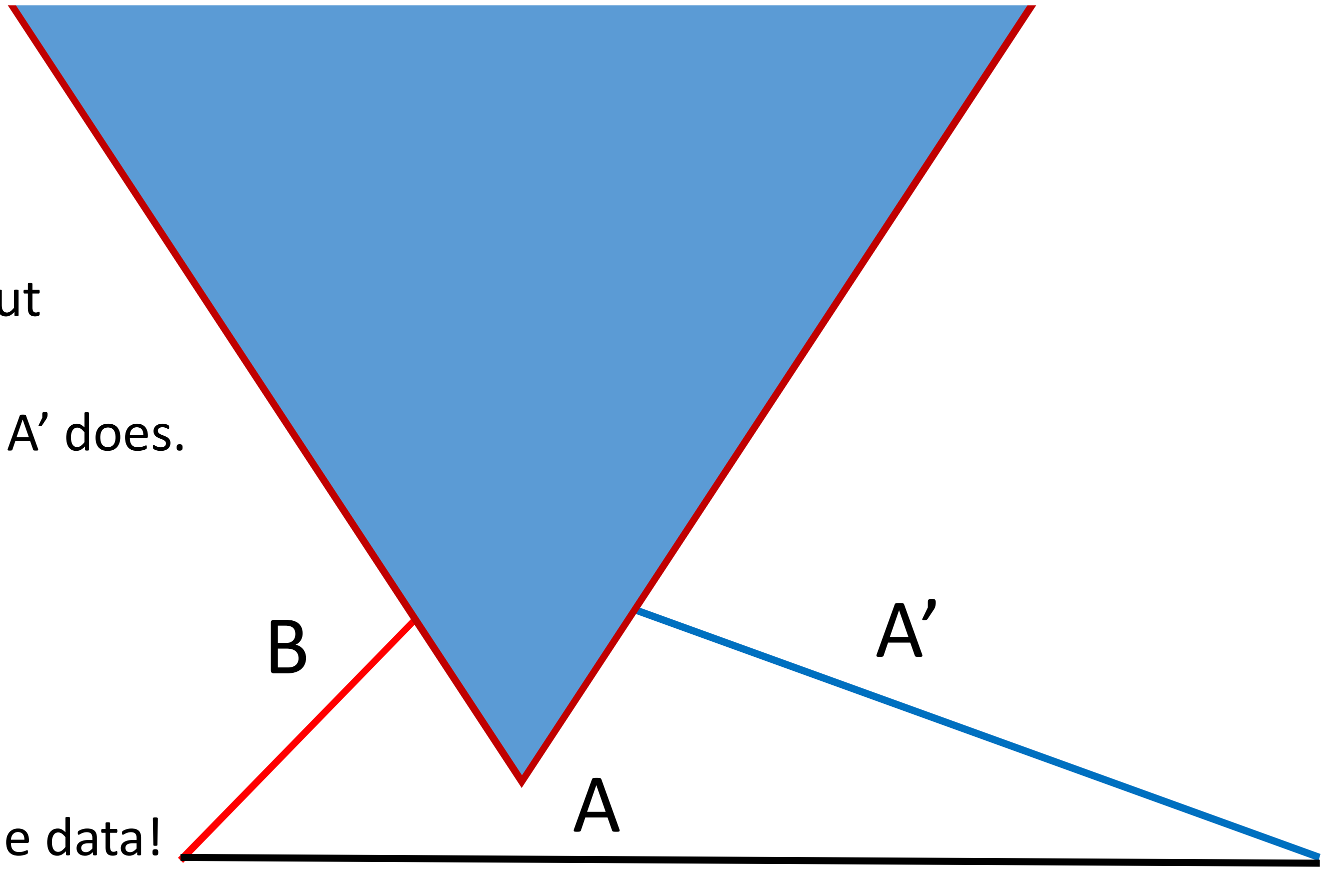
But for the ANEC we needed something a bit different.


B
A'
A

A does not know about

the folded string, but A’ does.

Tracing B increases the data!



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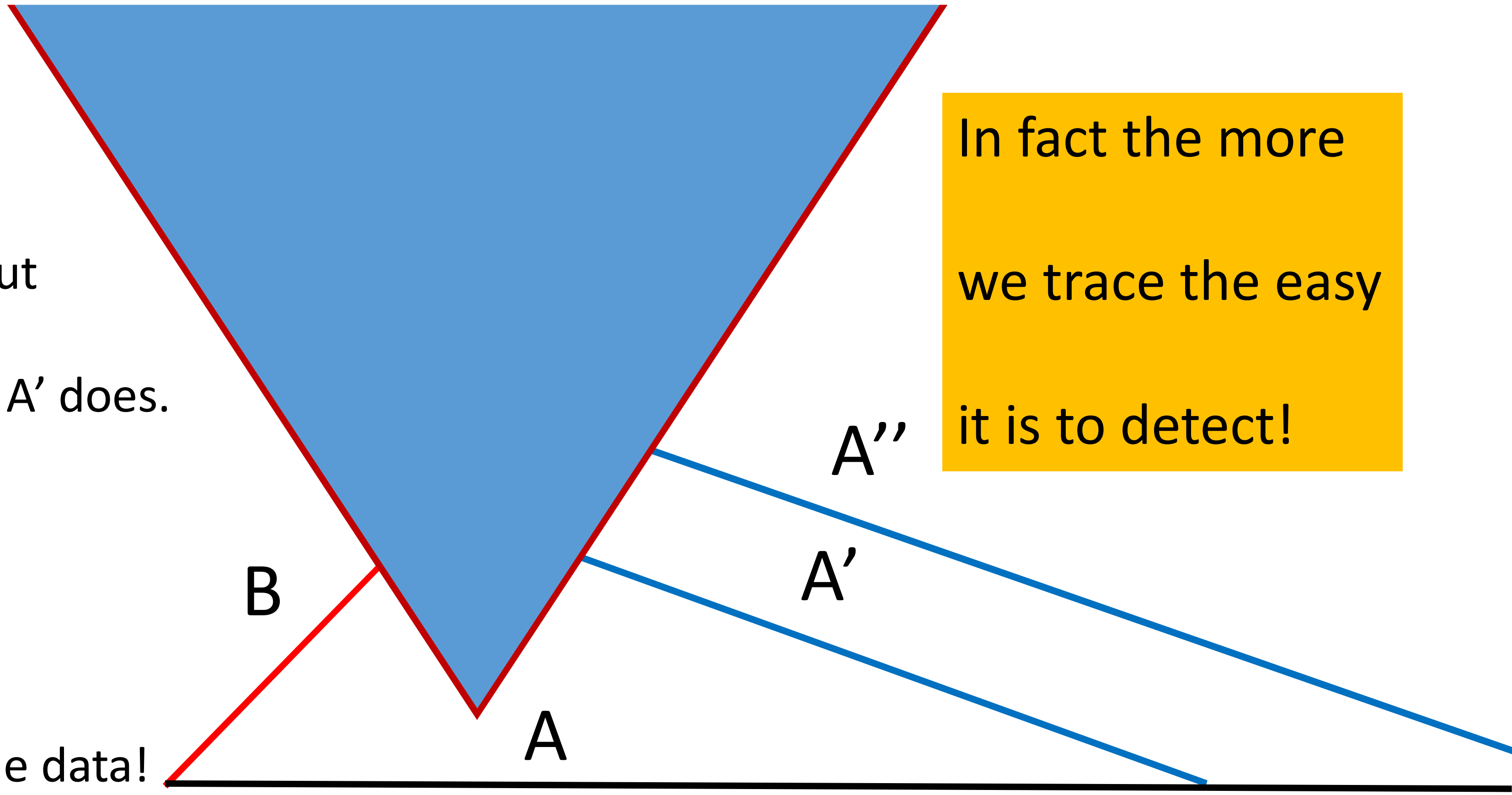

In fact the more

we trace the easy

it is to detect!

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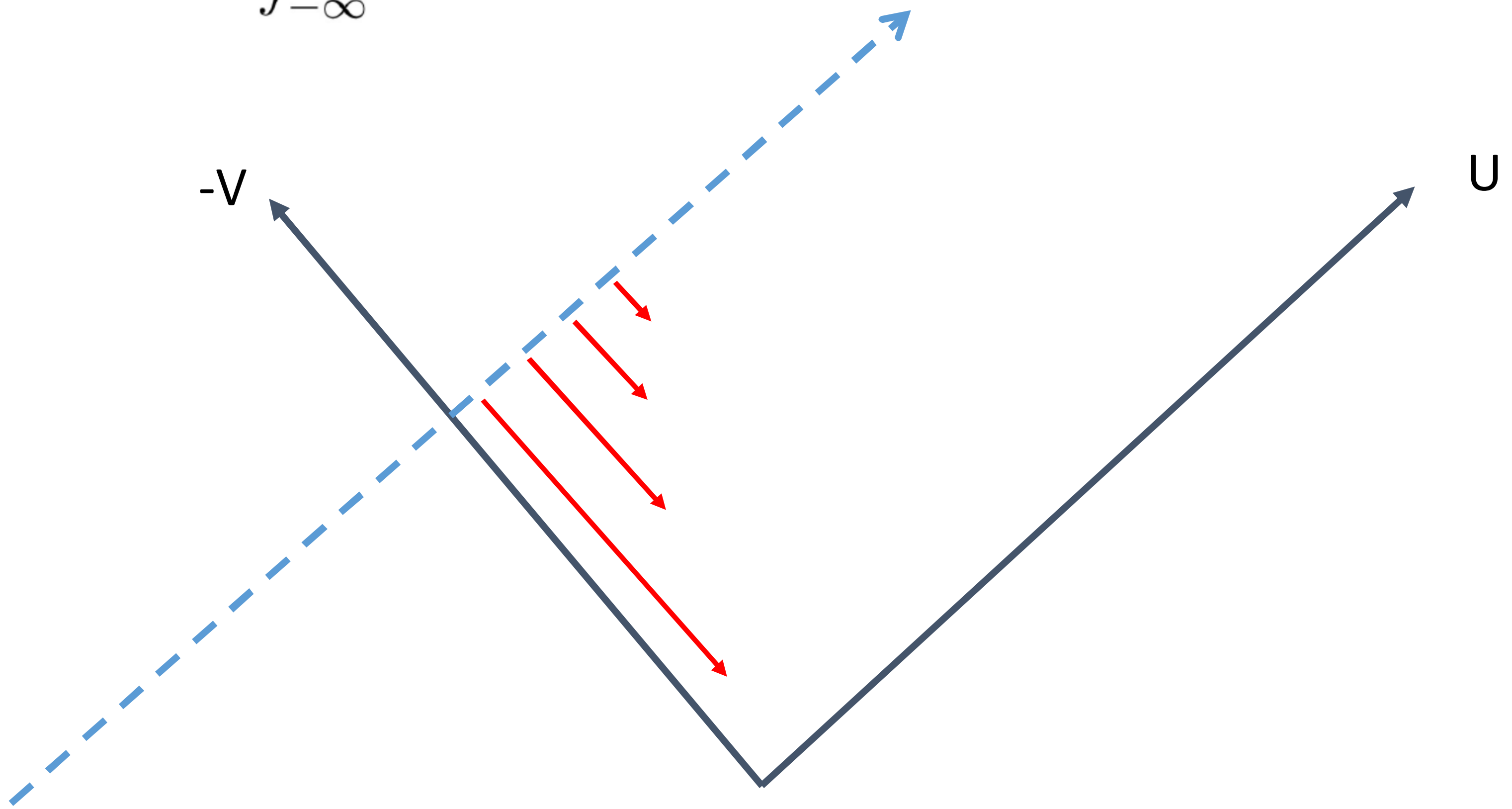

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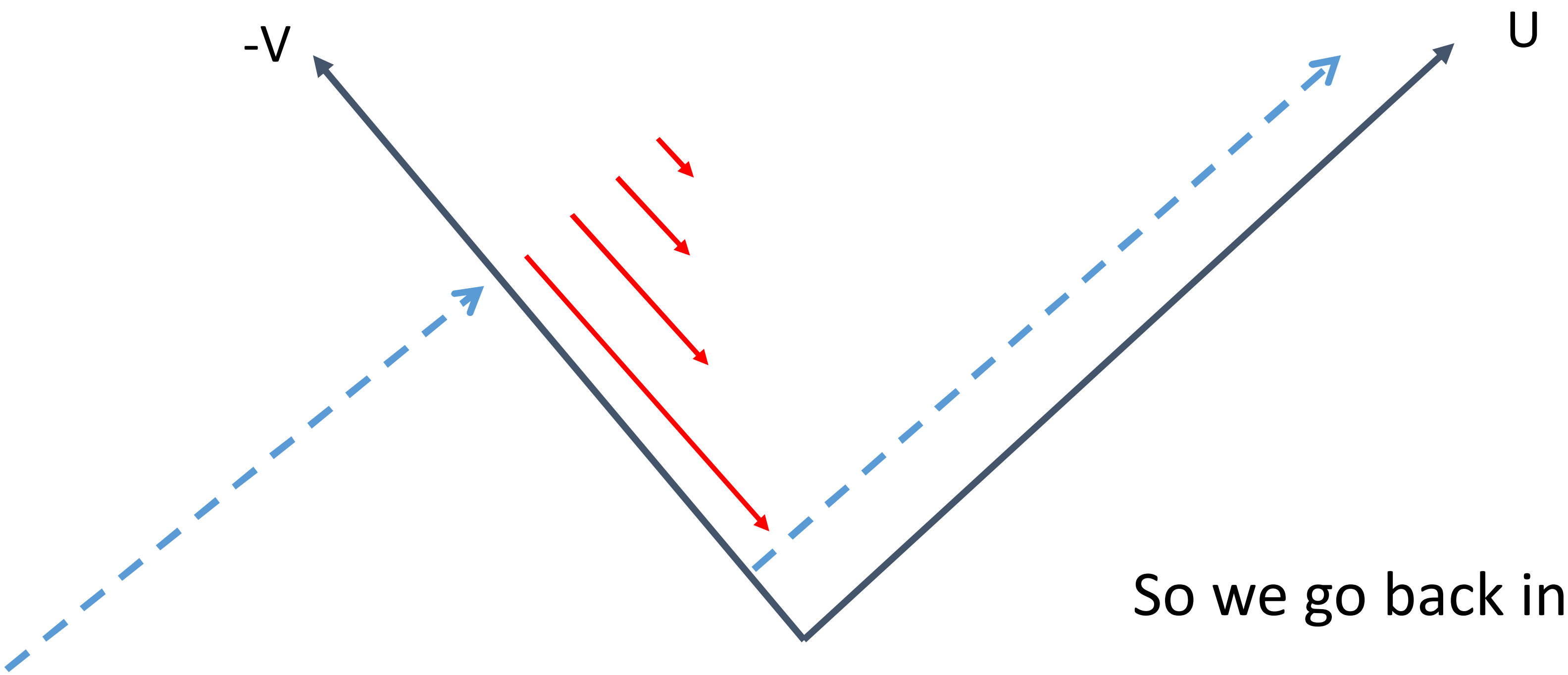

So we go back in time!

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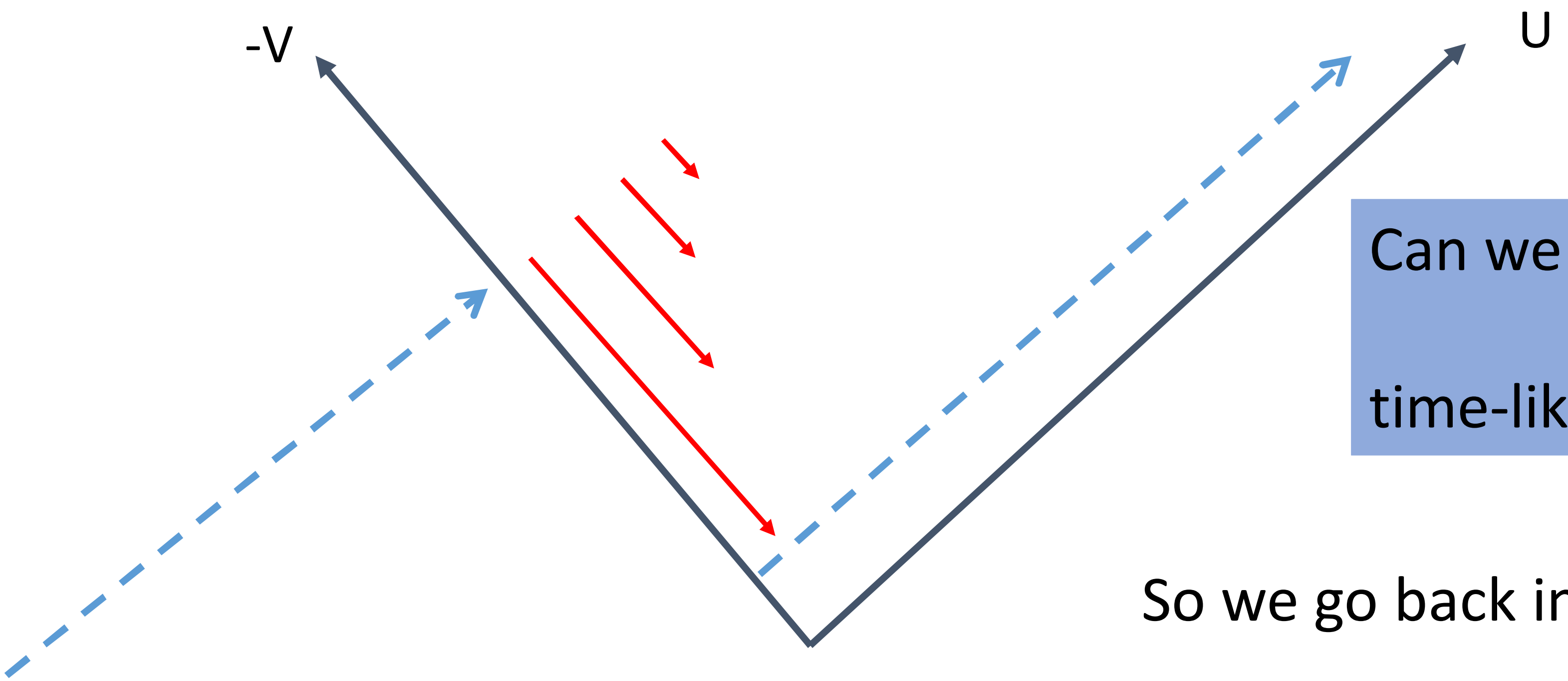


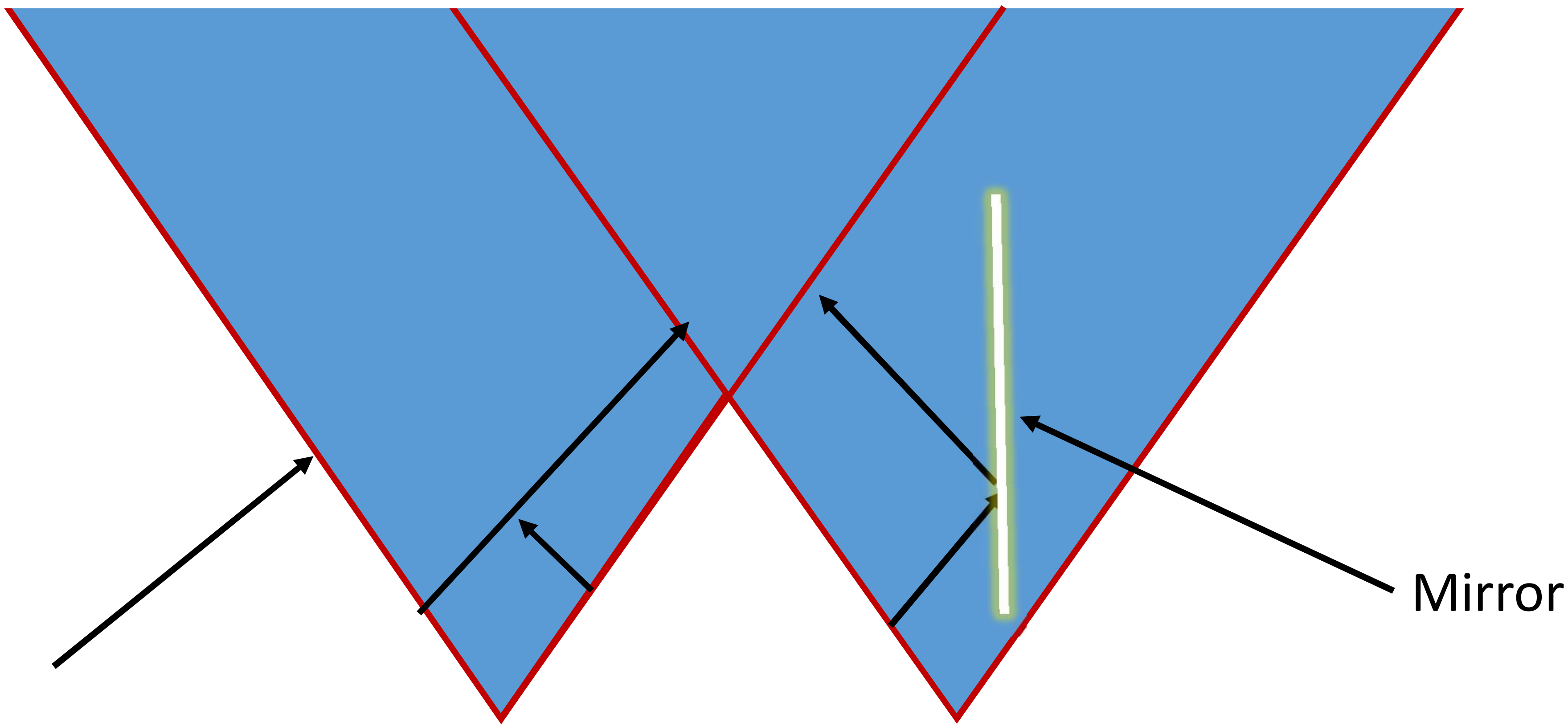
Can we have a closed

time-like curve?

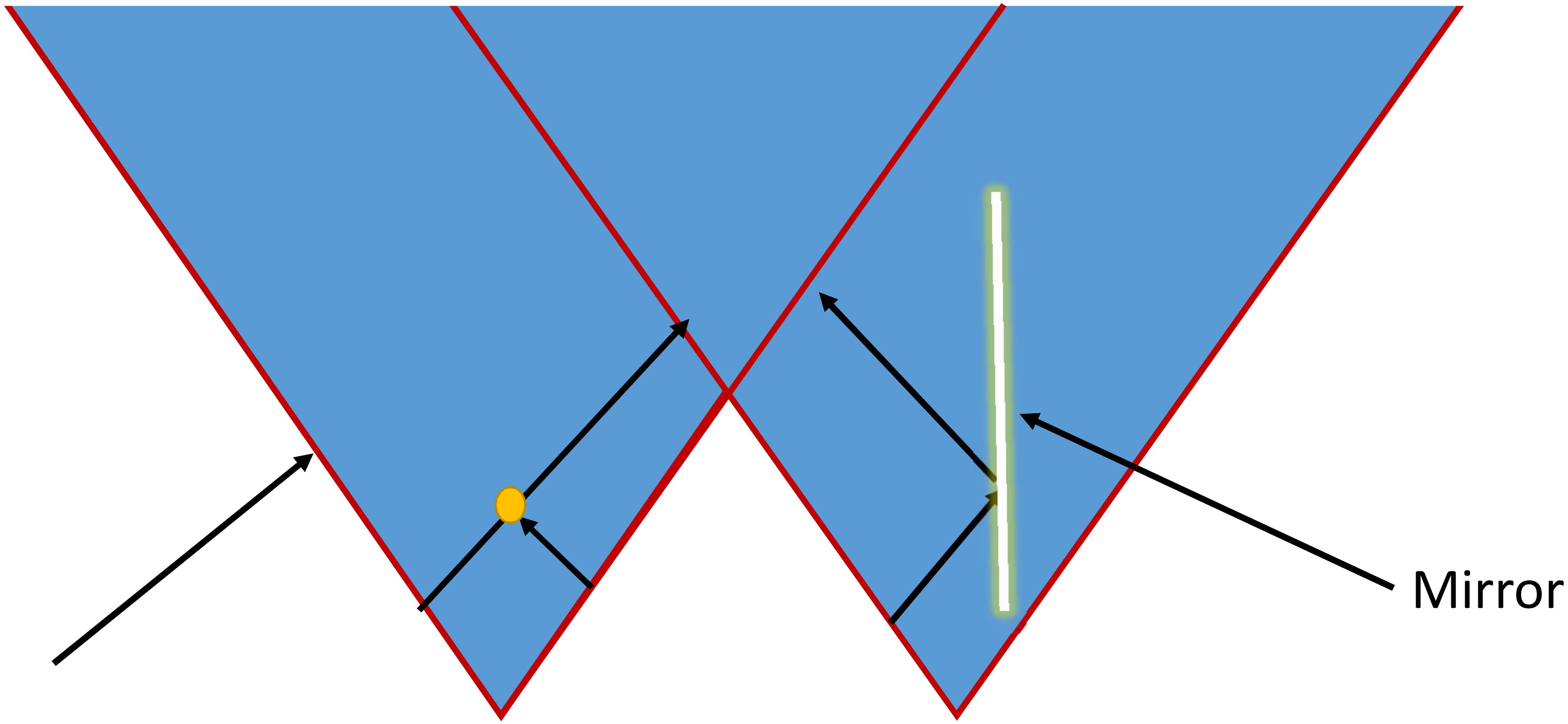
So we go back in time!

Yes we can

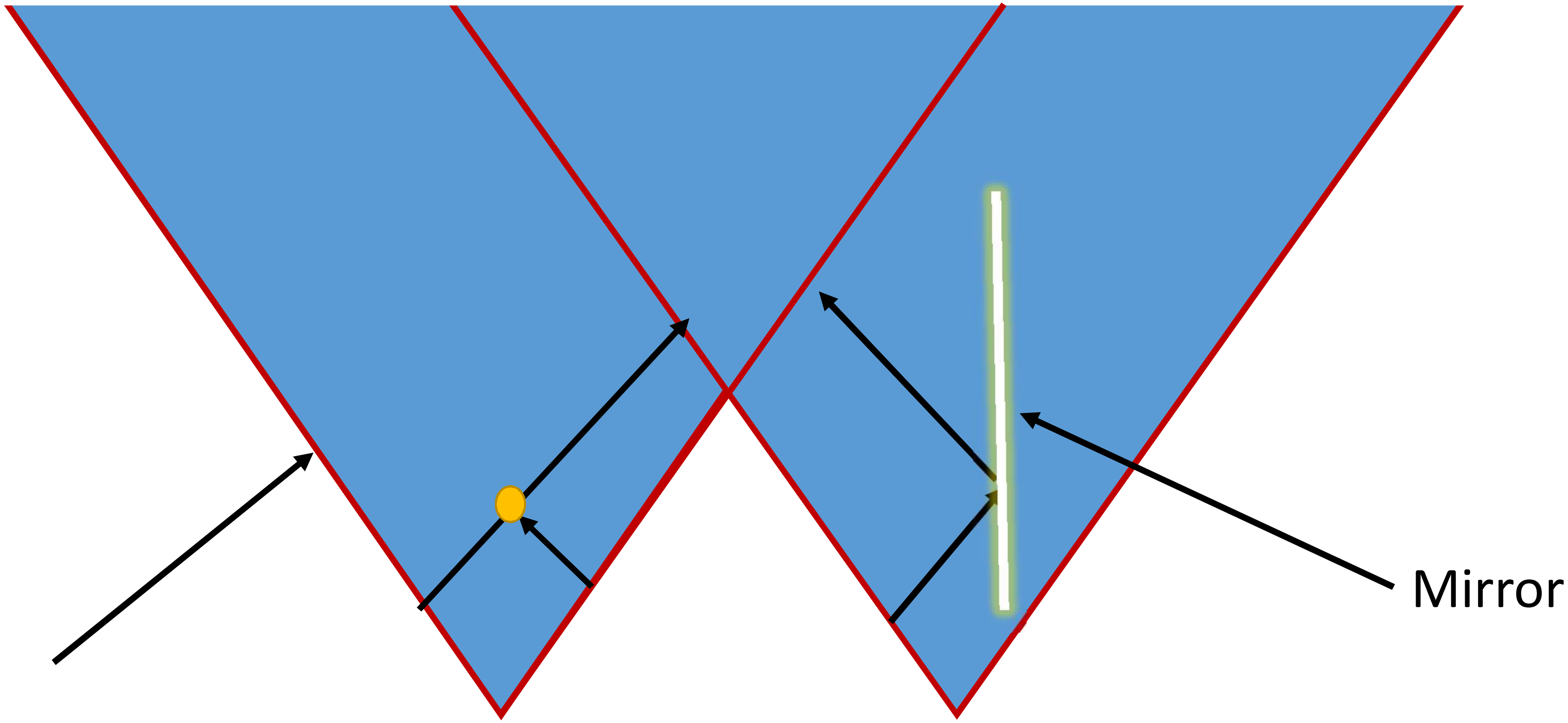
Yes we can



<u>Yes we can</u>



Can we?



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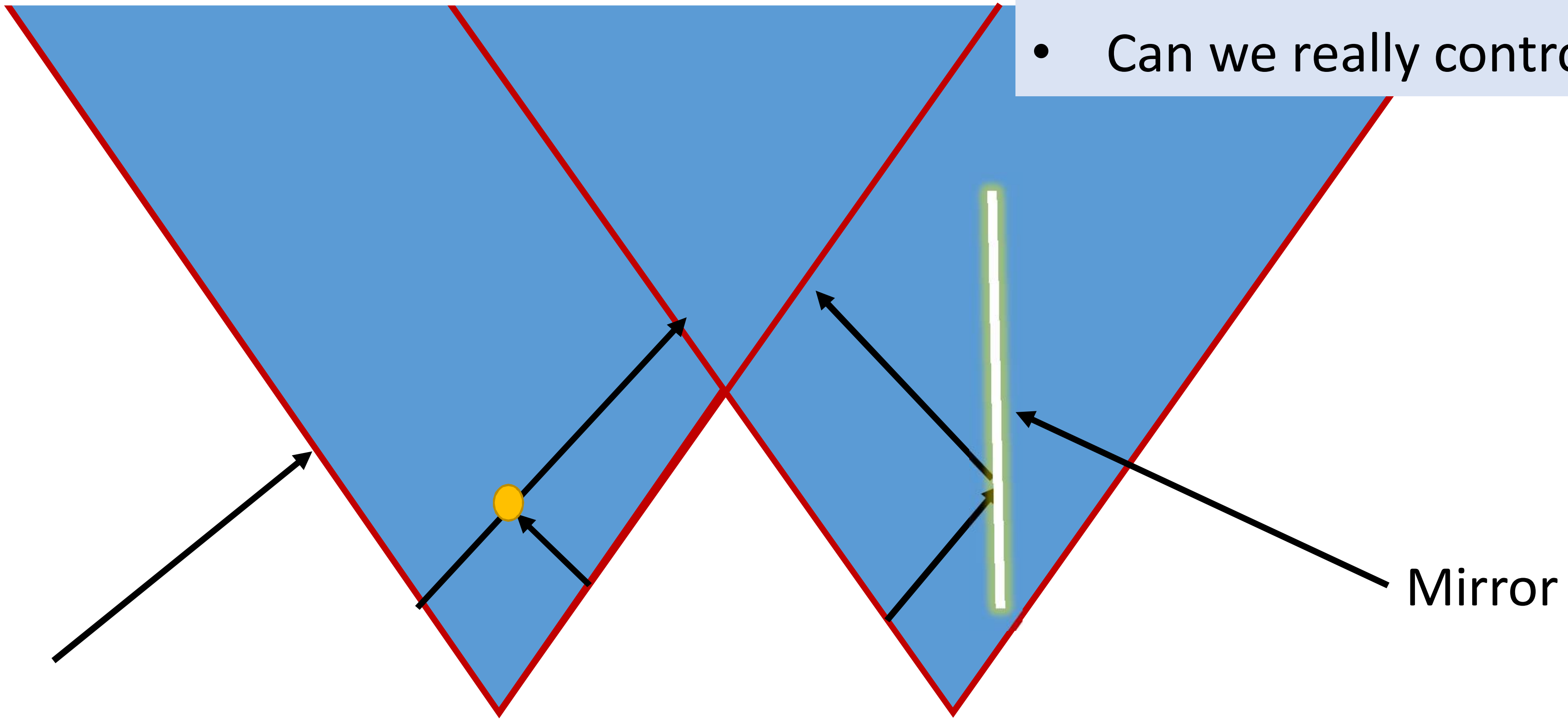

Issues:

- Can we really control this?

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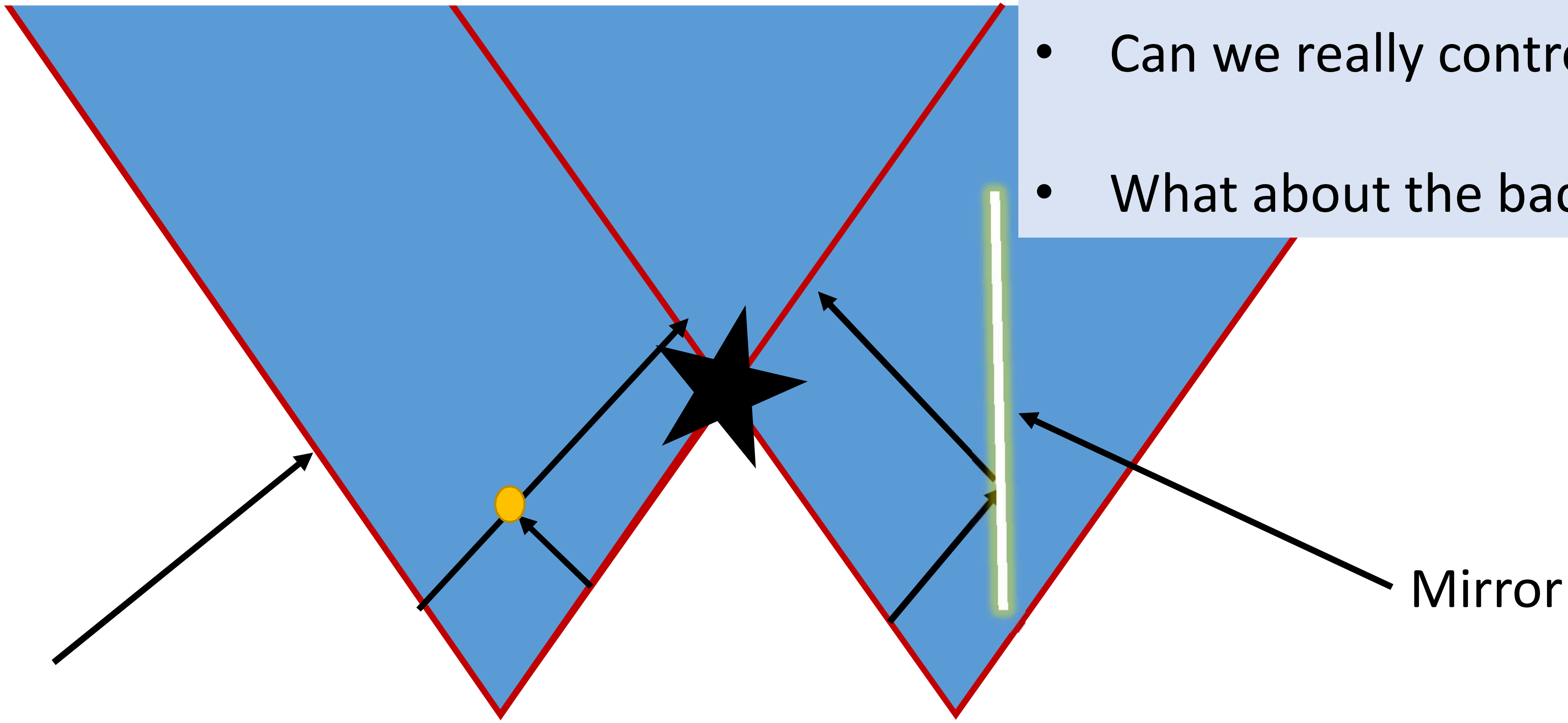
- What about the backreaction?



What about the argument from Holography?

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But we don’t have a holographic dual of time-like dilaton.

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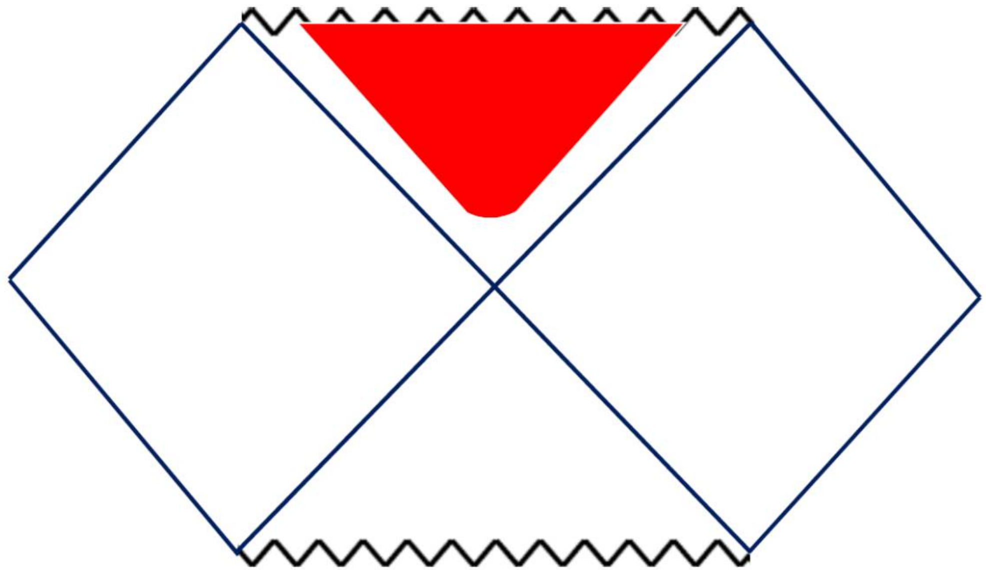
We do have time-like dilaton behind the horizon of the SL(2)/(1) BH that is

the near horizon of NS5-branes.

The SL(2)/U(1) BH is not empty, but is filled with folded strings



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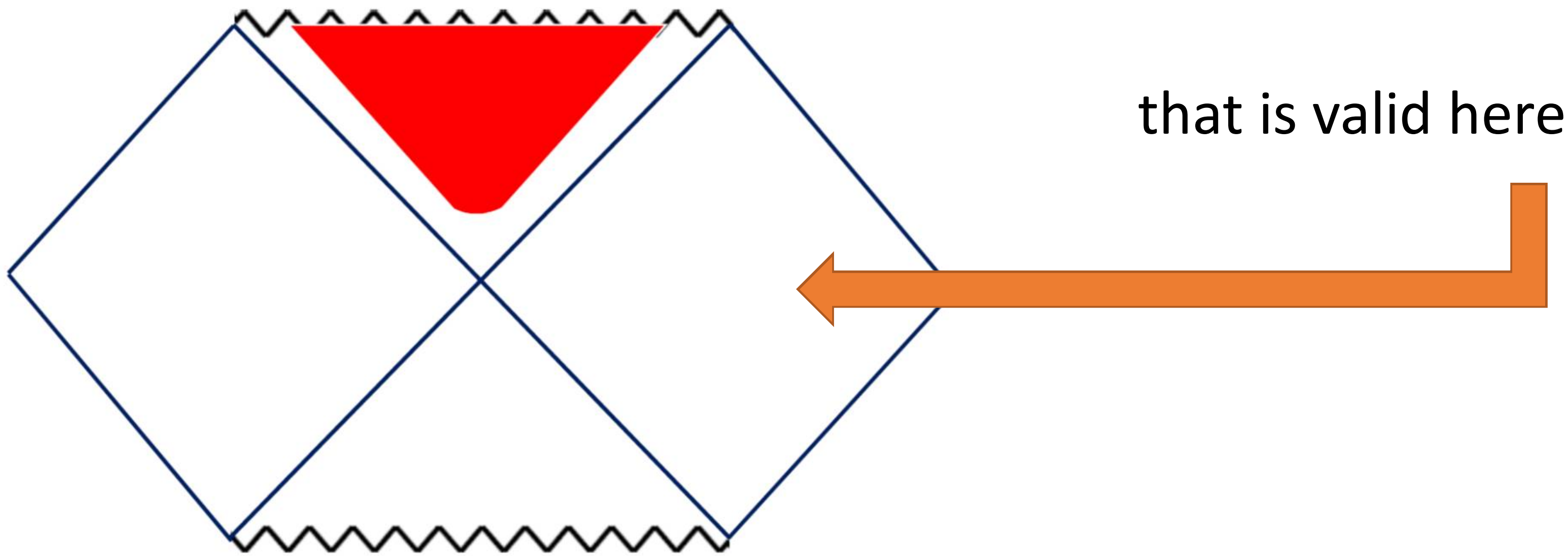

Fine with holography argument

that is valid here.

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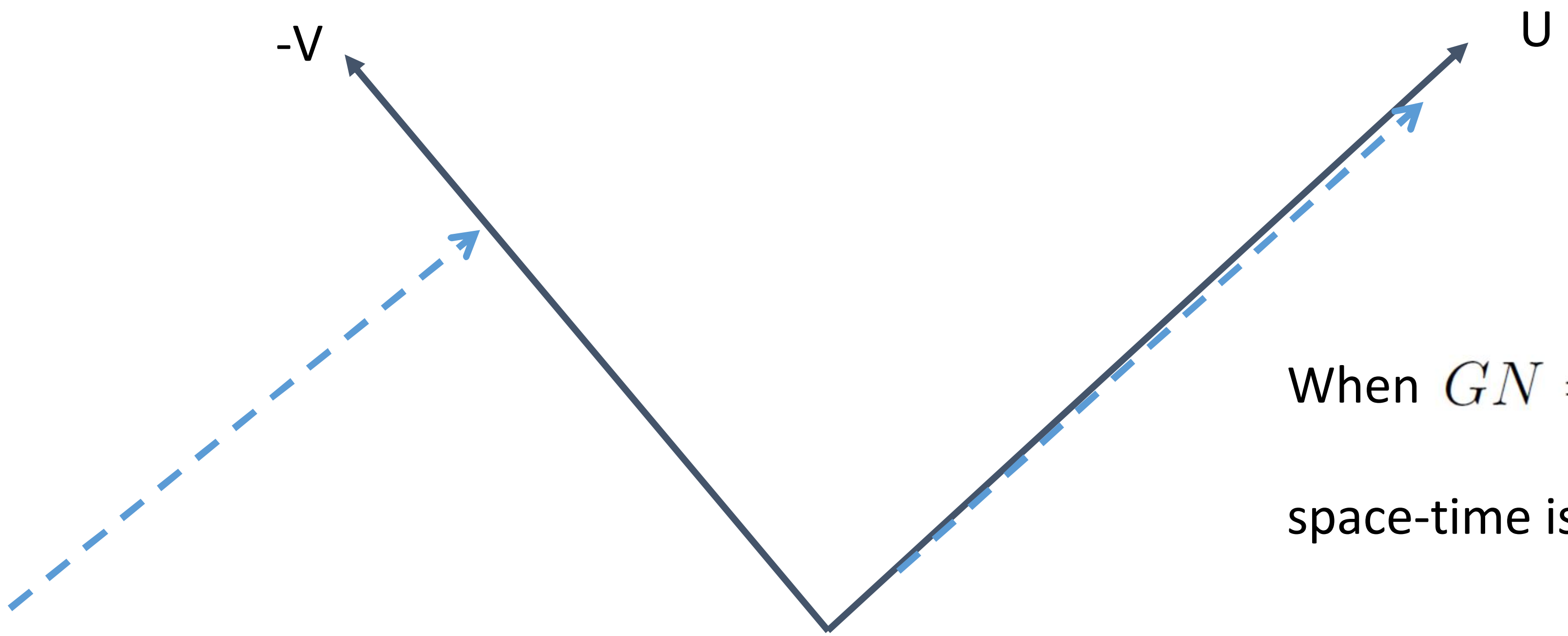
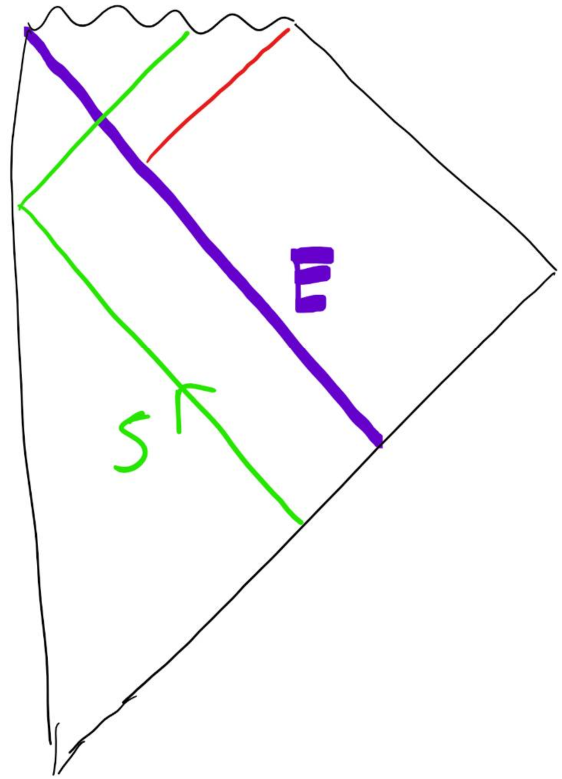


When $GN = 1$ part of space-time is cloaked.

Let’s go back to the firewall is not enough. We had this picture



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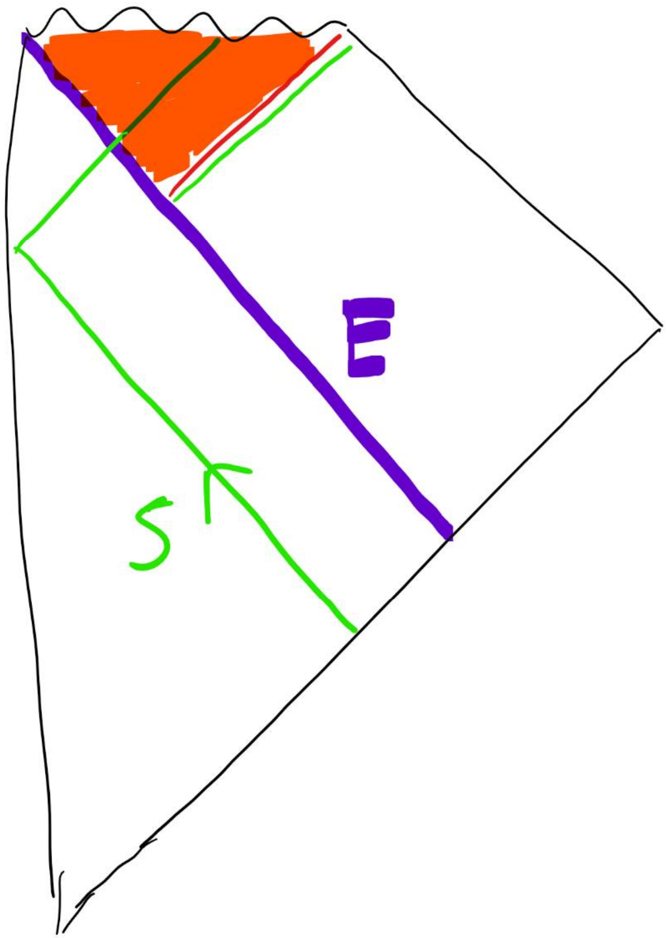
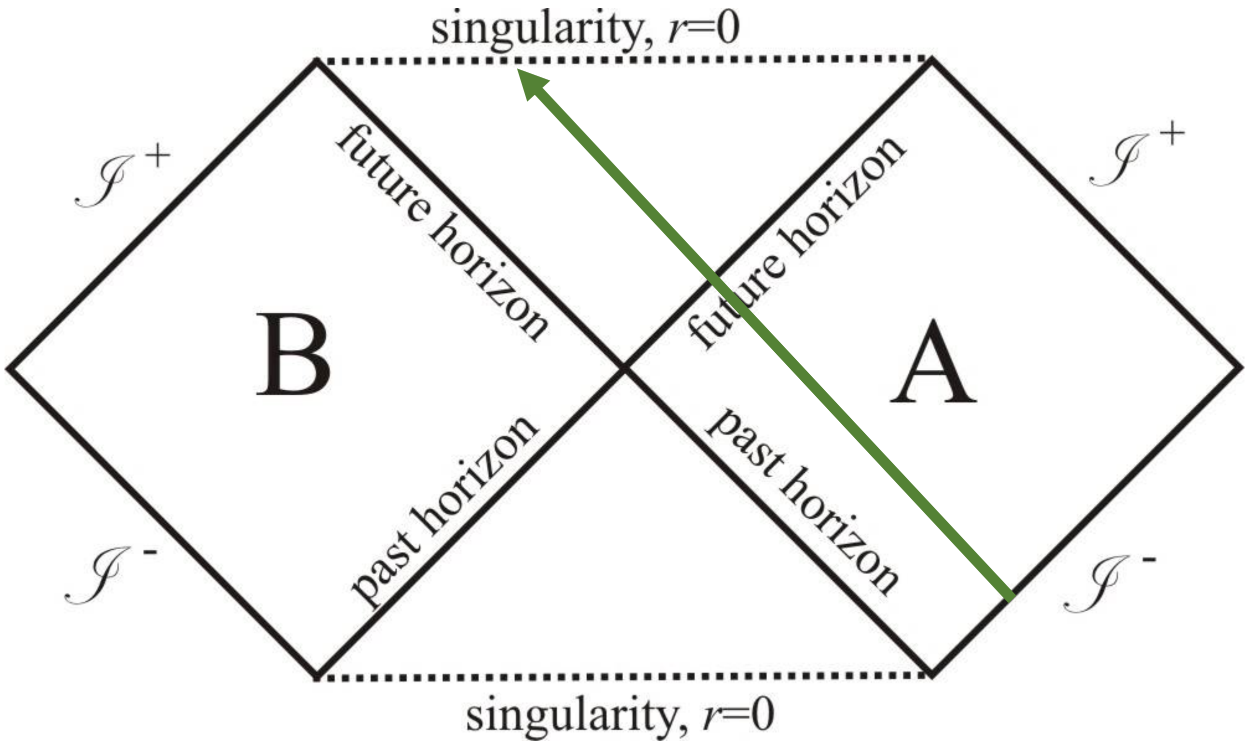


Wormhole still nontraversable



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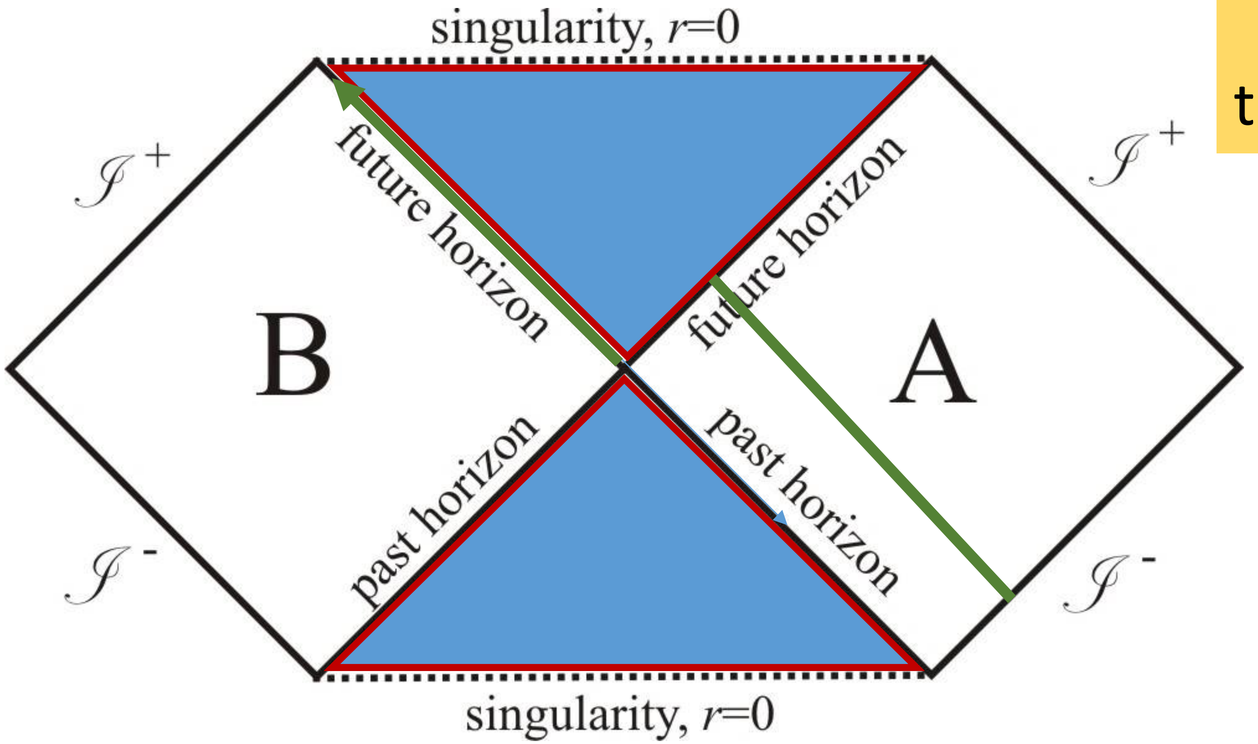


Cannot make it to

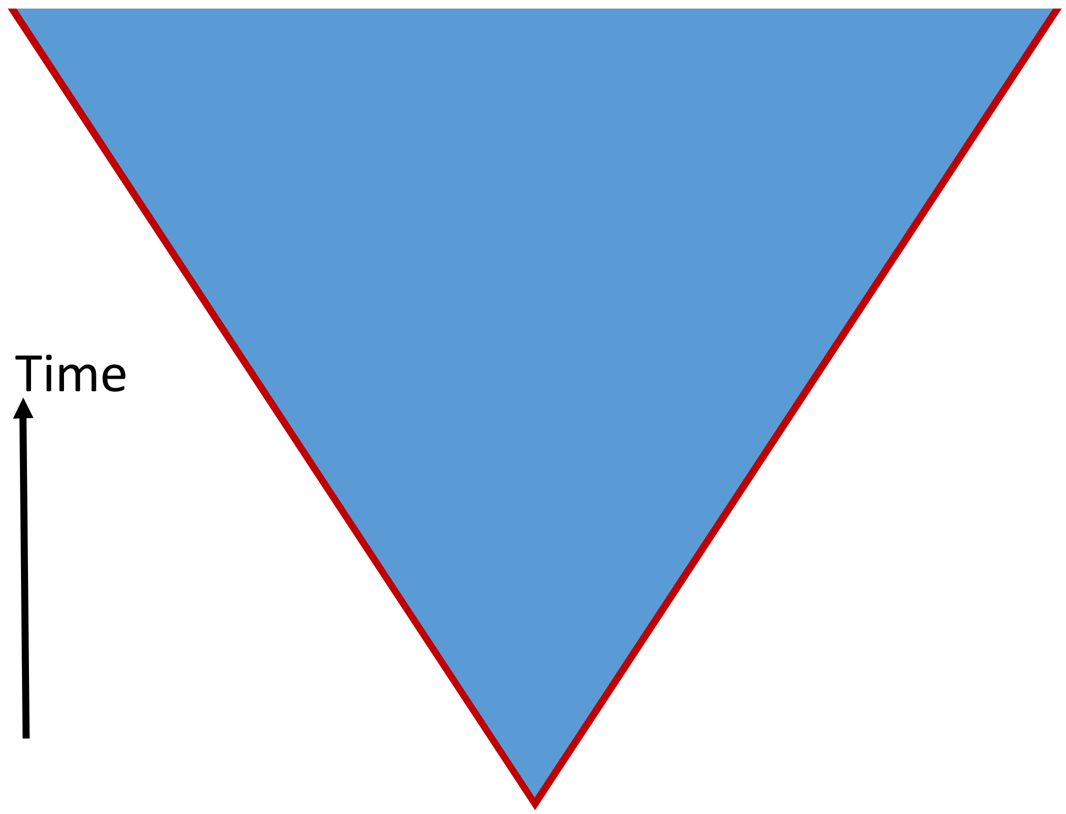
the other boundary

These objects open up new scenarios in cosmology:

For Q> 0 we have a new

Universe with a larger

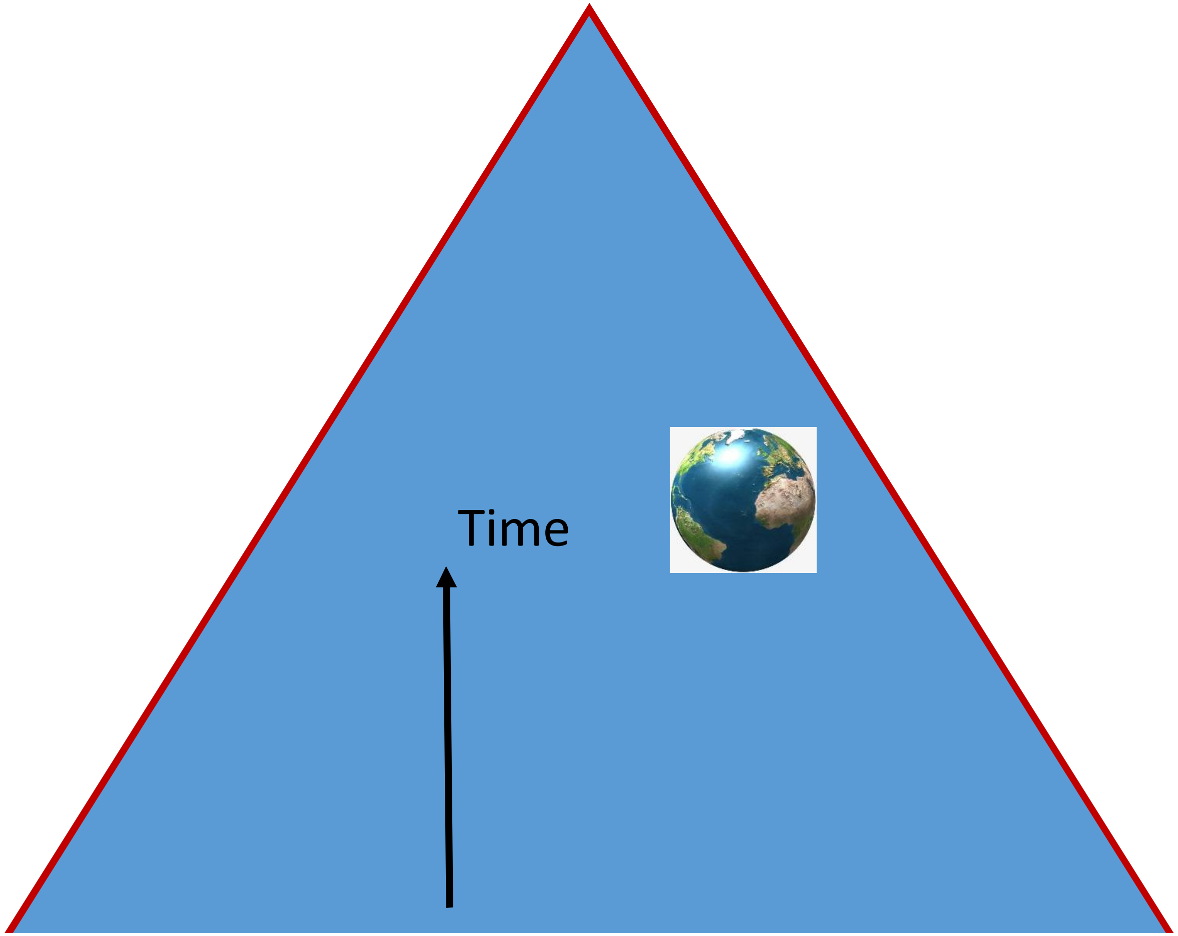
cosmological constant.



These objects open up new scenarios in cosmology:

For $Q < 0$ we might be on our

way towards a null singularity.



Conclusion:

- Much of our understanding of BH and cosmology relies on the ANEC.
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- It should be fun to revisit our understanding in light of that.

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Thank You