# We need anthropics, but it's not coming through for us.

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Outline:
Why we need anthropic reasoning.
Problems:
1. Infinite universes: the measure problem.
2. Finite universes: Anomalous observers.

# *Why anthropics?*

Goal of physics: Determine which theory is right based on observations/experiments.

Make observation. “Would this observation be likely in theory A?” If so, A is favored. If not, A is disfavored.

But in a very large universe, all observations will be made.

The bare fact ”this observation is being made” is uninformative.

Instead we need to use “I made this observation”.

The difference between “I saw” and “someone saw” is anthropics.

# *Codifying anthropic reasoning*

The Self-Sampling Assumption (SSA):

One should reason as if one were a random sample from the set of all observers in one's reference class. (Bostrom)

Thus "I saw" is the same as "a randomly chosen observer saw". If each observer's observation is determined by chance, then even though a few observers will be very unlucky, most will get the expected result.

Large (but finite) universes are now handled properly.

# *Variations in number of observers*

SSA behaves strangely when the number of observers is different in different theories. E.g., Theory A: there are many intelligent observers on Jupiter (Hartle and Srednicki). Theory B: there are none.

SSA tells you to disfavor theory A, because you are not a Jovian. Since you already you know you are human, why should this matter?

It also introduces dependence on the reference class. E.g., if ants are included, I should almost certainly have been an ant.

# *Variations in number of observers*

One solution: The “Self-Indication Assumption” (Dieks). Universes should be favored if they have more observers, because there’s more chance to exist there. Thus

SSA+SIA:

One should reason as if one were a random sample from the set of all possible observers.

Once I know that I am human, existence of Jovians does not matter. The chance to be in my exact circumstances depends only on the number of observers in my exact circumstance in different theories.

Reference class doesn’t matter. Use smallest possible reference class: subjectively indistinguishable observers.

# *Infinite universe*

Problem #1: Suppose the universe is infinite. Then these principles do not work.

We want to consider ourselves a random sample from some infinite class of observers with each one having equal weight.

No such distribution exists.
If $p(\text{each observer}) > 0$, then $\sum p = \infty$.

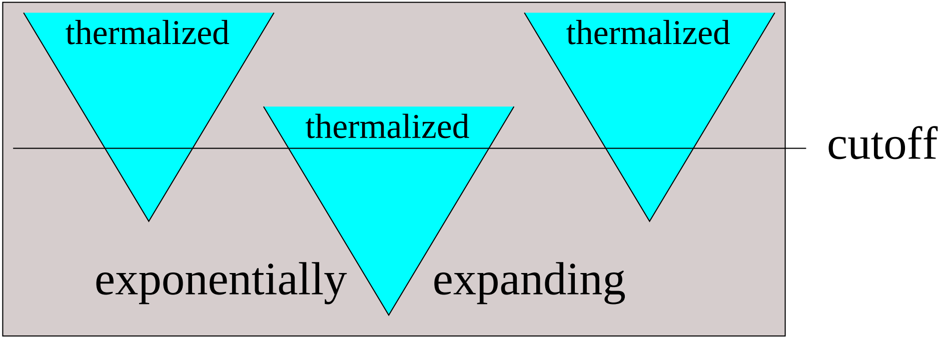
This is not just a technical problem. There are the same number of anomalous observers as there are normal observers.

To avoid this problem, we need a measure = some coherent scheme for assigning probabilities to possible observers.

# *Measures*

Usual plan: Take some finite subset of the observers. Reason as if only this subset exists. In many cases, take a limit as the subset becomes larger and larger.

For example, cut off the universe at some finite proper time after eternal inflation began.




This gives the “youngness paradox”.

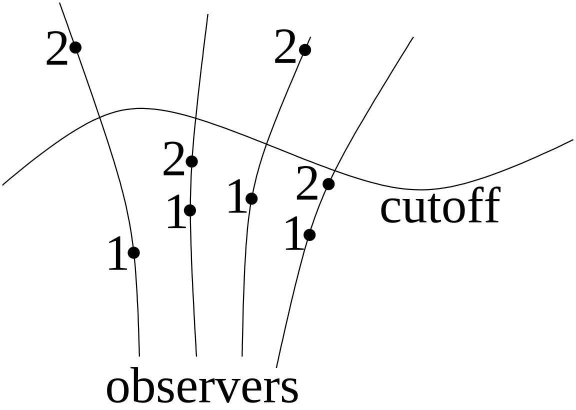
A better plan: cut off the universe at some finite amount of expansion. The “scale factor cutoff”.

There are many others.

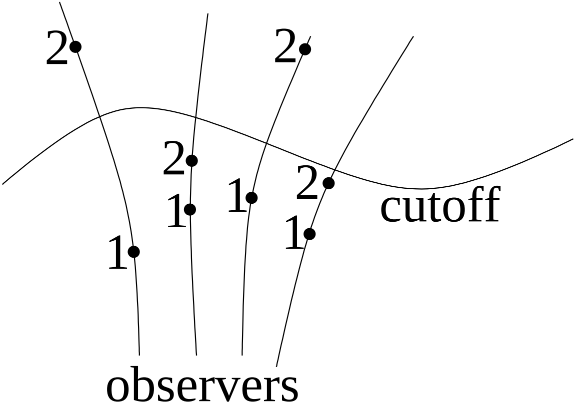
The measure problem: Which measure is the right one?

The even worse problem: There are no reasonable measures.

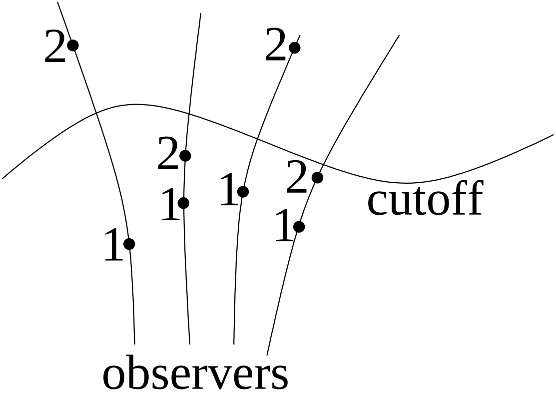
# *Guth-Vanchurin Paradox*




Most measures cut the world lines of observers. Then different observers are included at different times of their lives. This leads to a paradox where assessment of probabilities can change from only the passage of time.




Example (Guth, Vanchurin):
1. You flip a fair coin but don't look at it.
You go to sleep. Your alarm is set for
Heads: 10B years
Tails: 10 minutes.
2. You wake up not knowing how long you slept.




When you go to sleep, you think you are typical of all going-to-sleep observers before cutoff. Half of these have coins showing Tails.

When you wake up, you think you are typical of all waking-up observers before cutoff. Nearly all of these have coins showing Tails.

Paradox: you changed your assessment of probabilities based on nothing more than the passage of time.

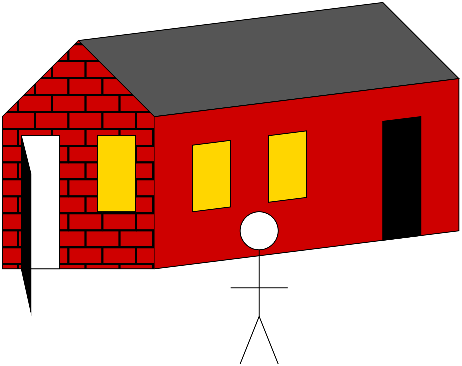
Taking cutoff $\to \infty$ limit would not help.

Is this OK? It would be OK if there was some possibility never to wake up. E.g., Tails you wake up in 10 minutes; heads you die. When you wake up you are sure of Tails. But this is not the situation here.

I claim that if the set of copies of you living through time 1 and time 2 in your life is the same, then you should never have to change your probabilities.

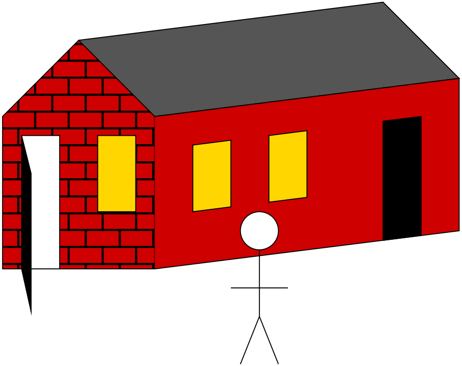
If we allow changes in probability due only to the passage of time, very strange things can happen.

# *The philosopher and the tiger*



12:00:00: You think 99% chance: front open, back locked.
1% chance: back open, front locked.

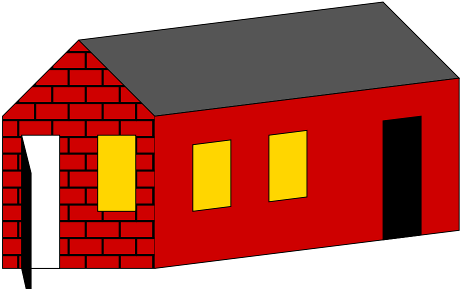
12:00:10: You think 99% chance: back open, front locked.
1% chance: front open, back locked.



12:00:00: Front open (99%)
12:00:10: Back open (99%)

Case 1: At 12:00:01 a hungry tiger appears.
You run for the front door.

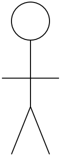
Case 2: At 12:00:11 a hungry tiger appears.
You run for the back door.

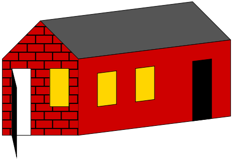


12:00:00: Front open (99%)
12:00:10: Back open (99%)

Case 3: You are far from your house when the tiger appears at 12:00:01. You can reach either door in 10 seconds. The tiger can reach either door in 12 seconds.

What do you do?





12:00:00: Front open (99%)
12:00:10: Back open (99%)

Choice A. When you see the tiger you're nearly certain that the front door is open. You run there, but when you arrive you're very sad, because now you're nearly sure it's locked.

Choice B. You head for the back door, because you know that when you get there you'll expect it to be open. But why are you at 12:00:01 trying to escape a tiger by running toward a door you think is locked?

# *Infinite universes*

There does not seem to be any measure that is reasonable in other ways and that avoids the problem of probabilities that change with only the passage of time.

I think probabilities changing only with time are unacceptable, so I claim:

There are no reasonable measures.

New ideas are needed.

# *What is an observer?*

Problem #2: Anomalous observers.

Return to a finite (but very large) universe. No measure problem.

Simplest application of reasoning: I use everything I know to try to predict something about my future.

Big universe contains several observers that have the exact same knowledge and different futures. Assign probabilities to my possible futures.

"Reference class" is observers subjectively indistinguishable from me. No Jovians, chimpanzees, ants, etc.

But there are still many issues, both classical and quantum.

# *Classical anomalous observers*

1. Computer simulations. Simulate molecules in the brain / neurons / thoughts. If simulation is good enough, observer should count in anthropics.

Computer operation: state stored in memory. Processor advances memory to next state. Initial state $s_0$. Then $s_1 = f(s_0)$, $s_2 = f(s_1)$, $\ldots$.

2. Duplicate computer. Same sequence $s_0, s_1, s_2, \ldots$.
Is the the duplicate a separate observer?
If not, what about tiny differences?

3. Slave computer. Copies states of master computer. Same sequence of states; different cause. Does it matter?

4. Offline storage. Is the computer that reads the tape a separate observer? Is the tape itself an observer?

# *Classical anomalous observers*

5. Compressed data. Computers sometimes store data in a compressed form. Let's store brain states using this extremely good compression system:

0 denotes $s_0$
1 denotes $f(s_0)$, i.e. $s_1$
2 denotes $f(f(s_0))$, i.e. $s_2$
...

Computer memory stores successively the numbers 0, 1, 2, . . . . Is it thinking?

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Nonsense! But where to draw the line?

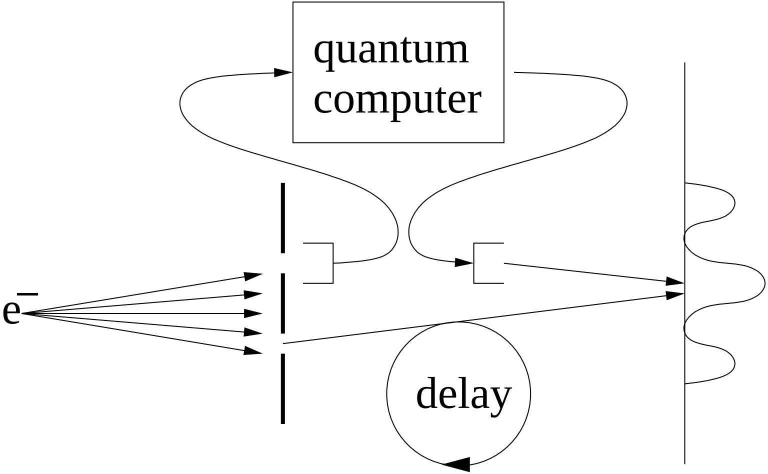
# *Quantum anomalous observers*

Boltzmann brains in the vacuum?

$$|0\rangle = \sum_\alpha a_\alpha |\alpha\rangle_{\rm in} \otimes |\alpha\rangle_{\rm out}$$

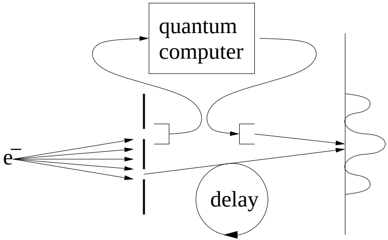
States $|\alpha\rangle_{\rm in}$ include everything that could possibly be in a box, including a brain (person, solar system, ...)

?With probability $p_\alpha = |a_\alpha|^2$ there is a brain in the box?




Quantum computer thinks (then unthinks) some thoughts, eventually restoring quantum state of electron.

Does it count for anthropics? With weight 0.5?




Does the computer run if $e^-$ goes through top slit and not if it goes through bottom? No! It always "runs", but with amplitude $1/\sqrt{2}$.

Maybe double-slit brain and vacuum Boltzmann brain don't count because there's no decoherence.

But what about de Sitter space? In a pure state of de Sitter space, bubble nucleates, leads eventually to us. Not "really" decoherent, because state is still pure.

## *The superpower of anthropic reasoning*

Do virtual particles actually exist? Which slit did the electron go through? Is a duplicate computer simulation a distinct person? Are there other universes entirely disconnected from ours?

Why should these questions have answers?

Anthropics makes the answers to these questions matter. It has the power to “look into” closed boxes.

It is this “superpower” that causes all the problems.

# *Conclusions*

Anthropic reasoning is very problematic.

Even in a finite universe, it leads to many paradoxes.

In an infinite universe, it can't be applied directly, so we need a measure, but reasoning with a measure in an infinite universe leads to more problems.

So let's dump anthropics.

But we can't! We need it. Otherwise how do we know the Higgs really exists? Maybe the experiments that found it were just seeing background. In one no-Higgs universe, that would be wildly unlikely, but in a huge no-Higgs universe it would be certain.

We can't live with anthropics and we can't live without it.