Boltzmann Brains [2]

Introduction

Depending on our cosmological model, we may be a brain floating through an otherwise unordered fog of particles.

Descartes and Brains in Vats

Reality is a demon tricking me, so it's incoherent that I have to pay for half of the bill when I only ate a margarita pizza, and I also paid for the drinks earlier. My sensory evidence for the drinks payment is real, the demon wouldn't trick me like that.

Descartes (he didn't actually say this)

- Brain in a vat
  - Biological Objection
  - Difference in experience due to different stimuli
  - Putnam's Objection: Our words don't necessarily refer to what we think they do, therefore if a brain in a vat thinks/says 'I am a brain in a vat' it can only refer to brains and vats it has experienced in the simulation [3].
  - Putnam believes reference is achieved via 'causal connection'
  - Implicit argument from all living humans.
- Boltzmann: Where we're going, we won't need vats

Boltzmann

- Boltzmann
  - Classical to statistical physics.

$$S = k \log W$$

Second 'Law' of Thermodynamics:

$$\frac{\mathrm{d}S}{\mathrm{d}t} \geq 0$$

(i.e. S is always either increasing or constant)

Particles in a Partitioned Box, First State Space

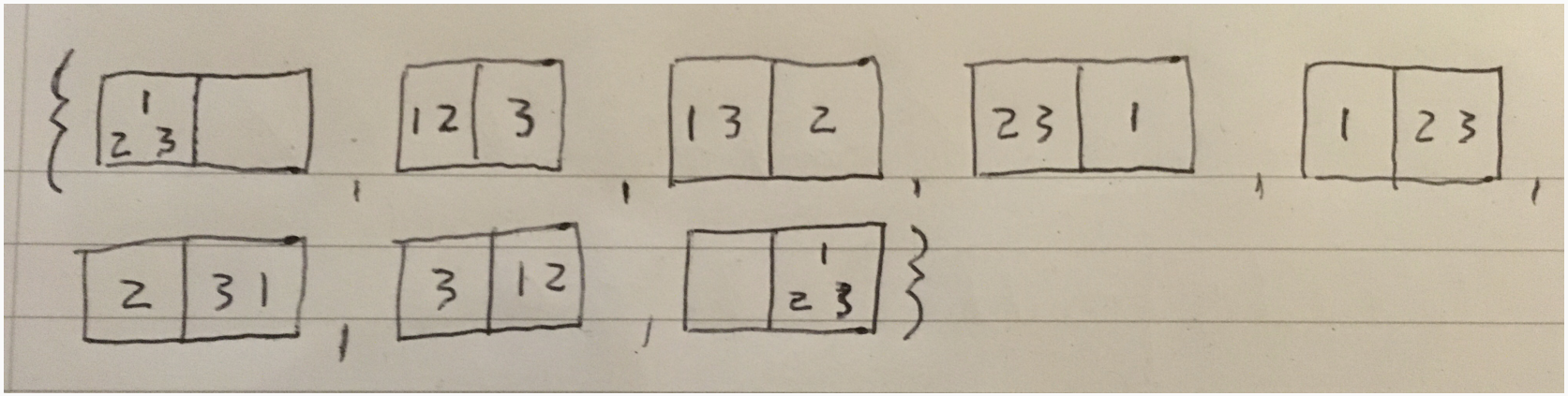


Figure 1: State space at the highest precision

Transitions

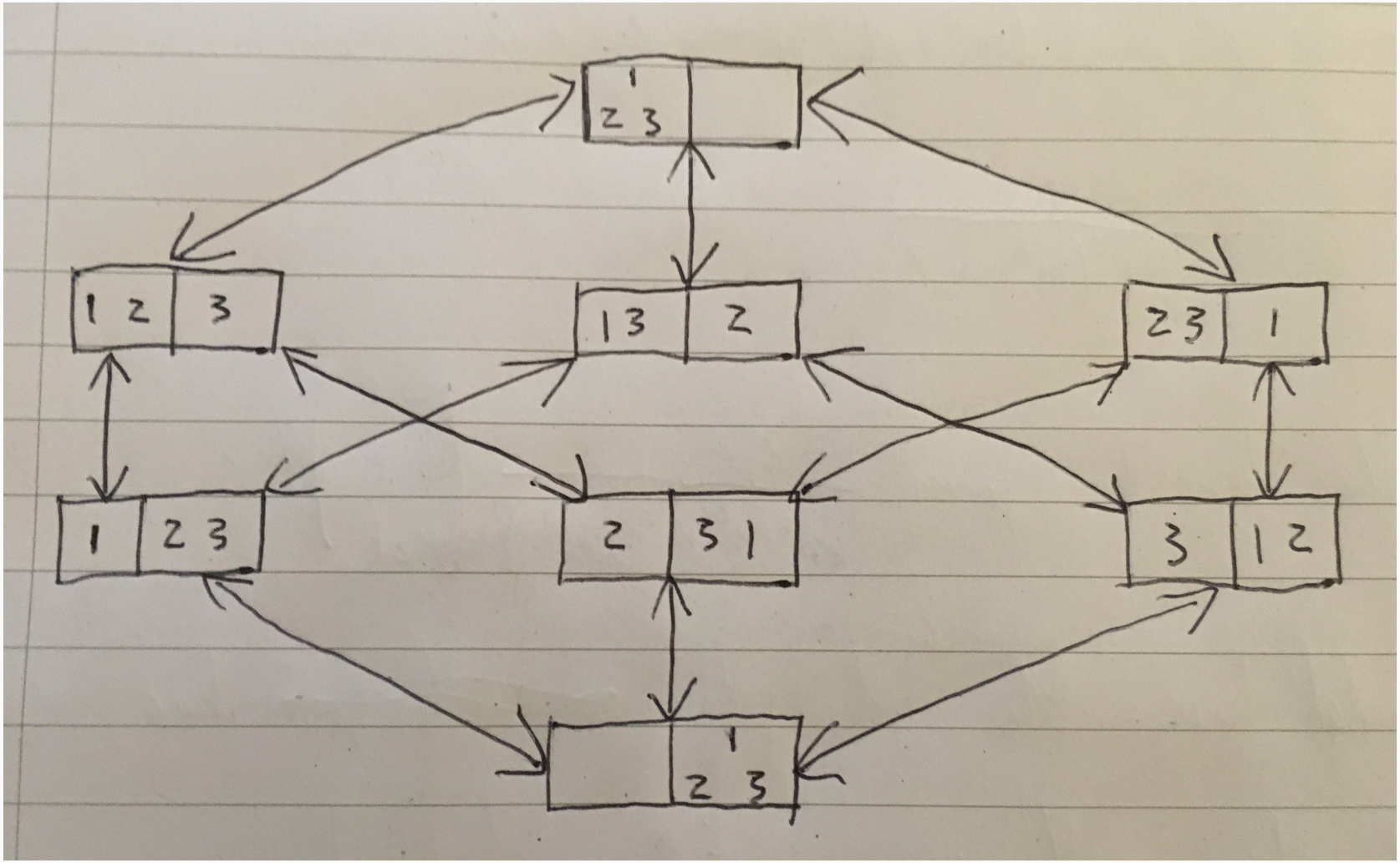


Figure 2: Transition Diagram

First Equilibrium

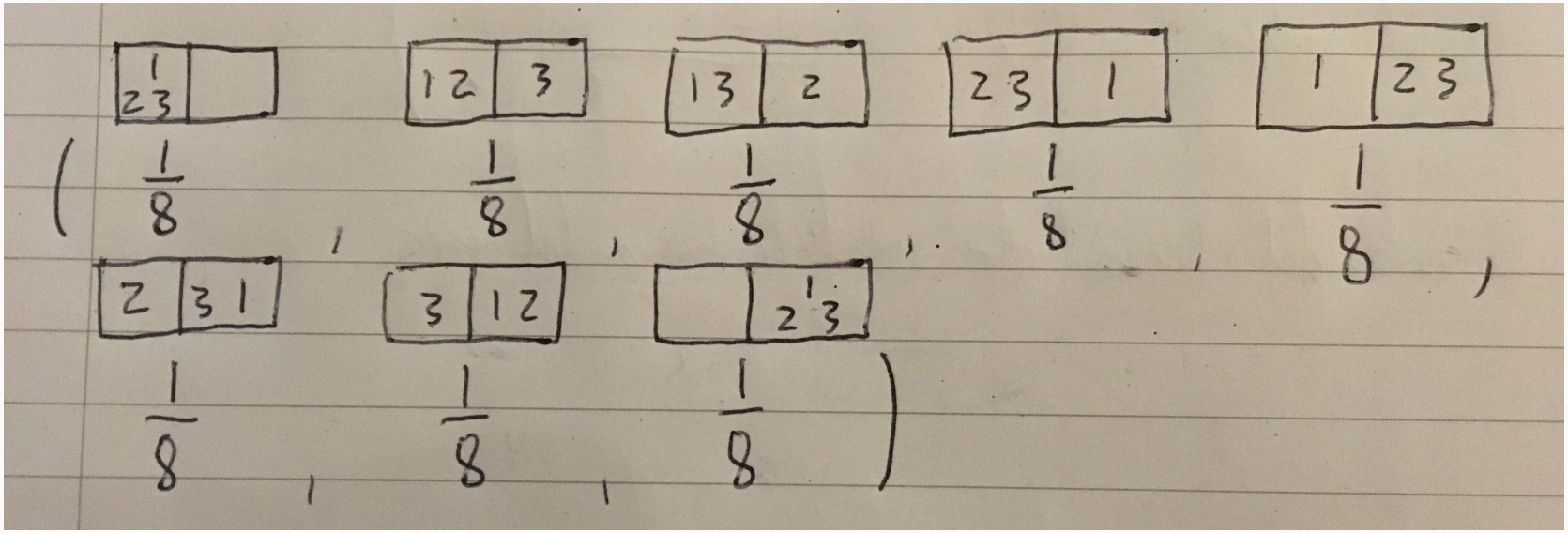


Figure 3: Equilibrium distribution at the highest precision

Lets get stupider

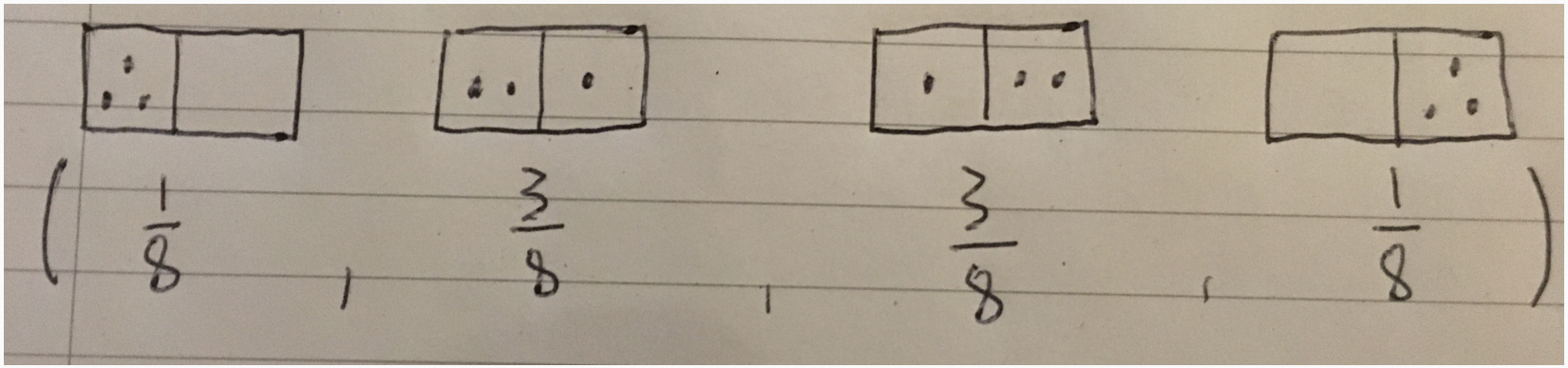
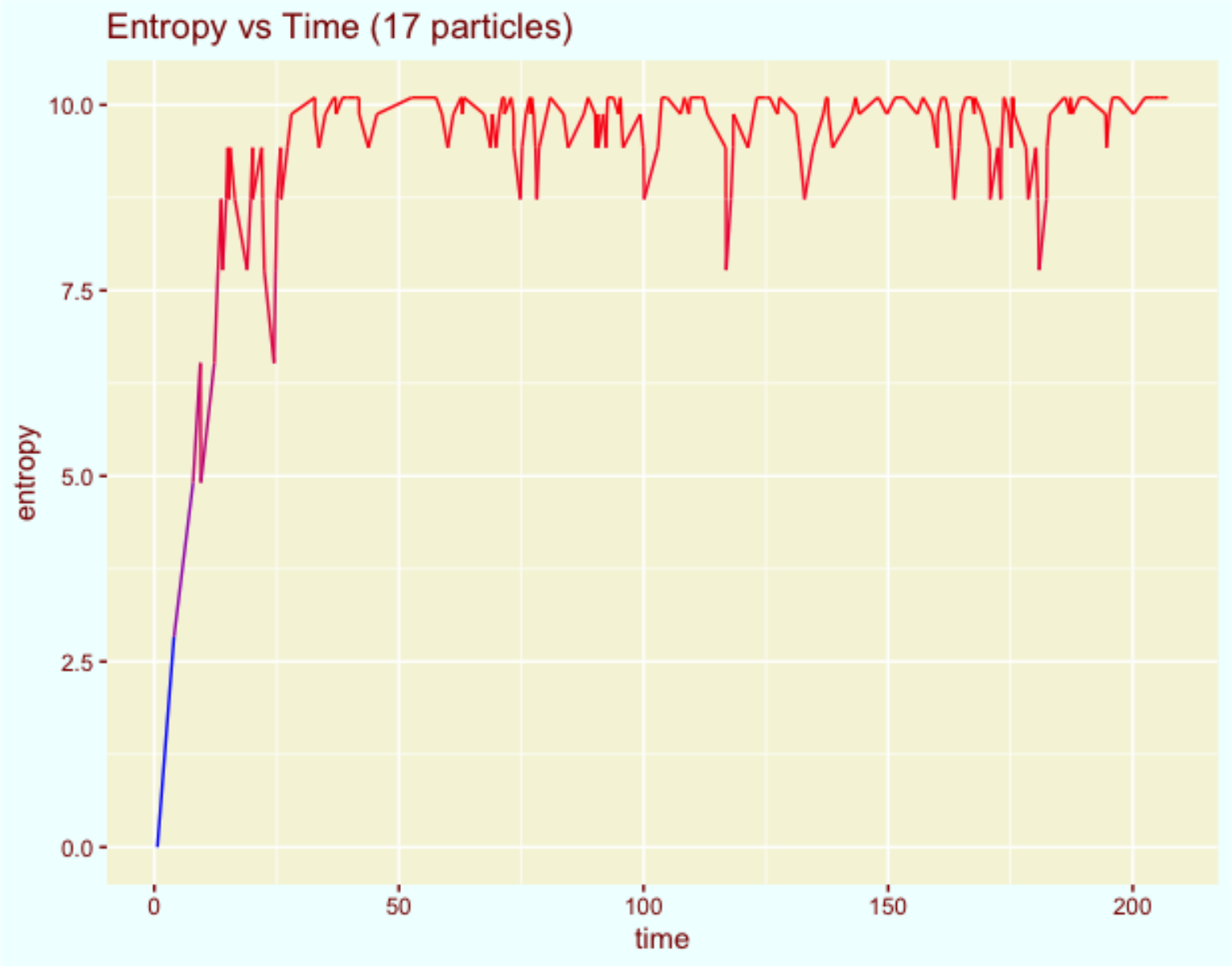


Figure 4: Equilibrium distribution at the new precision

Simulation


Entropy vs Time (17 particles)
entropy
10.0
7.5
5.0
2.5
0.0
0
50
100
150
200
time

Simulation II

There are 2 states with the lowest entropy (all particles in one chamber or the other)

There are

$$2 \times \binom{17}{8} = 48,620$$

states with the highest entropy ($2^{17} \approx 130,000$ states in total)

Poincaré Objects, Boltzmann replies

- Poincaré: The universe should recur.
  - First discussed by Poincaré (1890), formalized and proved using measure theory by Carathéodory (1919).
- Boltzmann: Ok, we might be near the start.
  - The past hypothesis

Descartes II: The Rise of Eddington

Eddington: Actually, all we need is for brains to exist. This is way more probable than a large region of low entropy.

Universes A and B

Quantifying Eddington's interjection: 2 Universes

1. Universe A: Young universe in which the 2nd law of thermodynamics holds.
2. Universe B: Universe old enough to exhibit thermal equilibrium and Poincare recurrence

2 types of observer:

1. Ordinary Observers (OOs): This is who we think we are (before hearing about Boltzmann brains/reading Descartes etc. etc.)
2. Boltzmann Brains (BBs)

Which observer are we?

$$N_{OO}(A) \approx N_{OO}(B) \leq 10^{124}$$

$$N_{BB}(A) \sim 0$$

$$N_{BB}(B) \sim e^{10^{122}}$$

So in universe A the probability of being an OO is basically 1, and in universe B the the probability of being a BB is basically 1 ($\approx \frac{e^{10^{122}}}{e^{10^{122}}+10^{124}}$)

Let's get Bayesian

Copernican Principle: For a given reference class of observers, we are equally likely to be any one of them.

Bayes' Theorem: If we have a set of theories $\{T_i\}$ that partition the space of all possible theories, and data D then

$$P(T_i|D) = \frac{P(D|T_i)}{P(D)} P(T_i)$$

We start with $T_A =$ The universe is A and $T_B =$ The universe is B. Our data is $D =$ Sense data (or local environment etc.) of OOs.

Naive calculation

$$P(D|T_A) \sim \frac{N_{OO}}{N_{OO} + N_{BB}(T_A)} = 1$$

$$P(D|T_B) \sim \frac{N_{OO}}{N_{OO} + N_{BB}(T_B)} = e^{-10^{122}}$$

$$\frac{P(T_A|D)}{P(T_B|D)} = \frac{\frac{P(D|T_A)}{P(D)} P(T_A)}{\frac{P(D|T_B)}{P(D)} P(T_B)} = \frac{P(D|T_A)}{P(D|T_B)} \frac{P(T_A)}{P(T_B)} = e^{10^{122}} \frac{P(T_A)}{P(T_B)}$$

Adjusting Priors: SIA

Self Indicating Assumption (SIA): we should form our priors (beliefs before data) as if we were chosen randomly from the set of possible observers given a theory

$$P(T_A) \propto N_{OO} + N_{BB}(T_A) \propto P(D|T_A)^{-1}$$

$$P(T_B) \propto N_{OO} + N_{BB}(T_B) \propto P(D|T_B)^{-1}$$

$$\frac{P(T_A|D)}{P(T_B|D)} = \frac{P(D|T_A)}{P(D|T_B)} \frac{P(T_A)}{P(T_B)} = \frac{P(D|T_A)}{P(D|T_B)} \frac{P(D|T_A)^{-1}}{P(D|T_B)^{-1}} = 1$$

Adjusting Priors: Presumptuous Philosopher

Bostrom: Weighting priors by number of observers introduces bias that makes us unscientific [1].

Adjusting Likelihoods: Jupiter

Hartle + Srednicki [4]: Our likelihoods shouldn't obey

$$P(D|T_i) \sim \frac{N_{OO}}{N_{OO} + N_{BB}(T_i)}$$

They imagine the following scenario:

$$P(\text{Life on Jupiter}) = \frac{1}{2}$$

$$P(\text{Intelligent population with } 10^{12} \text{ Jovians}|\text{Life on Jupiter}) = 1$$

So we have a half probability of only humans, a half probability of

$$\frac{\text{Jupiter's Population}}{\text{Total Population}} = \frac{10^{12}}{10^{12} + 10^{10}} = \frac{100}{100 + 1} \approx 99\%$$

Jovians

Adjusting Likelihoods: Jupiter II

$$
\begin{aligned}
P(\text{Life on Jupiter}|\text{We are Human}) &= \frac{P(\text{We are H}|\text{Life on J})}{P(\text{We are H})} P(\text{Life on J}) \\
&= P(\text{We are H}|\text{Life on J}) P(\text{Life on J}) \\
&= \frac{N_H}{N_H + N_J(\text{Life on J})} P(\text{Life on J}) \\
&= \frac{10^{10}}{10^{12} + 10^{10}} \frac{1}{2} \\
&= \frac{10^{10}}{10^{10}} \frac{1}{100 + 1} \frac{1}{2} \\
&= \frac{1}{202} < 0.01
\end{aligned}
\tag{1}
$$

Unreliable Data

- Nothing we do to our likelihood/priors (barring inclusion of extreme bias) can prevent the fact that D is best explained *for every* D by being a Boltzmann brain.
- Carroll: That's just no way to live [2].
- The argument that you are a Boltzmann brain is cognitively unstable:
- Man cannot do science from data alone: you need some philosophy/methodology/(???) which, under the Boltzmann brain scenario, was probably implanted in your brain by a random fluctuation.
- If ([our reasoning about the universe] $\implies$ 'we shouldn't trust our reasoning about the universe') we should reason differently.
- Carroll "It seems unreasonable to grant substantial credence to the prospect that we have no right to be granting substantial credence to anything"
- This doesn't discount the possibility of BBs.

Thoughts

- If our philosophy of science/(???) is due to a random fluctuation does that necessarily mean it's wrong?
  - How lucky would we have to be to get the "correct" philosophy of science as a BB?
- BBs may be infeasible: depends on philosophy of QM
- Making a prior probability 0 means the posterior probability is automatically 0, and if you were to use that posterior as a prior, the new posterior would be 0 etc. etc.
  - What this means is that literally no amount of data in support of the theory could give it a non-zero probability (bad imo)
- $p \implies$ not p is not a contradiction. If the implication is true, we would need p to be false, and here p is "our theory of physics"
  - This isn't actually what's going on with cognitive instability: we actually need "our theoretical/brain framework to support p is incidental" instead of not p
  - What difference does this make?
  - Can we find any parallels to other theories where this type of pattern of reasoning holds?

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