Quantum Mechanics with Horizons

Stefan Leichenauer
Caltech (soon UC Berkeley)

Outline

- Quantum Mechanics
- Black Hole Puzzles
- Cosmology Puzzles
- Lessons from AdS/CFT
- Fleshing out a thought experiment…

Quantum Mechanics

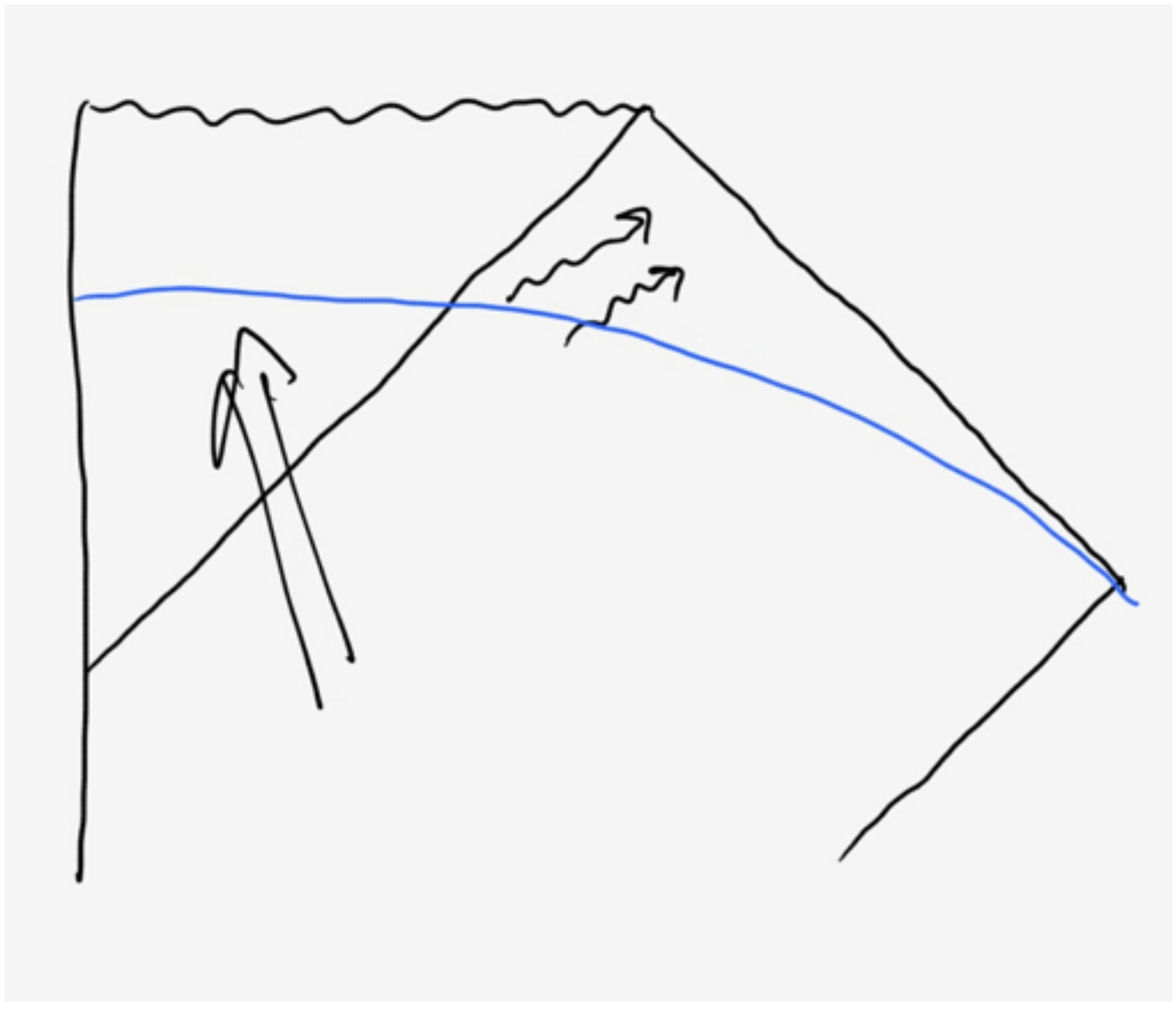
- The role of the observer is very important.

- Super-observer: exists outside of the system, can choose to “observe” and sees Born Rule probabilities.

- Observer within the system: large? classical? lives on a branch? makes records?

- The super-observer can ask questions about the observer. Proceeding without the super-observer perspective is difficult/controversial.

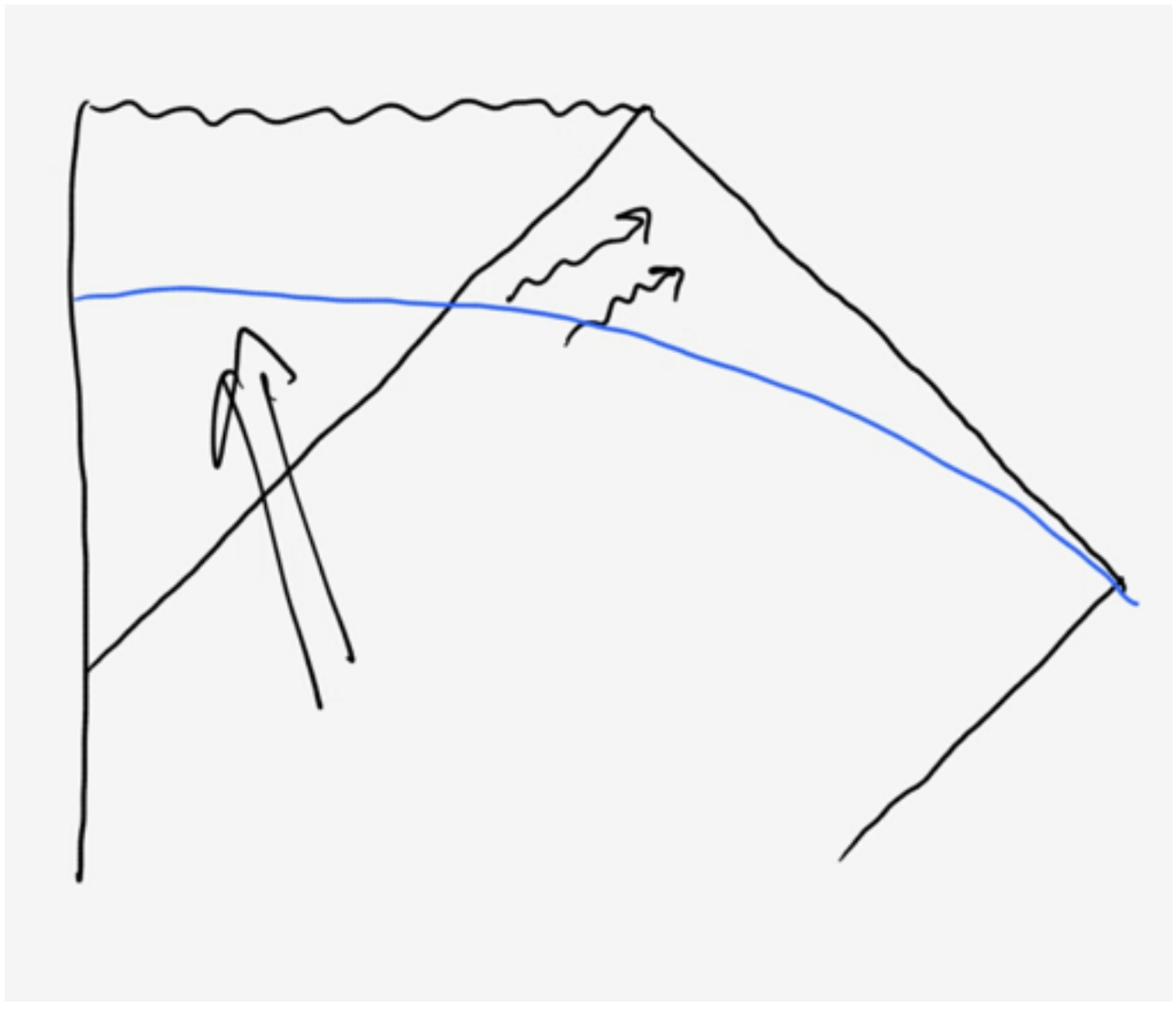
Black Hole Puzzles



Hawking calculation: information paradox. non-unitarity? large deviations from EFT?

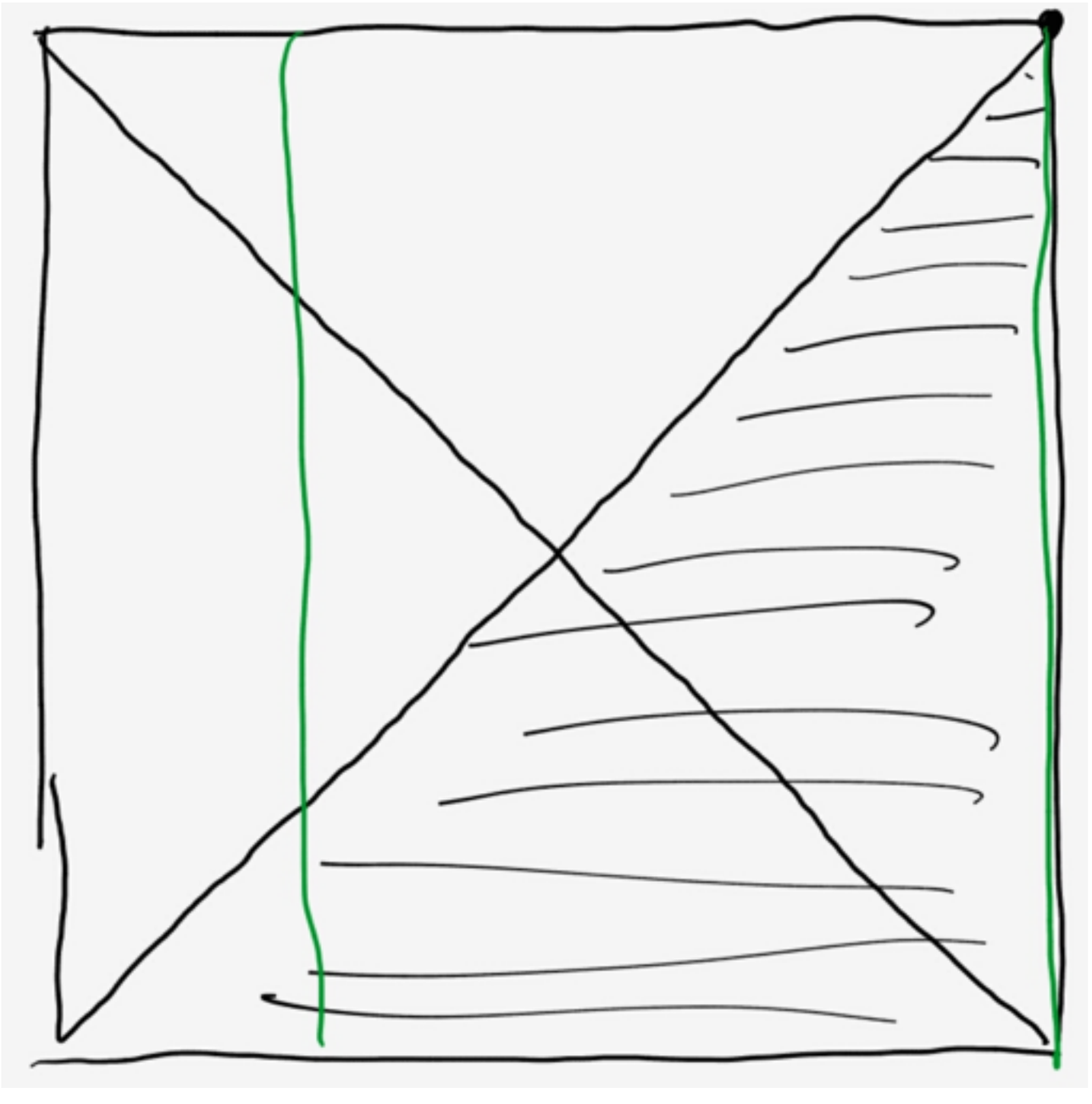
Apparent quantum cloning: both the infalling matter and the Hawking radiation on the same slice. Inconsistency of the global super-observer perspective.

Black Hole Puzzles



Solution(?): Complementarity. The global super-observer perspective is unphysical: no observer within the system can probe both inside and outside.

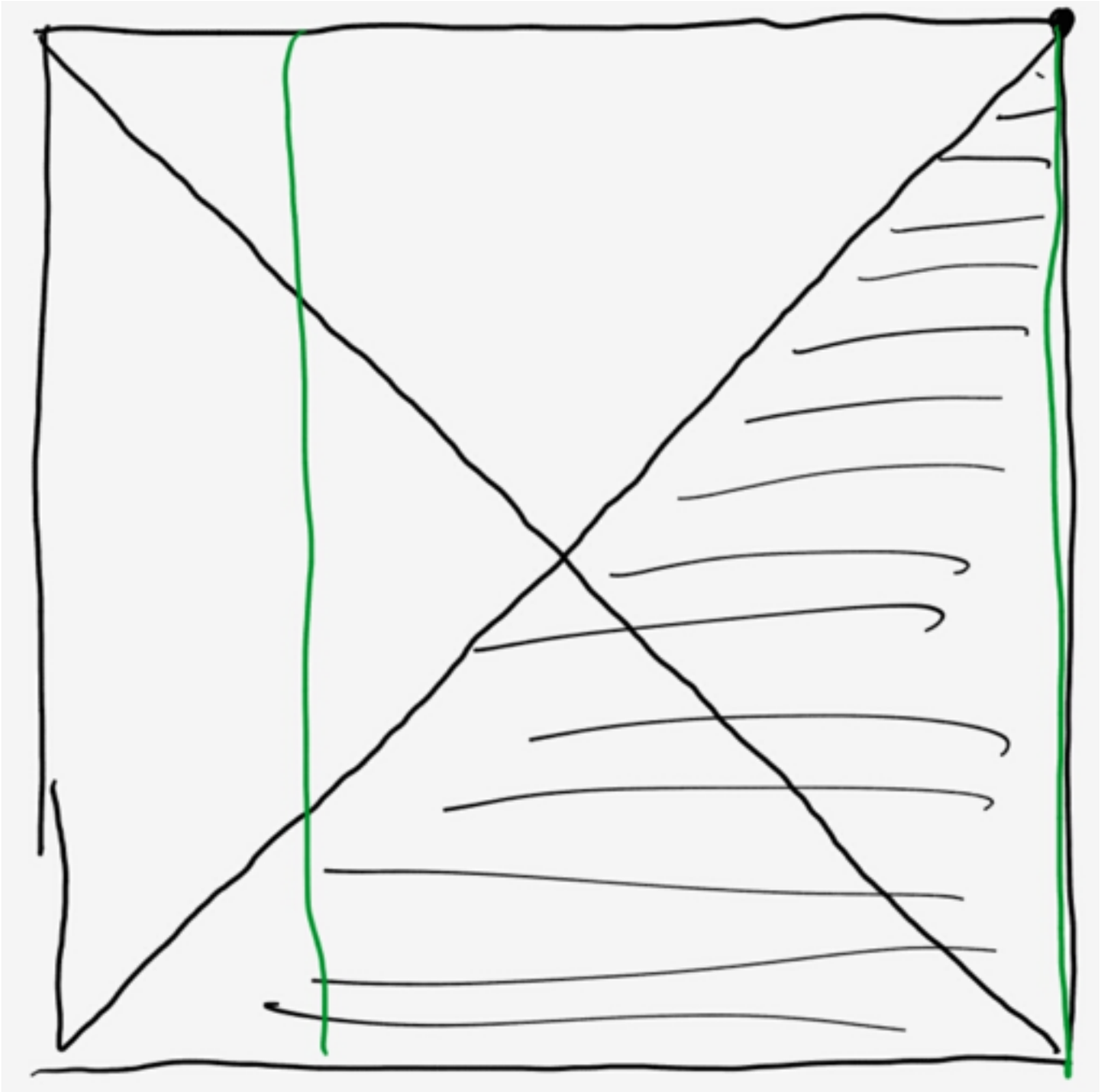
Cosmology Puzzles



Horizons also occur in de Sitter space.

Difference between BH and dS horizons: dS horizons do not evaporate, no information paradox.

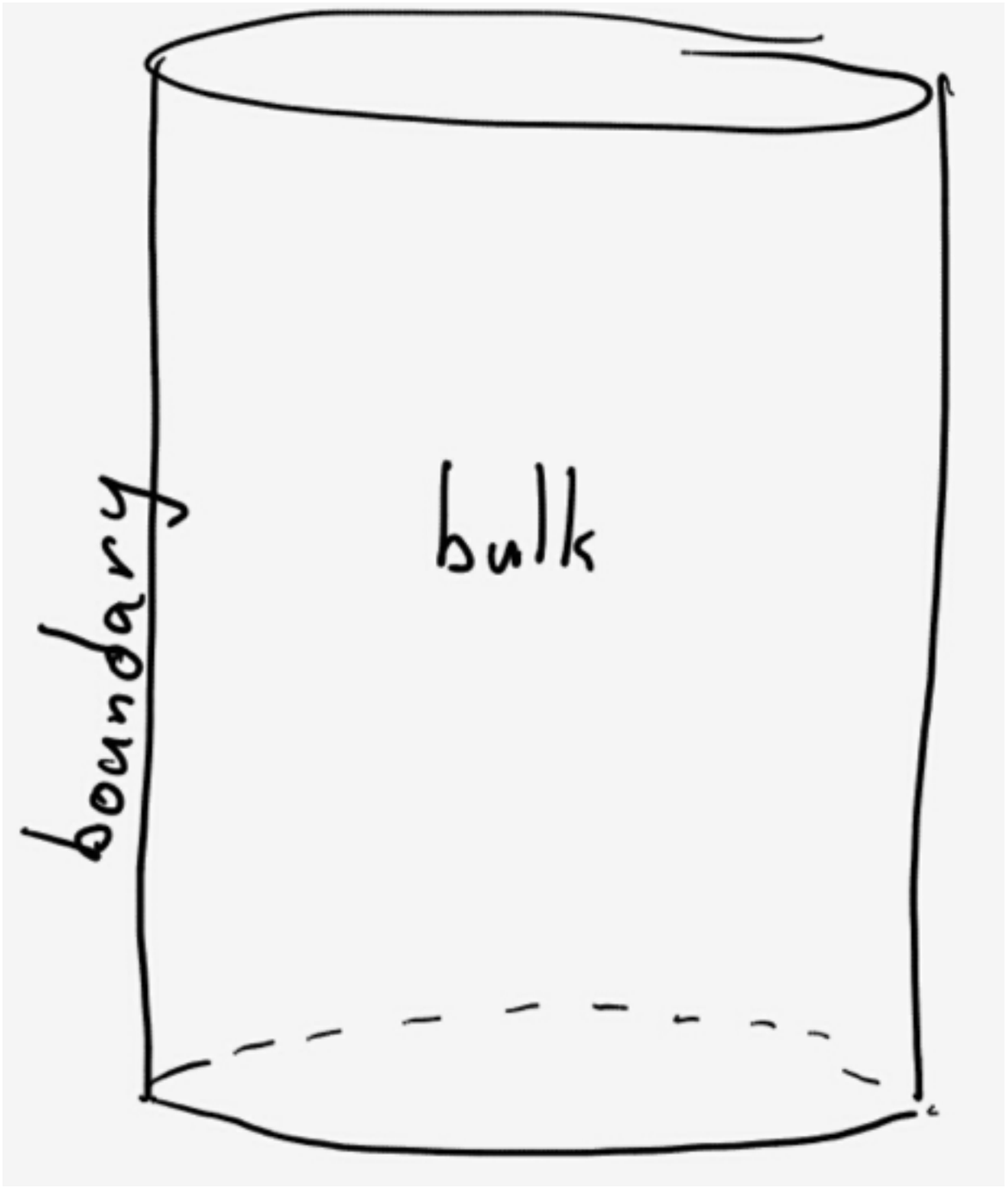
Cosmology Puzzles



Puzzle: Landscape + dS = Multiverse and the measure problem

Complementarity: the lesson from black holes is that QG wants to be a theory of one causal patch (at a time?). Helps with measure problem.

AdS/CFT



Quantum field theory on the boundary = quantum gravity in the bulk

Local operators in field theory = operators at infinity in the bulk

To probe deep inside the bulk, must look at something nonlocal in the field theory.

Lessons from AdS/CFT

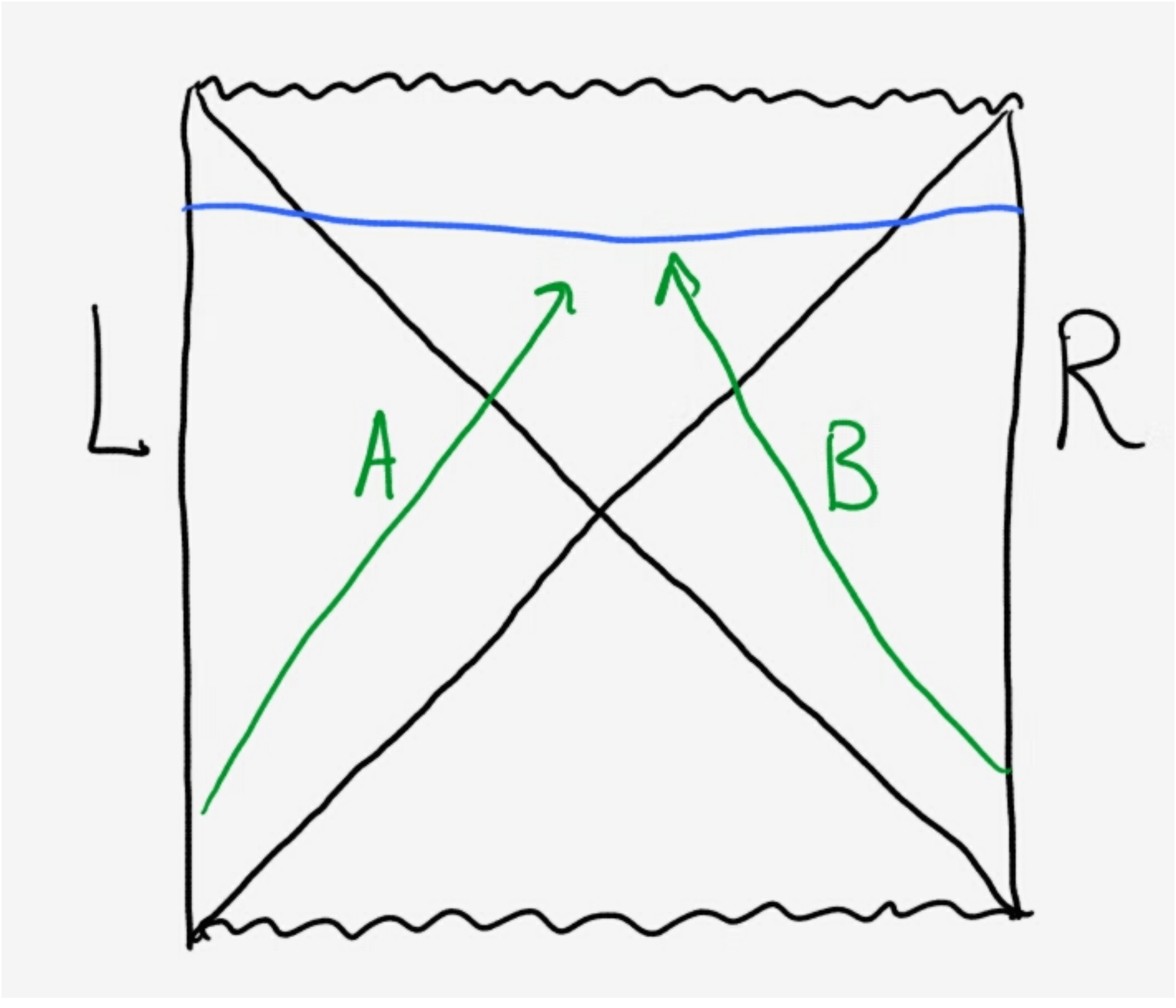
- This is QG, we just need to understand it. There is only a partial understanding of the dictionary.

- This is a super-observer theory, complete with Hilbert space and wavefunction. We can put the universe in a lab.

- Can we see complementarity? How do we go inside the horizon?

Black Holes in AdS/CFT

- Thermofield double state in CFTxCFT.
- Outside of the horizon: no problem.
- Behind the horizon??? (some entanglement calculations make use of the behind-the-horizon region)


L
R
A
B

A thought experiment…

- Alice and Bob jump into opposite sides of the eternal AdS black hole. Do they meet?

- There is no interaction between the two CFTs. Contrast with two people meeting in the middle of a room.

- How can we track the degrees of freedom of Alice and Bob as they cross the horizon? Can the region behind the horizon be made of entanglements of two CFTs?

- Toy model or no-go theorem would be nice!