

The input-output graph of this or any other universal computer is a microcosm of all cause-effect relations that can be demonstrated by deductive logic or numerical simulation

The awesome power of the notion of Computational Universality suggests a complementary thesis

It from Bit: Physics is Informational

Dynamics should be viewed as computation

Physics should be seen as a branch of mathematics, aiming to develop a mathematical model of all possible worlds wherein our own world can be seen as typical

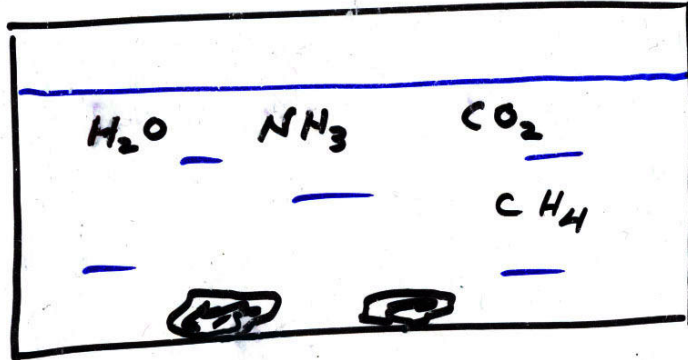
Anthropic Principle

We are (merely) thoughts in the mind of God

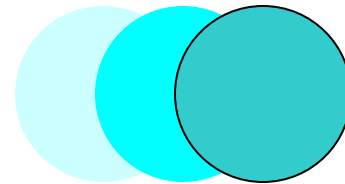
What is the difference between complex dynamics (like our universe seems to have) and simple dynamics (like that of a free particle or harmonic oscillator)?

Can mathematical physics, in particular quantum mechanics, give a non-anthropocentric, non-circular explanation of this difference?

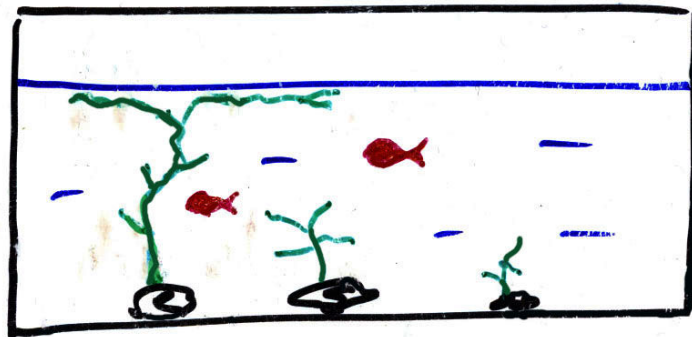
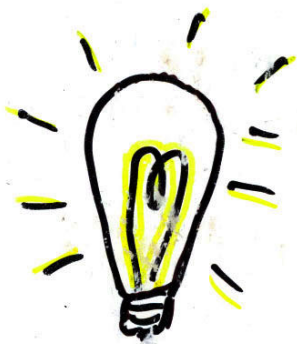
Complex



Simple



Much later



Given a quantum Hamiltonian, how do we decide whether it represents complex dynamics or simple dynamics?

Simple answer: We cannot, because any Hamiltonian represents a trivial evolution of its energy eigenstates. In Schumacher's words, "Hilbert space is too smooth" to distinguish one state from another, or one unitary evolution from another.

Besides the Hamiltonian, what else do we need to know/specify to separate simple from complex dynamics?

- A preferred basis (probably more than we need) or
- A factorization of the Hilbert space into subsystems (probably this is enough). But where we get this factorization from is another question we won't discuss here.

But what is complexity? Can we give a nonanthropocentric definition?

(For the moment we pose this question in the simpler area of classical discrete dynamical processes, e.g. cellular automata)

Heat death: a world at thermal equilibrium is no fun.
Our world is only fun because it's still out of equilibrium.



For a fully equilibrated system (the same 1D cellular automaton), a single snapshot is typically random and hence shallow, but a pair of snapshots far apart in time, when taken together (as a single $2n$ bit string) can be deep if it contains evidence of a nontrivial intervening history.

From whose viewpoint can a physical dynamics be recognized as complex?

- The physicists standing outside the system and trying to look nonanthropocentrically at its Hamiltonian?
- The inhabitant of the world described by the Hamiltonian?

Classically, a reversible system needs to be out of equilibrium for its inhabitants to realize that it is complex. At equilibrium two-time correlations are needed, which cannot be seen by the inhabitant.

Extra slides

