# Philosophy and the Sciences

*Introduction to the Philosophy of the Physical Sciences*

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## The Anthropic Principle and Multiverse Cosmology

What is the Anthropic Principle?
What are the problems and prospects of this view?

### The Anthropic Principle and Philosophy

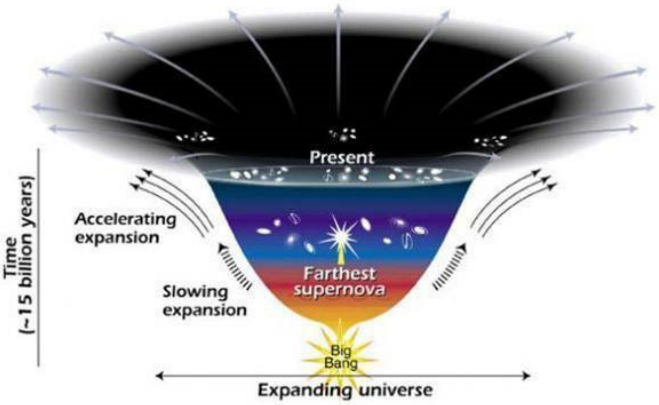
Anthropic reasoning can explain the dimensionality of space (and time), the ratio of gravitational and electromagnetic forces, the valency of carbon bonds, and the ages of the stars we observe in the night sky. Other anthropic explanations suggest that our universe ought to be a gigantic time machine and that we may live inside a 'Matrix'-style computer-simulated reality.

• The term was coined by Australian physicist **Brandon Carter** and first appeared in print in Carter (1974).

• Carter's key idea could be expressed thus: we are physically-based observers that can thrive in only a narrow range of physical conditions and *context-sensitive observers* like us are only likely to observe conditions suitable for our evolution.

• A key component of the Anthropic Principle is the philosophical idea that *good explanations* should make whatever it is that you're trying to explain seem more probable or typical.

• Looking around at the physical conditions that surround us, we see that many apparently incidental features cannot differ from what we observe and still have observers around to notice them.




• Many otherwise independent physical conditions have something in common: they appear as if *'fine-tuned'* into the narrow life-permitting band. Anthropic effects suggest ours is one universe out of a whole ensemble or *'multiverse'*.

• Several physical / philosophical theories have postulated the existence of many alternative, equally actual, realities.

• If all the physically possible ways a universe could be exist, those universes with more or fewer macroscopic spatial dimensions don't permit life and don't get observed. If a multiverse exists, it is then unsurprising we live in that (perhaps tiny) fraction of the multiverse that allows life to evolve.

• The Anthropic Principle can be formulated several different ways, some of them mutually contradictory or otherwise misleading.

• At least two versions of the Anthropic Principle have been discussed in the literature: the **Weak Anthropic Principle** (WAP) and the **Strong Anthropic Principle** (SAP).

• WAP is closest to capturing the essential Carter claim, namely that context-sensitive observers are likely to have evolved in conditions suitable for their evolution.

• SAP generalizes WAP: the presence of observers suggests that the entire universe is amenable to evolution of such observers. SAP is not necessarily claiming that life is the universe's goal or intended end-state, or that the universe must have been set up to produce life.

## Cosmology and the Anthropic Multiverse

### Un-natural aspects of cosmology

• A shared problem with particle physics: the largest energy imaginable is the Planck energy of quantum gravity (1019 GeV or 2 x 10−8 kg via )

• Why are all particle masses much less than this?

• Why is the energy density of the vacuum much less than the Planck-scale value (very roughly 10100 kg m−3)

## Problems for the Big Bang

Why is the universe expanding?

What happened before t=0?

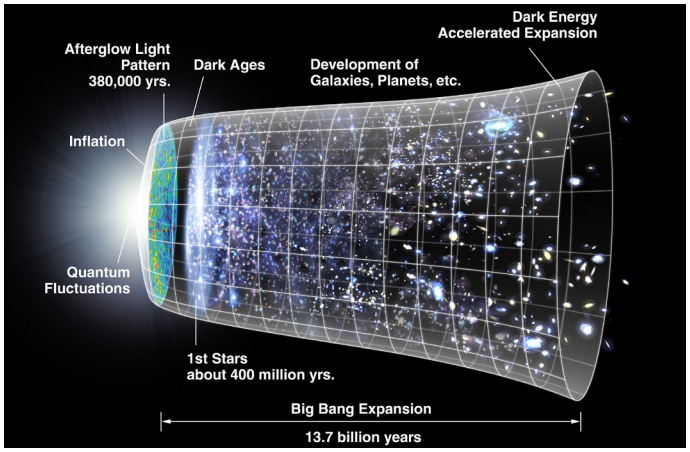
How did it arrange to be so uniform, even though there is no time for different parts to have communicated? (Horizon problem)

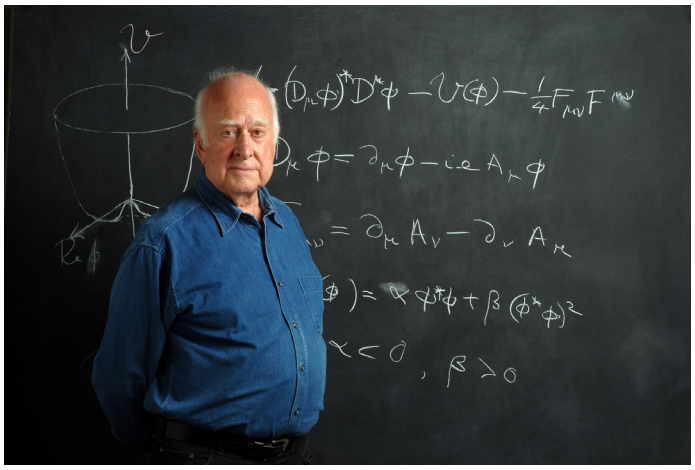
## The Inflationary Universe

The expanding universe may be launched by anti-gravitational properties of empty space.

**Antigravity** can blow a big bubble from a subatomic patch, growing faster than light.

The presently visible universe was once of subatomic size. **Peter Higgs** (1964): explaining masses of elementary particles needs vacuum energy.



*Professor Peter Higgs*

Higgs field is dynamical – vacuum density reduces as field 'rolls' down the potential. Inflation uses this mechanism with a new field.

**Starobinsky** (1979): if quantum mechanics applies to gravity, inflation will make gravitational waves.

**Gravitational waves** allow us to see earlier times in the universe. They propagate through a sphere of last scattering.

Implication of inflation: we have no idea if this is close to a big bang: inflation can continue indefinitely. If inflation is true, we can never learn about an initial singularity.

### Fine tuning: the need for a multiverse

How can the scalar field cancel the vacuum energy so precisely? Maybe there are many minima, and different inflationary bubbles have different vacuum densities – then observers only arise when the vacuum density is low by chance.

## The multiverse hypothesis: is this science at all?

We've had to introduce a hypothesis of many other universes, which are in principal completely unobservable.

Science should be constrained by observations. We confront theories with observations. The theories either match the observations or they fall. But if we can never carry out this test, how can we test the theory?