Philosophy and the Sciences

Introduction to the Philosophy of the Physical Sciences

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The origins of our universe

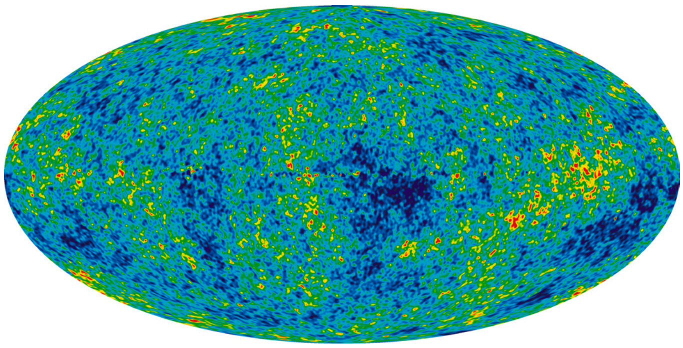
How did our universe form and evolve?
Was there really a Big Bang, and what came before it?

Why cosmology? What's so special about it?

For centuries cosmology was regarded as a branch of metaphysics rather than a science.

The Kant–Laplace nebular hypothesis is one of the first attempts at a scientific explanation of the origins of the universe.

Cosmology faces three distinctive methodological problems as a science: the applicability of the laws of nature, the uniqueness of its object of study, and the unobservability of vast portions of the universe.



The image reveals 13.77 billion year old temperature fluctuations (shown as color differences) that correspond to the seeds that grew to become the galaxies. (NASA)

A brief history of cosmology

• We know that the universe is expanding thanks to the observed *redshift* of the spectrum of light coming galaxies. In 1929, Edwin Hubble announced that almost all galaxies appeared to be moving away from us.

• De Sitter found the first expanding cosmological model.

• This expansion obeys *Hubble's Law*:

H= vD
v=recessional velocity of the galaxy,
H= Constant of proportionality:
Hubble's Constant, D= Proper distance to the galaxy

Philosophical difficulties with the expanding universe

There is no 'outside'.

We are not at the centre of the universe – there is no centre.

Space is not 'stretching' locally (a common misconception)

To follow the evolution of an expanding universe, we've got to deal with gravity.

Newton's law of gravitation

$$F = G\frac{m_1 m_2}{r^2}$$

This equation was replaced in 1915 by **Einstein**'s theory of general relativity: Matter moves along curved space-time.

Einstein changed the law of gravity, introducing a **Cosmological Constant Λ**, giving a density to empty space. This constant would later be replaced by **Dark Energy**.

The origin of the expansion lay in a past singularity -**the Big Bang.** With the discovery of the **Cosmic Microwave Background** in 1965, this hot origin for the universe became the accepted picture.

The early universe was small and hot. Only when the universe is expanded and cooled can protons and electrons come together, and make ordinary atoms.

According to the current cosmological model, the main constituents of the universe seem to be **dark matter** and **dark energy**. The former is a form of matter; the latter is an energy density associated with the vacuum, which causes the expansion of the universe to accelerate.

Open unanswered questions

If the universe began with the Big Bang, what happened before?

Why did the universe start expanding?

And why did the universe contain small fluctuations in density that subsequently formed the galaxies that we now inhabit?

Three problems for cosmology

1. Laws of nature

How can we be sure that the same laws we know today, apply also to the origins of the universe? Did not our laws come into existence with the existence of our universe? How can we extrapolate from the present physics and its laws, to the physics of the early universe?

• Hermann Bondi and other defenders of the steady-state universe introduced the *Perfect Cosmological Principle*, which postulates that the universe is homogeneous in its physical laws.

• But the steady-state universe has long been disproved by experimental evidence (e.g. CMB) about an evolving universe.

• The physicist **Lee Smolin** defends that laws are not timeless and eternal but instead they evolve in real time.

2. Uniqueness

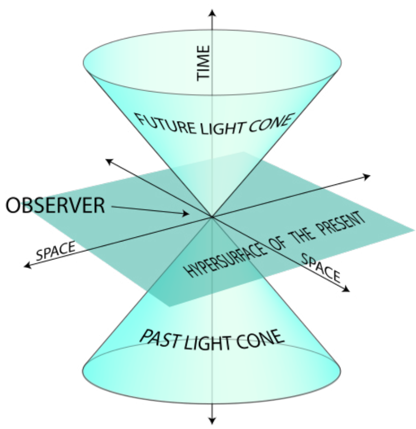
If repeating tests on multiple samples and in different circumstances is key to experimenting, cosmology faces a problem. We have only one object to observe and to experiment upon: our universe, unique and unrepeatable that it is.

• **Popper** believed that the method of science consisted in a deductive method, whereby given a hypothesis or conjecture with risky novel predictions, scientists go about and search for one single piece of negative evidence that can potentially falsify the hypothesis.

3. Unobservability

The past light cone, i.e. the parts of space that have been able to send information to us given the limit on the velocity of light constrains what we can 'observe'.

In an accelerating universe, like ours, there exists an event horizon: points sufficiently far apart can never contact each other. Thus, there are bound to be vast regions of our Universe that will remain forever unobservable to us. Hence , given our past light cone, we might inductively infer to very different, and yet observationally indistinguishable spacetime models, and no facts can make the inference to one of these models more legitimate or justified than to another.



Light cone by K. Aainsqatsi (CC BY-SA 3.0)