Multiverse

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Abstract: *Multiverse scenarios in cosmology assume that other universes exist "beyond" our own universe. They are an exciting challenge both for empirical and theoretical research as well as for philosophy of science. They could be necessary to understand why the big bang occurred, why (some of) the laws of nature and the values of certain physical constants are the way they are, and why there is an arrow of time. This essay clarifies competing notions of "universe" and "multiverse"; it proposes a classification of different multiverse types according to various aspects how the universes are or are not separated from each other; it reviews the main reasons for assuming the existence of other universes: empirical evidence, theoretical explanation, and philosophical arguments.*

Keywords: Big bang, universe, multiverse, cosmic inflation, time, quantum gravity, string theory, laws of nature, physical constants, fine- tuning, anthropic principle, philosophy of science, metaphysics, falsifications

1. INTRODUCTION

The multiverse (or meta-universe) is the hypothetical set of infinite or finite possible universes (including the universe we consistently experience) that together comprise everything that exists: the entirety of space, time, matter, and energy as well as the physical laws and constants that describe them. The various universes within the multiverse are sometimes called parallel universe or "alternative universes"

The structure of the multiverse, the nature of each universe within it and the relationships among the various constituent universes, depend on the specific multiverse hypothesis considered. Multiple universes have been hypothesized in cosmology, physics, astronomy, religion, philosophy, transpersonal psychology, and fiction, particularly in science fiction and fantasy. In these contexts, parallel universes are also called "alternative universes", "quantum universes", "interpenetrating dimensions", "parallel dimensions", "parallel worlds", "alternative realities", "alternative timelines", and "dimensional planes," among others. The term 'multiverse' was coined in 1895 by the American philosopher and psychologist William James in a different context.

The multiverse hypothesis is a source of debate within the physics community. Physicists disagree about whether the multiverse exists, and whether the multiverse is a proper subject of scientific inquiry. Supporters of one of the multiverse hypotheses include Stephen Hawking, Steven Weinberg, Brian Greene, Max Tegmark, Alan Guth, Andrei Linde, Michio Kaku, David Deutsch, Leonard Susskind, Raj Pathria, Sean Carroll, Alex Vilenkin,Laura Mersini-Houghton, and Neil deGrasse Tyson. In contrast, critics such as Jim Baggott, David Gross, Paul Steinhardt, George Ellis and Paul Davies have argued that the multiverse question is philosophical rather than scientific, that the multiverse cannot be a scientific question because it lacks falsifiability, or even that the multiverse hypothesis is harmful or pseudoscientific.

2. MULTIVERSE HYPOTHESES IN PHYSICS

Swedish-American cosmologist Max Erik Tegmark, an American theoretical physicists and many other physicists have hypothesized various classification schemes that categorize the various theoretical types of multiverse. Some of the prominent hypothesis are discussed below:

2.1 Max Tegmark's four levels hypothsis

Cosmologist Max Tegmark has provided a taxonomy of universes beyond the familiar observable universe.

The levels according to Tegmark's classification are arranged such that subsequent levels can be understood to encompass and expand upon previous levels, and they are briefly described below.

2.1.1 Level I: Beyond our cosmological horizon

A generic prediction of chaotic inflation is an infinite ergodic universe, which, being infinite, must contain Hubble volumes realizing all initial conditions. Accordingly, an infinite universe will contain an infinite number of Hubble volumes, all having the same physical laws and physical constants. In regard to configurations such as the distribution of matter, almost all will differ from our Hubble volume. However, because there are infinitely many, far beyond the cosmological horizon, there will eventually be Hubble volumes with similar, and even identical, configurations. Tegmark estimates that an identical volume to ours should be about 10^{10115} meters away from us. Given infinite space, there would, in fact, be an infinite number of Hubble volumes identical to ours in the universe. This follows directly from the cosmological principle, wherein it is assumed our Hubble volume is not special or unique.

2.1.2 Level II: Universes with different physical constants

In the chaotic inflation theory, a variant of the cosmic inflation theory, the multiverse as a whole is stretching and will continue doing so forever, but some regions of space stop stretching and form distinct bubbles, like gas pockets in a loaf of rising bread. Such bubbles are embryonic level I multiverses. Linde and Vanchurin calculated the number of these universes to be on the scale of $10^{1010,000,000}$. Different bubbles may experience different spontaneous symmetry breaking resulting in different properties such as different physical constants.

2.1.3 Level III: Many-worlds interpretation of quantum mechanics

Hugh Everett's many-worlds interpretation (MWI) is one of several mainstream interpretations of quantum mechanics. In brief, one aspect of quantum mechanics is that certain observations cannot be predicted absolutely. Instead, there is a range of possible observations, each with a different probability. According to the MWI, each of these possible observations corresponds to a different universe. Suppose a die is thrown that contains six sides and that the numeric result of the throw corresponds to a quantum mechanics observable. All six possible ways the die can fall correspond to six different universes. Tegmark argues that a level III multiverse does not contain more possibilities in the Hubble volume than a level I-II multiverse. In effect, all the different "worlds" created by "splits" in a level III multiverse with the same physical constants can be found in some Hubble volume in a level I multiverse. Tegmark writes that "The only difference between Level I and Level III is where your doppelgängers reside. In Level I they live elsewhere in good old three-dimensional space. In Level III they live on another quantum branch in infinite-dimensional Hilbert space." Similarly, all level II bubble universes with different physical constants can in effect be found as "worlds" created by "splits" at the moment of spontaneous symmetry breaking in a level III multiverse.

2.1.4 Level IV: Ultimate ensemble

The ultimate ensemble or mathematical universe hypothesis is the hypothesis of Tegmark himself. This level considers equally real all universes that can be described by different mathematical structures. Tegmark writes that "abstract mathematics is so general that any Theory Of Everything (TOE) that is definable in purely formal terms (independent of vague human terminology) is also a mathematical structure. For instance, a TOE involving a set of different types of entities (denoted by words, say) and relations between them (denoted by additional words) is nothing but what mathematicians call a set-theoretical model, and one can generally find a formal system that it is a model of." He argues this "implies that any conceivable parallel universe theory can be described at Level IV" and "subsumes all other ensembles, therefore brings closure to the hierarchy of multiverses, and there cannot be say a Level V."

Jürgen Schmidhuber, however, says the "set of mathematical structures" is not even well-defined, and admits only universe representations describable by constructive mathematics, that is, computer programs. He explicitly includes universe representations describable by non-halting programs whose output bits converge after finite time, although the convergence time itself may not be predictable by a halting program, due to Kurt Gödel's limitations. He also explicitly discusses the more restricted ensemble of quickly computable universes.

2.2 Brian Greene's hypothesis

American theoretical physicist and string theorist Brian Greene discussed nine types of parallel universes in his book "The Hidden Reality" published on 2011.

- The **quilted multiverse** only works in an infinite universe. With an infinite amount of space, every possible event will occur an infinite number of times. However, the speed of light prevents people from being aware of these other identical areas.
- The **inflationary multiverse** is composed of various pockets where inflaton fields collapse and form new universes.
- The **brane multiverse** follows from M-theory and states that each universe is a three-dimensional brane that exists with many others. Particles are bound to their respective branes except for gravity.
- The **cyclic multiverse** has multiple branes (each a universe) that collided, causing Big Bangs. The universes bounce back and pass through time, until they are pulled back together and collide again, destroying the old contents and creating them anew.
- The **landscape multiverse** relies on string theory's Calabi-Yau shapes. Quantum fluctuations drop the shapes to a lower energy level, creating a pocket with a different set of laws from the surrounding space.
- The **quantum multiverse** creates a new universe when a diversion in events occurs, as in the many-worlds interpretation of quantum mechanics.
- The **holographic multiverse** is derived from the theory that the surface area of a space can simulate the volume of the region.
- The **simulated multiverse** exists on complex computer systems that simulate entire universes.
- The **ultimate multiverse** contains every mathematically possible universe under different laws of physics.

3. Multiverse hypotheses in philosophy and logic

3.1 Model realism

Possible worlds are a way of explaining probability, hypothetical statements and the like, and some philosophers such as David Lewis believe that all possible worlds exist, and are just as real as the actual world (a position known as modal realism).

3.2 Trans-world identity

A metaphysical issue that crops up in multiverse schema that posit infinite identical copies of any given universe is that of the notion that there can be identical objects in different possible worlds. According to the counterpart theory of David Lewis, the objects should be regarded as similar rather than identical.

3.3 Fictional realism

The view that because fictions exist, fictional characters exist as well. There are fictional entities, in the same sense in which, setting aside philosophical disputes, there are people, Mondays, numbers and planets.

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