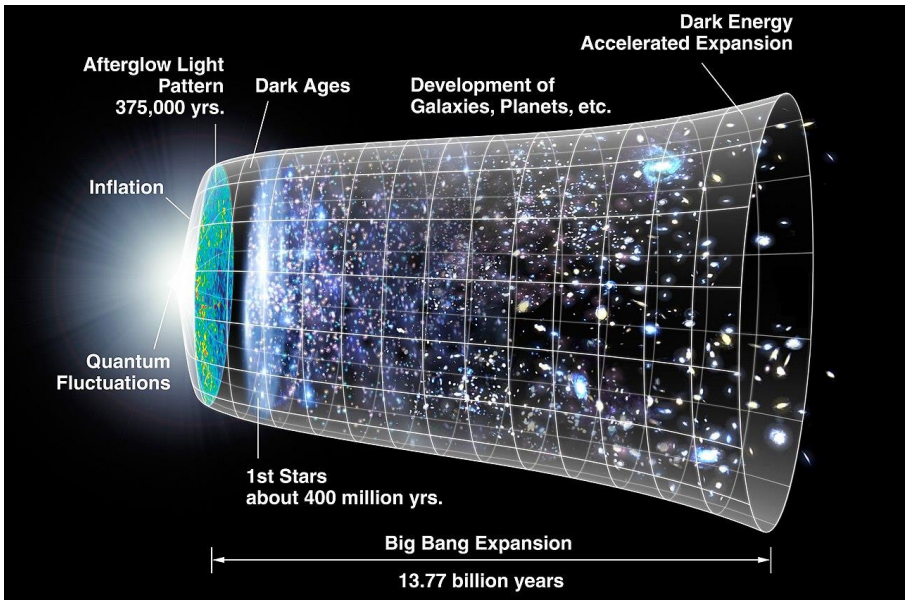
The Early Universe

Cosmologists agree that the current Universe has evolved from an extremely dense and hot state and refer to the phase the Universe underwent 13.8 billion years ago as the Big Bang, which would have been followed by a sudden inflation.

Origin and expansion of the Universe

In this diagram, time increases from left to right and one space dimension has been removed. At a given moment, the Universe, which appears spatially infinite, is represented by a section of the diagram. At the very beginning of its evolution, the Universe underwent a sudden phase of inflation. Over the following billion years, the expansion of the Universe slowed down under the effect of its own gravity. More recently, under the effect of dark energy, the expansion has been accelerating again.



Credit: NASA/WMAP Science Team

The term Big Bang, as famous as it is misleading, likens the beginning of the Universe to an explosion that dispersed matter in all directions to fill a supposedly empty space. But it is space itself that is expanding, increasing the distances between the objets dragged along in its expansion. The term Big Bang was coined in 1949 by Fred Hoyle. At the time, Hoyle thought he was mocking a new theory on the beginning of the Universe, without suspecting that it would end up gaining acceptance, just as the term used to refer to it today.

This theory dates back to the mid-1920s when Alexander Friedmann and Georges Lemaître independently laid the foundation for the expansion of the Universe, based on Einstein's general relativity. At the same time, Edwin Hubble, who was studying the distant Universe, noticed that the most distant galaxies were those with the greatest redshift in the lines observed in their spectrum. As early as in 1929, Hubble published this proportionality relation as a law that bears his name.

The Hubble law does not stem from galaxies moving through space whose redshifting would be due to the Doppler effect. Galaxies do not move away: they are contained in an expanding space. And general relativity implies that the wavelength of the radiation produced by a resting galaxy in an expanding space-time increases all the more as the galaxy is distant.

In 1948 George Gamow postulated the existence of a radiation permeating the entire Universe whose energy density decreases as the Universe expands. In 1965 Arno Penzias and Robert Wilson identified this cosmic microwave background radiation. Proving the existence of a very dense and hot phase of the Universe, this radiation is one of the three pillars of the Big Bang theory, along with the expansion of the Universe and primordial nucleosynthesis.

Alan Guth

One of the 'fathers' of the concept of inflation

The observable Universe is assumed to be homogeneous and isotropic. This entails postulating that in the immediate aftermath of the Big Bang all distances increased by a huge factor ($\sim 10^{50}$) in a very short time ($\sim 10^{-50}$ s), compared with the much smaller factor expansion (~1,000) that prevailed over the following 13.8 billion years. As a result of such an inflationary phase, vast regions in today's Universe would have been small at the time of the Big Bang and therefore likely to have been homogenised.

An inflationary phase would also explain the temperature fluctuations seen in the cosmic microwave background radiation; they would be the seeds of the large structures that can be observed today. However, any confirmation of the inflation concept will have to await a better understanding of the laws of physics that governed the early Universe.

Translated from 'Le début de l'Univers',* Passeport pour les deux infinis, *IN2P3/Dunod, https://pass2i.ijclab.in2p3.fr/ (French); updated with ICHEP2024 conference (https://ichep2024.org) for IPPOG