The Dark Ages of the Universe

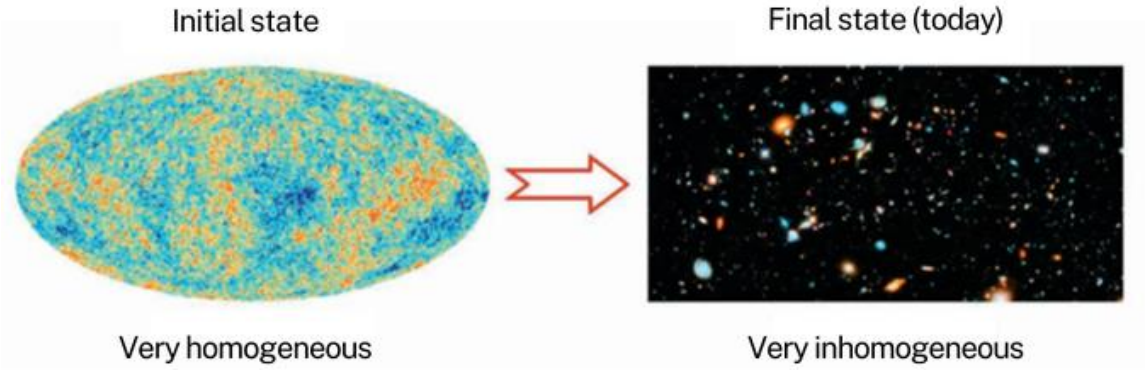
In its early stages, the Universe went from being very homogeneous to a state close to the one known today.

13.8 billion years ago the Universe was much denser and hotter. It was also much more homogeneous: the density of matter was almost exactly the same at every point of space. Today, the situation is quite different: here, galaxies and their stars; there, vacuum. The transition from one state to the other is precisely the “adolescence” of the Universe. This transition period began 380,000 years after the Big Bang, when the Universe became transparent to its own radiation. It ended a few hundred million years later, when ordinary matter was sufficiently concentrated for the first stars to ignite. In between, no stars shone, hence the other name given to this period: the Dark Ages.

But how do we go from a seemingly so simple primordial Universe to the incredible complexity observed in the cosmos today? In reality, ordinary matter is a very small minority in the Universe. Another type of matter is present everywhere, and in much greater proportion. It is this dark matter, whose nature remains a mystery, that concentrated under the effect of its own mass and dragged ordinary matter with it as it collapsed.

Current evolution of the Universe

The small inhomogeneities in the cosmological background radiation (image on the left) correspond to the seeds of the galaxies that are observed today. The Dark Ages of the Universe play a crucial part in the transition from a very homogeneous initial state to the very inhomogeneous state astronomers can see today.



Credit: from P. Brun

Caught in the dark matter crucible, ordinary matter concentrated to the point where the increasing density enabled nuclear fusion reactions to start and the first stars to ignite. As soon as they began to shine, these stars produced streams of ultraviolet radiation that peeled away the atoms in the interstellar medium, which had remained neutral since recombination. This period, known as re-ionisation, marked the beginning of the Universe's maturity, with the great diversity of stars displayed today. Without dark matter, galaxies would probably never have formed.

Credit: J. Diemand, M. Kublen and P. Madau, Via Lactea project

The dark blue zones on the map of the cosmological background radiation (the initial state in the left figure) are the coldest; they are literally galaxy seeds. They signal that dark matter has started to concentrate, and with it, ordinary matter. To picture what was happening in the Universe at that time, imagine a very homogeneous cake batter in which lumps are forming. These lumps are the outlines of galaxies that will grow and merge with one another during the Dark Ages. The theoretical calculations describing this period are extremely complex. They involve the equations of general relativity, whose numerical resolution requires very powerful computers.

Invisible dark matter

If dark matter could be seen, here is what our galaxy would look like in 'negative' view: a huge lumpy halo of dark matter 20 times the diameter of the Milky Way's.

The lumps continued growing and merging even after the stars ignited. The massive halo of dark matter surrounding our own galaxy is undoubtedly populated by a myriad of such lumps, all of which are remnant evidence of the way the halo formed more than 12 billion years ago.

Translated from 'Les âges sombres 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