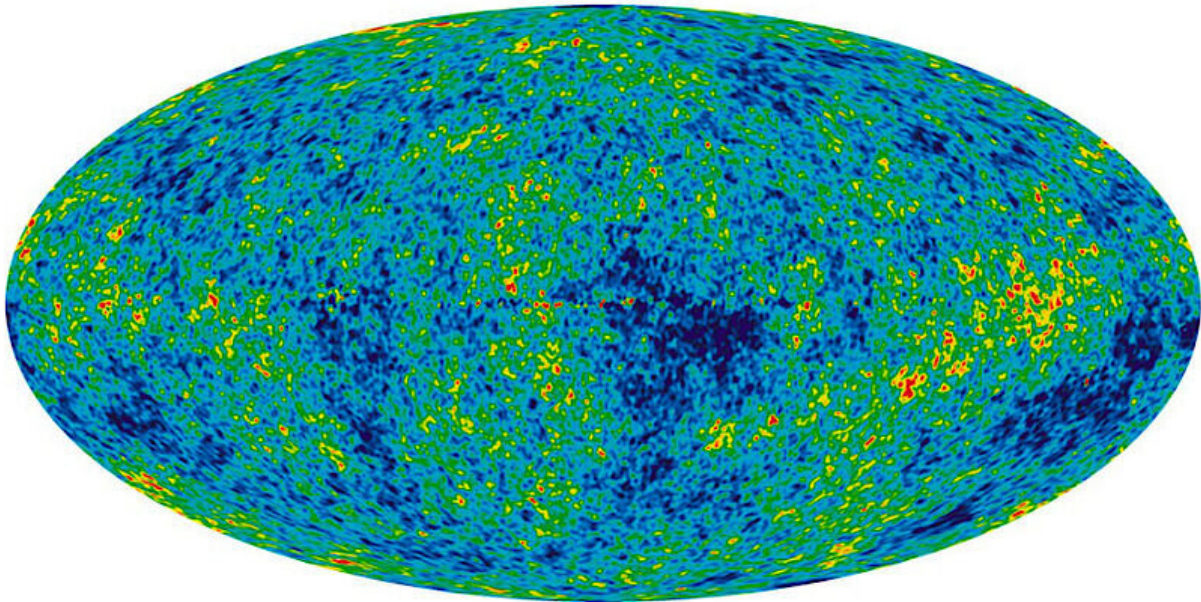


# Gravity causes homogeneity of the universe

September 24 2020, by Pia Gärtner

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During its expansion, the universe evolved towards its present state, which is homogeneous and isotropic on large scales. This is inferred, among other things, from the measurement of the so-called background radiation as nicely seen in the full sky image of the WMAP data. New results published in the renowned journal PRL show that homogenization in the investigated class of cosmological models is already completely explained by Einstein's theory of gravity and does not require any additional modifications. Credit: NASA / WMAP Science Team

Gravity can accelerate the homogenization of space-time as the universe evolves. This insight is based on theoretical studies of the physicist

David Fajman of the University of Vienna. The mathematical methods developed within the research project allow to investigate fundamental open questions of cosmology such as why the universe today appears so homogeneous. The results have been published in the journal *Physical Review Letters*.

The temporal evolution of the [universe](#), from the Big Bang to the present, is described by Einstein's field equations of general relativity. However, there are still a number of open questions about cosmological dynamics, whose origins lie in supposed discrepancies between [theory](#) and observation. One of these open questions is: Why is the universe in its present state so homogeneous on large scales?

## **From the Big Bang to the present**

It is assumed that the universe was in an extreme state shortly after the Big Bang, characterized in particular by strong fluctuations in the curvature of spacetime. During the long process of expansion, the universe then evolved towards its present state, which is homogeneous and isotropic on large scales—in simple terms: the cosmos looks the same everywhere.

This is inferred, among other things, from the measurement of the so-called background radiation, which appears highly uniform in every direction of observation. This homogeneity is surprising in that even two regions of the universe that were causally decoupled from each other—i.e., they could not exchange information—still exhibit identical values of background radiation.

## **Alternative theories**

To resolve this supposed contradiction, the so-called inflation theory was

developed, which postulates a phase of extremely rapid expansion immediately after the Big Bang, which in turn can explain the homogeneity in the background radiation.

However, how this phase can be explained in the context of Einstein's theory requires a number of modifications of the theory, which seem artificial and cannot be verified directly.

## **New findings: Homogenization by gravitation**

Up to now, it was not clear whether the homogenization of the universe can be explained completely by Einstein's equations. The reason for this is the complexity of the equations and the associated difficulty to analyze their solutions—models for the universe—and to predict their behavior.

In the concrete problem, the [time evolution](#) of the originally strong deviations from the homogeneous state as cosmological gravitational waves has to be analyzed mathematically. It has to be shown that they decay in the course of the expansion thus allowing the universe to get its homogeneous structure.

Such analyses are based on modern [mathematical methods](#) in the field of geometric analysis. Until now, these methods could only achieve such results for small deviations from the homogeneous space-time geometry. David Fajman from the University of Vienna has now succeeded for the first time to transfer these methods to the case of arbitrarily large deviations.

The results published in the renowned journal PRL show that homogenization in the investigated class of models is already completely explained by Einstein's theory and does not require any additional modifications. If this finding can be transferred to more general models,

it means that it does not necessarily need a mechanism like inflation to explain the state of our present universe, but that Einstein's theory could finally triumph once again.

**More information:** David Fajman. Future Attractors in 2+1 Dimensional  $\Lambda$  Gravity, *Physical Review Letters* (2020). [DOI: 10.1103/PhysRevLett.125.121102](https://doi.org/10.1103/PhysRevLett.125.121102)

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