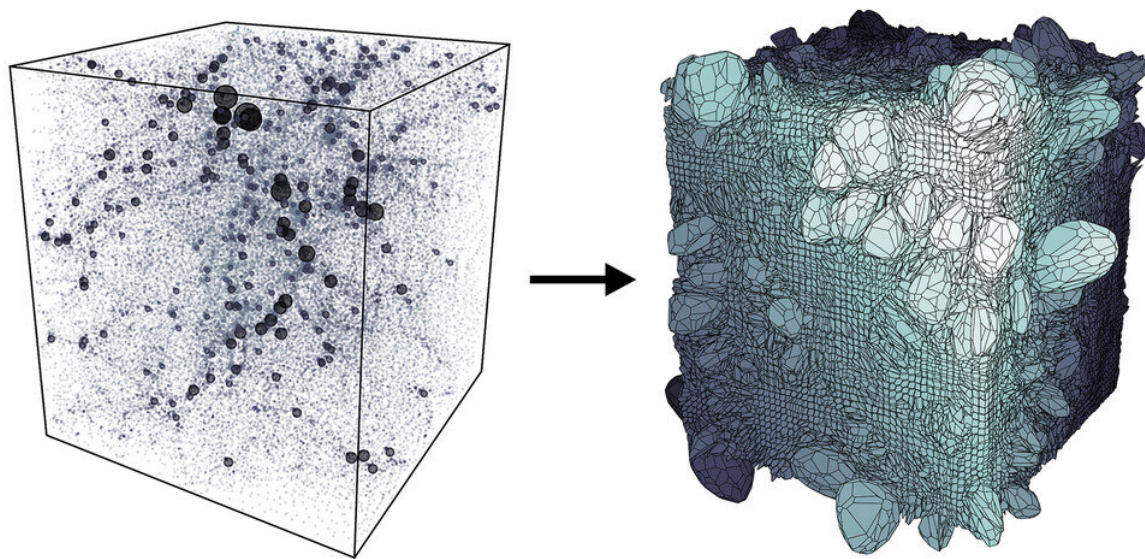


How the early universe developed 'lumpy clumps of matter'

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A new study led by Yale's Farnik Nikakhtar suggests that the universe, once "smooth and uniform with very tiny density fluctuations," very slowly became filled with lumpy clumps of matter. For the study, they used an algorithm based on the optimal transport theory—which seeks to understand the most efficient way of moving objects from place to another—to reconstruct the universe's initial density field. Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.129.251101

Ever feel like the universe is just a big carton of old milk? Well, you may be correct.

In a new study in the journal *Physical Review Letters*, Farnik Nikakhtar, a postdoctoral fellow in Yale's Department of Physics, theorizes that, ever-so-slowly, the universe has become filled with lumpy clumps of matter. "Initially smooth and uniform with very tiny density fluctuations," Nikakhtar said, "the universe became clumpier over time as gravity pulled more matter into denser regions."

Nikakhtar and his co-authors—Ravi K. Sheth of the University of Pennsylvania, Bruno Lévy of Centre Inria de Paris, and Roya Mohayaee of Institut d'Astrophysique de Paris and the University of Oxford—developed an "assumption-free" [algorithm](#) to model the universe's initial density. The algorithm is based on the mathematical concept of "Optimal Transport Theory," which seeks to understand the most efficient way of moving objects from one place to another.

"Optimal Transport is very well-suited to the problem of reconstructing the [universe's](#) initial density field," Nikakhtar said. "This method also opens up new possibilities for measuring cosmological parameters."

At Yale, Nikakhtar is working with associate professor of [physics](#) and astronomy Nikhil Padmanabhan to apply the [new algorithm](#) to observations from the Dark Energy Spectroscopic Instrument (DESI), a cosmological survey that will map 40 million galaxies and quasars.

More information: Farnik Nikakhtar et al, Optimal Transport Reconstruction of Baryon Acoustic Oscillations, *Physical Review Letters* (2022). [DOI: 10.1103/PhysRevLett.129.251101](https://doi.org/10.1103/PhysRevLett.129.251101)

Provided by Yale University

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