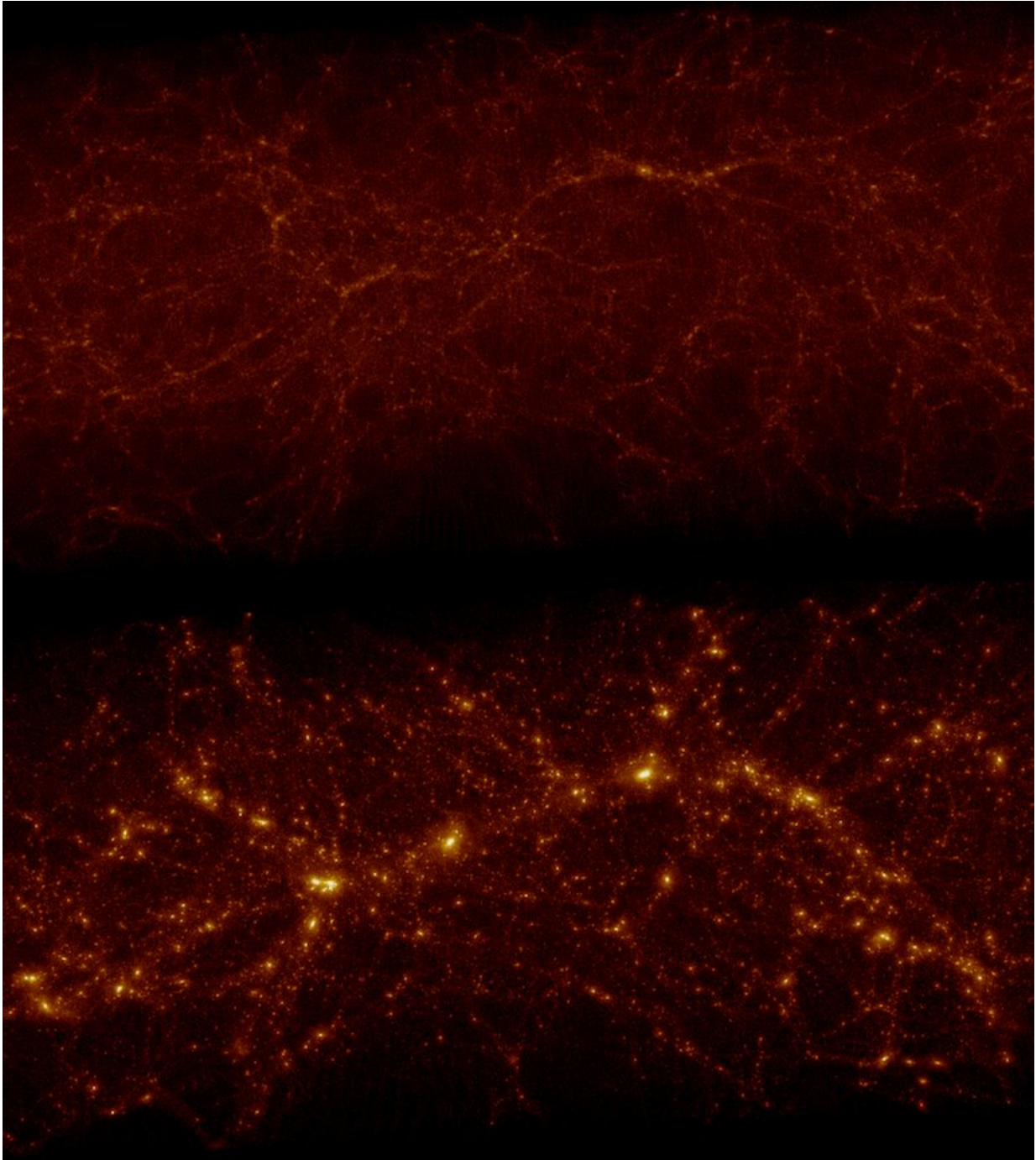


# 'Time machine' simulations created to study the lifecycle of ancestor galaxy clusters

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Screenshots from the simulation show (top) the distribution of matter corresponding to the observed galaxy distribution at a light travel time of 11 billion years (when the Universe was only 2.76 billion years old or 20% its current age), and (bottom) the distribution of matter in the same region after 11 billion light years or corresponding to our present time. Credit: Ata et al.

For the first time, researchers have created simulations that directly recreate the full life cycle of some of the largest collections of galaxies observed in the distant universe 11 billion years ago, reports a new study in *Nature Astronomy*.

Cosmological simulations are crucial in determining how the universe became the shape it is today, but many do not typically match what astronomers observe through telescopes. Most are designed to match the real universe only in a statistical sense. Constrained cosmological simulations, on the other hand, are designed to directly reproduce the structures we actually observe. However, most existing simulations of this kind have been applied to our local universe, meaning close to Earth, but never for observations of the [distant universe](#).

A team of researchers, led by Kavli Institute for the Physics and Mathematics of the Universe Project Researcher and first author Metin Ata and Project Assistant Professor Khee-Gan Lee, were interested in distant structures like massive galaxy protoclusters, which are ancestors of present-day galaxy clusters before they could clump under their own gravity. They found current studies of distant protoclusters were sometimes oversimplified, meaning they were done with simple models and not simulations.

"We wanted to try developing a full simulation of the real distant universe to see how structures started out and how they ended," said Ata.

Their result was COSTCO (CONstrained Simulations of The COsmos Field).

Lee said developing the simulation was much like building a [time machine](#). Because light from the distant universe is only reaching Earth

now, the [galaxies](#) that telescopes observe today are a snapshot of the past.

"It's like finding an old black-and-white picture of your grandfather and creating a video of his life," he said.

In this sense, the researchers took snapshots of "young" grandparent galaxies in the universe and then fast-forwarded their age to study how clusters of galaxies would form.

The light from galaxies the researchers used traveled a distance of 11 billion light-years to reach us.

What was most challenging was taking the large scale environment into account.

"This is something that is very important for the fate of those structures whether they are isolated or associated with a bigger structure. If you don't take the environment into account, then you get completely different answers. We were able to take the large scale environment into account consistently, because we have a full [simulation](#), and that's why our prediction is more stable," said Ata.

Another important reason why the researchers created these simulations was to test the standard model of cosmology, which is used to describe the physics of the universe. By predicting the final mass and final distribution of structures in a given space, researchers could unveil previously undetected discrepancies in our current understanding of the [universe](#).

Using their simulations, the researchers were able to find evidence of three already published galaxy protoclusters and disfavor one structure. On top of that, they were able to identify five more structures that

consistently formed in their simulations. This includes the Hyperion proto-supercluster, the largest and earliest proto-supercluster known today that is 5,000 times the mass of our Milky Way galaxy, which the researchers found out it will collapse into a large 300-million-light-year filament.

Their work is already being applied to other projects including those to study the cosmological environment of galaxies, and absorption lines of distant quasars to name a few.

Details of their study were published in *Nature Astronomy* on 2 June.

**More information:** Metin Ata et al, Predicted future fate of COSMOS galaxy protoclusters over 11 Gyr with constrained simulations, *Nature Astronomy* (2022). [DOI: 10.1038/s41550-022-01693-0](https://doi.org/10.1038/s41550-022-01693-0)

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