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The bubbling universe: A previously unknown phase transition in the early universe

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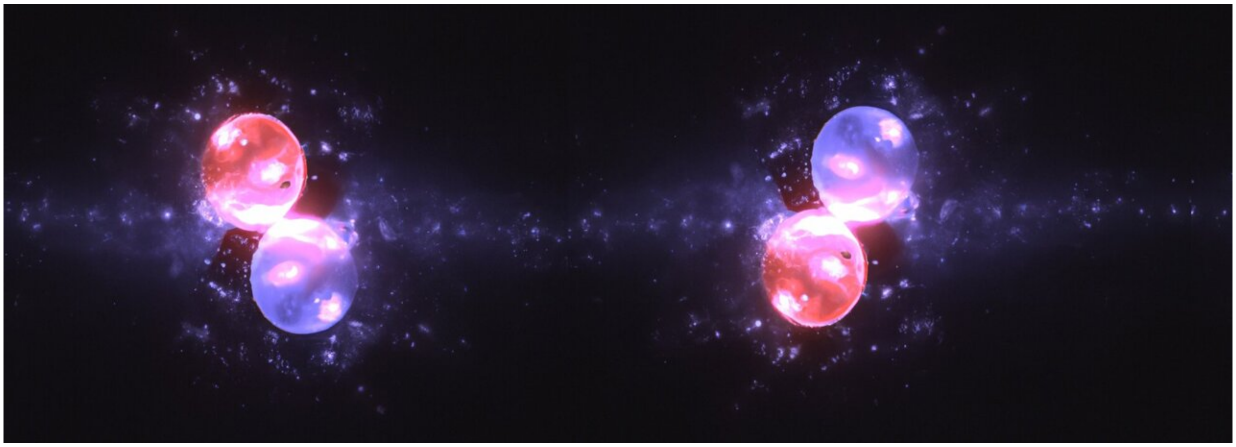


AI generated illustration of colliding bubbles in early universe. Credit: Birgitte Svennevig, University of Southern Denmark

Think of bringing a pot of water to the boil: As the temperature reaches the boiling point, bubbles form in the water, burst and evaporate as the water boils. This continues until there is no more water changing phase from liquid to steam.

This is roughly the idea of what happened in the very early universe, right after the Big Bang, 13.7 billion years ago.

The idea comes from particle physicists Martin S. Sloth from the Center for Cosmology and Particle Physics Phenomenology at University of Southern Denmark and Florian Niedermann from the Nordic Institute for Theoretical Physics (NORDITA) in Stockholm. Niedermann is a previous postdoc in Sloth's research group. In this new scientific article, they present an even stronger basis for their idea.

Many bubbles crashing into each other

"One must imagine that bubbles arose in various places in the early universe. They got bigger and they started crashing into each other. In the end, there was a complicated state of colliding bubbles, which released energy and eventually evaporated," said Martin S. Sloth.

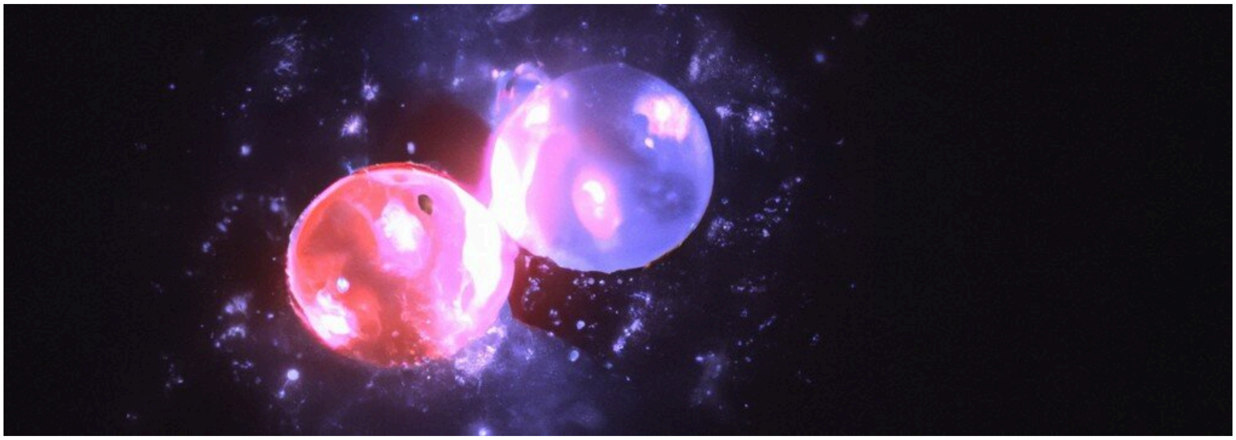
The background for their theory of phase changes in a bubbling universe is a highly interesting problem with calculating the so-called Hubble constant; a value for how fast the universe is expanding. Sloth and Niedermann believe that the bubbling universe plays a role here.

The Hubble constant can be calculated very reliably by, for example, analyzing cosmic background radiation or by measuring how fast a galaxy or an exploding star is moving away from us. According to Sloth and Niedermann, both methods are not only reliable, but also scientifically recognized. The problem is that the two methods do not lead to the same Hubble constant. Physicists call this problem "the Hubble tension."

Is there something wrong with our picture of the early universe?

"In science, you have to be able to reach the same result by using different methods, so here we have a problem. Why don't we get the same result when we are so confident about both methods?" said Florian Niedermann.

Sloth and Niedermann believe they have found a way to get the same Hubble constant, regardless of which method is used. The path starts with a phase transition and a bubbling universe—and thus an early, bubbling universe is connected to "the Hubble tension." "If we assume that these methods are reliable—and we think they are—then maybe the methods are not the problem. Maybe we need to look at the starting point, the basis, that we apply the methods to. Maybe this basis is wrong."



AI generated illustration of colliding bubbles in the universe. Credit: Birgitte Svennevig, University of Southern Denmark

An unknown dark energy

The basis for the methods is the so-called Standard Model, which assumes that there was a lot of radiation and matter, both normal and dark, in the early universe, and that these were the dominant forms of energy. The radiation and the normal matter were compressed in a dark, hot and dense plasma; the state of the universe in the first 380.000 years after Big Bang.

When you base your calculations on the Standard Model, you arrive at different results for how fast the universe is expanding—and thus different Hubble constants.

But maybe a new form of dark energy was at play in the early universe? Sloth and Niedermann think so.

If you introduce the idea that a new form of dark energy in the early universe suddenly began to bubble and undergo a phase transition, the calculations agree. In their model, Sloth and Niedermann arrive at the same Hubble constant when using both measurement methods. They call this idea New Early Dark Energy—NEDE.

Change from one phase to another—like water to steam

Sloth and Niedermann believe that this new, dark energy underwent a phase transition when the universe expanded, shortly before it changed from the dense and hot plasma state to the universe we know today.

"This means that the dark energy in the early universe underwent a phase transition, just as water can change phase between frozen, liquid and steam. In the process, the energy bubbles eventually collided with other bubbles and along the way released energy," said Niedermann.

"It could have lasted anything from an insanely short time—perhaps just the time it takes two particles to collide—to 300,000 years. We don't know, but that is something we are working to find out," added Sloth.

Do we need new physics?

So, the phase transition model is based on the fact that the universe does not behave as the Standard Model tells us. It may sound a little scientifically crazy to suggest that something is wrong with our fundamental understanding of the universe; that you can just propose the existence of hitherto unknown forces or particles to solve the Hubble tension.

"But if we trust the observations and calculations, we must accept that our current model of the universe cannot explain the data, and then we must improve the model. Not by discarding it and its success so far, but by elaborating on it and making it more detailed so that it can explain the new and better data," said Martin S. Sloth, adding, "It appears that a phase transition in the dark energy is the missing element in the current Standard Model to explain the differing measurements of the universe's expansion rate."

The findings are published in the journal *Physics Letters B*.

More information: Florian Niedermann et al, Hot new early dark energy: Towards a unified dark sector of neutrinos, dark energy and dark matter, *Physics Letters B* (2022). DOI: 10.1016/j.physletb.2022.137555

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