Astronomers develop novel way to 'see' the first stars through the fog of the early universe

July 21 2022

The REACH hexagonal dipole radio antenna has been installed on the Karoo radio reserve, South Africa. Credit: The REACH collaboration

A team of astronomers has developed a method that will allow them to "see" through the fog of the early universe and detect light from the first stars and galaxies.

The researchers, led by the University of Cambridge, have developed a methodology that will allow them to observe and study the first stars through the clouds of hydrogen that filled the universe about 378,000 years after the Big Bang.

Observing the birth of the first stars and galaxies has been a goal of astronomers for decades, as it will help explain how the universe evolved from the emptiness after the Big Bang to the complex realm of celestial objects we observe today, 13.8 billion years later.

The Square Kilometre Array (SKA)—a next-generation telescope due to be completed by the end of the decade—will likely be able to make images of the earliest light in the universe, but for current telescopes the challenge is to detect the cosmological signal of the stars through the thick hydrogen clouds.

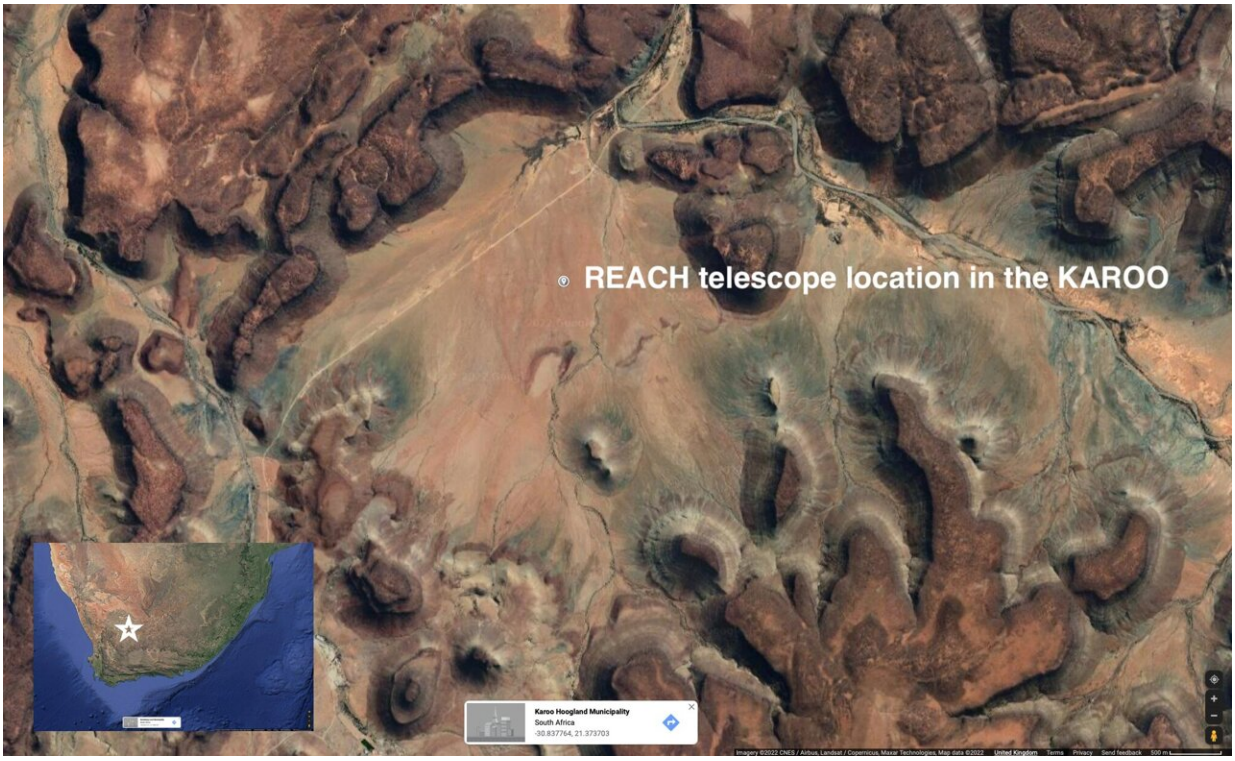
The signal that astronomers aim to detect is expected to be approximately one hundred thousand times weaker than other radio signals coming also from the sky—for example, radio signals originating in our own galaxy.

Using a radio telescope itself introduces distortions to the signal received, which can completely obscure the cosmological signal of interest. This is considered an extreme observational challenge in modern radio cosmology. Such instrument-related distortions are commonly blamed as the major bottleneck in this type of observation.

Now the Cambridge-led team has developed a methodology to see through the primordial clouds and other sky noise signals, avoiding the

detrimental effect of the distortions introduced by the radio telescope. Their methodology, part of the REACH (Radio Experiment for the Analysis of Cosmic Hydrogen) experiment, will allow astronomers to observe the earliest stars through their interaction with the hydrogen clouds, in the same way we would infer a landscape by looking at shadows in the fog.

Their method will improve the quality and reliability of observations from radio telescopes looking at this unexplored key time in the development of the universe. The first observations from REACH are expected later this year.



Aerial view of the observing site in the Karoo radio reserve, South Africa. Credit: Google Maps

The results are reported today in the journal *Nature Astronomy*.

"At the time when the first stars formed, the universe was mostly empty and composed mostly of hydrogen and helium," said Dr. Eloy de Lera Acedo from Cambridge's Cavendish Laboratory, the paper's lead author.

He added, "Because of gravity, the elements eventually came together and the conditions were right for nuclear fusion, which is what formed the first stars. But they were surrounded by clouds of so-called neutral hydrogen, which absorb light really well, so it's hard to detect or observe the light behind the clouds directly."

In 2018, another research group (running the "Experiment to Detect the Global Epoch of Reioniozation Signature"—or EDGES) published a result that hinted at a possible detection of this earliest light, but astronomers have been unable to repeat the result—leading them to believe that the original result may have been due to interference from the telescope being used.

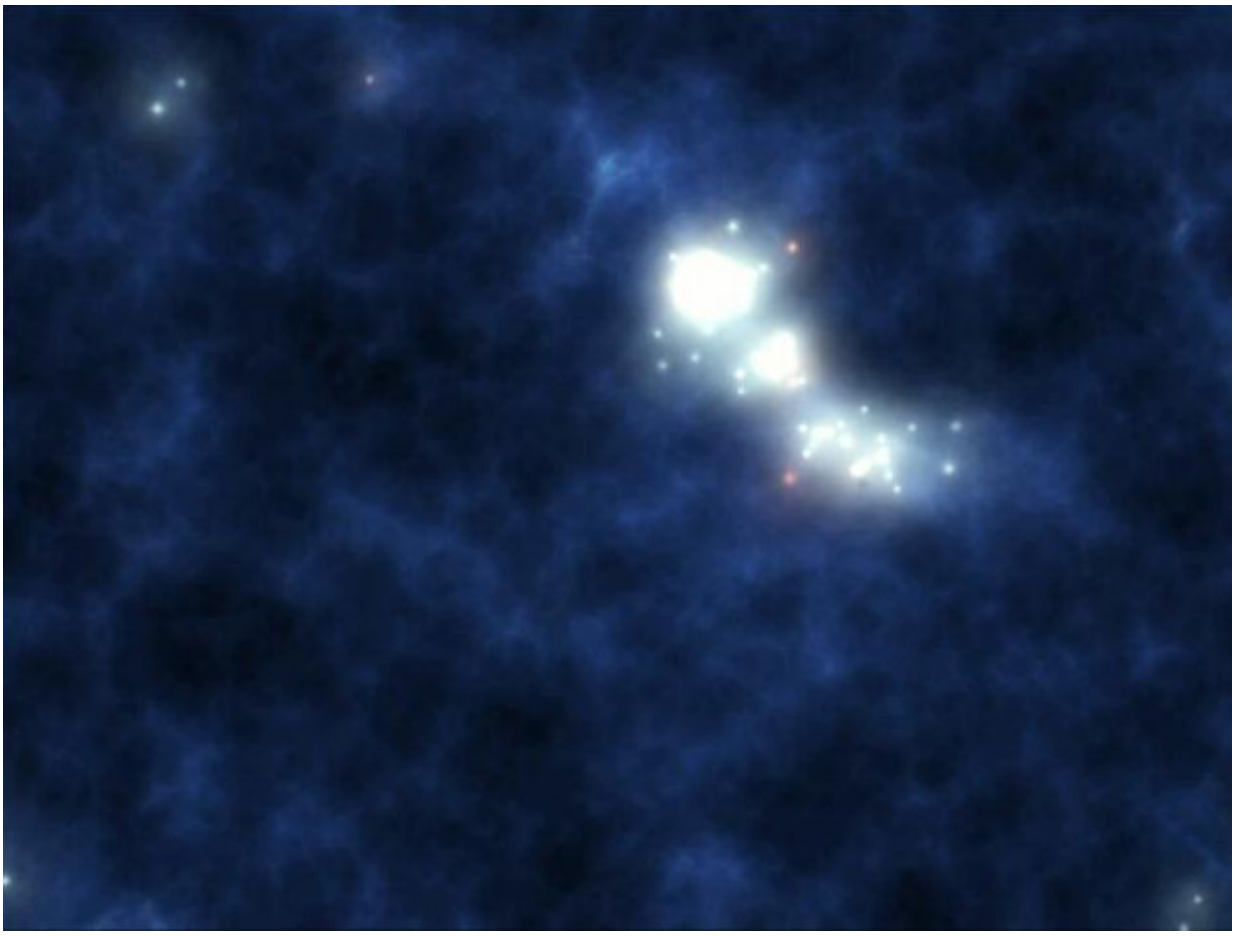
"The original result would require new physics to explain it, due to the temperature of the hydrogen gas, which should be much cooler than our current understanding of the universe would allow. Alternatively, an unexplained higher temperature of the background radiation—typically assumed to be the well-known Cosmic Microwave Background—could be the cause," said de Lera Acedo.

"If we can confirm that the signal found in that earlier experiment really was from the first stars, the implications would be huge."

In order to study this period in the universe's development, often referred to as the Cosmic Dawn, astronomers study the 21-centimeter line—an electromagnetic radiation signature from hydrogen in the early universe. They look for a radio signal that measures the contrast between

the radiation from the hydrogen and the radiation behind the hydrogen fog.

The methodology developed by de Lera Acedo and his colleagues uses Bayesian statistics to detect a cosmological signal in the presence of interference from the telescope and general noise from the sky, so that the signals can be separated.



Artist's impression of the emergence of stars in the early Universe. Credit: NASA/ JPL-Caltech

To do this, state-of-the-art techniques and technologies from different fields have been required.

The researchers used simulations to mimic a real observation using multiple antennas, which improves the reliability of the data—earlier observations have relied on a single antenna.

"Our method jointly analyzes data from multiple antennas and across a wider frequency band than equivalent current instruments. This approach will give us the necessary information for our Bayesian data analysis," said de Lera Acedo.

"In essence, we forgot about traditional design strategies and instead focused on designing a telescope suited to the way we plan to analyze the data—something like an inverse design. This could help us measure things from the Cosmic Dawn and into the epoch of reionization, when hydrogen in the universe was reionized."

The telescope's construction is currently being finalized at the Karoo radio reserve in South Africa, a location chosen for its excellent conditions for radio observations of the sky. It is far away from human-made radio frequency interference, for example television and FM radio signals.

The REACH team of over 30 researchers is multidisciplinary and distributed worldwide, with experts in fields such as theoretical and observational cosmology, antenna design, radio frequency instrumentation, numerical modeling, digital processing, big data and Bayesian statistics. REACH is co-led by the University of Stellenbosch in South Africa.

Professor de Villiers, co-lead of the project at the University of Stellenbosch in South Africa said, "Although the antenna technology

used for this instrument is rather simple, the harsh and remote deployment environment, and the strict tolerances required in the manufacturing, make this a very challenging project to work on."

"We are extremely excited to see how well the system will perform, and have full confidence we'll make that elusive detection."

The Big Bang and very early times of the universe are well understood epochs, thanks to studies of the Cosmic Microwave Background (CMB) radiation. Even better understood is the late and widespread evolution of stars and other celestial objects. But the time of formation of the first light in the Cosmos is a fundamental missing piece in the puzzle of the history of the universe.

More information: Eloy de Lera Acedo, The REACH radiometer for detecting the 21-cm hydrogen signal from redshift z ≈ 7.5–28, *Nature Astronomy* (2022). DOI: 10.1038/s41550-022-01709-9. www.nature.com/articles/s41550-022-01709-9

Provided by University of Cambridge

Citation: Astronomers develop novel way to 'see' the first stars through the fog of the early universe (2022, July 21) retrieved 21 September 2024 from https://phys.org/news/2022-07-astronomers-stars-fog-early-universe.html