Scientists think they have discovered what existed before the Big Bang

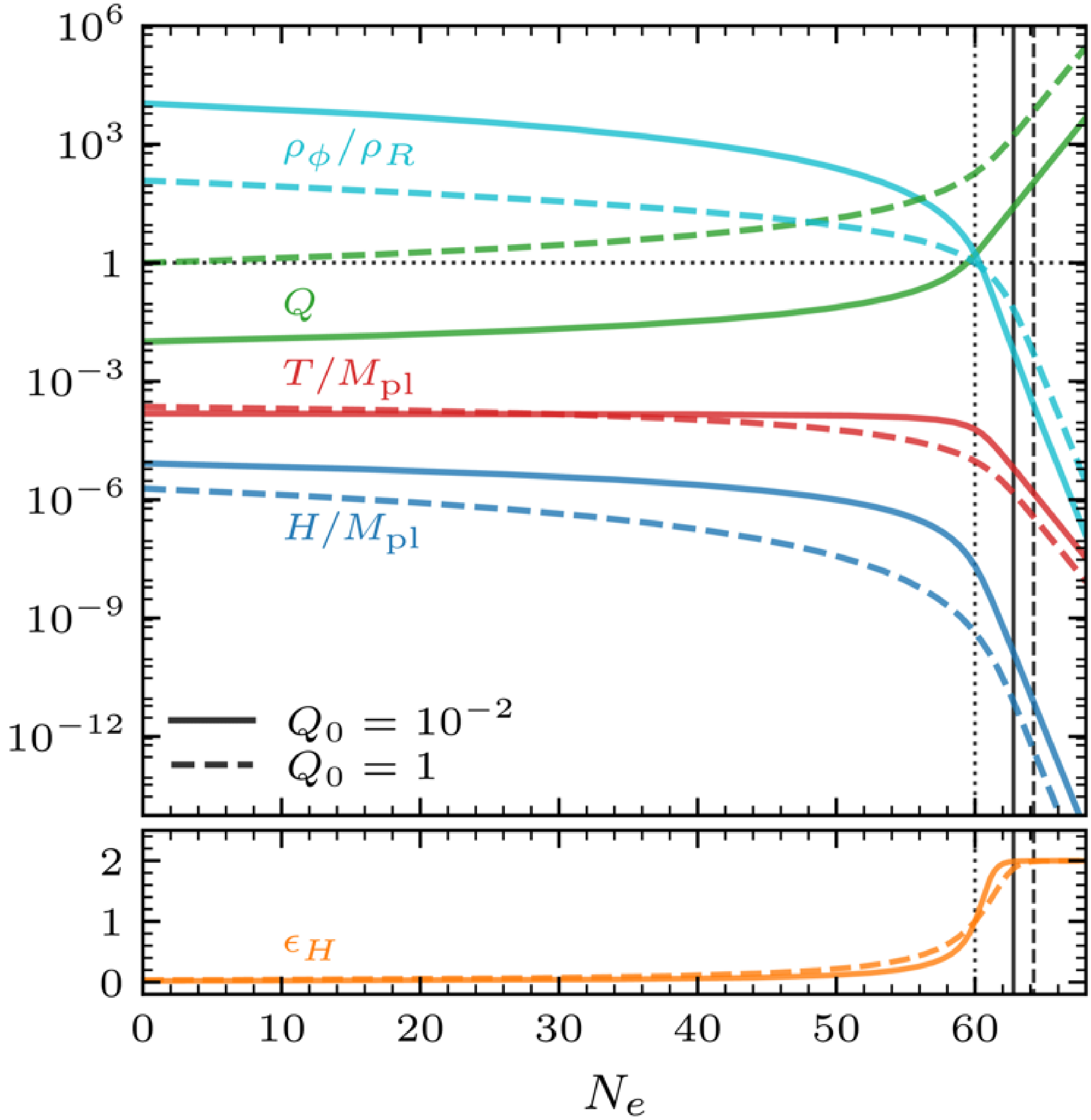
Around 85% of all matter in the universe remains invisible, eluding detection by today's most sophisticated scientific instruments

Dark matter has baffled physicists for nearly a century, quietly shaping our universe's unseen framework. Invisible yet influential, it provides the gravity necessary to hold galaxies together, driving their motion and structure.

About 85% of all matter in the universe stays hidden, undetectable even with today's best technology. Remarkably, scientists suspect this mysterious material may have existed even before the Big Bang.

In the 1930s, researchers first noticed oddities in how galaxies moved, suggesting something invisible exerted gravitational pull. Decades later, studies of the cosmic microwave background—the lingering radiation from the universe's birth—confirmed dark matter's importance in shaping cosmic evolution.

A pivotal study by the Planck Collaboration in 2018 revealed that dark matter makes up roughly 27% of the universe's total energy. By comparison, ordinary matter—the stuff of planets, stars, and us—accounts for only 5%.



The evolution of various quantities for the case of WI with V (ϕ)=λ ϕ4 as a function of the number of e-folds after the onset of inflation, for two initial values of the dissipation strength Q≡Υ/(3H), namely 10−2 (solid lines) and (dashed lines

Scientists have spent decades trying to understand what dark matter might be. Supersymmetry, a popular theory in particle physics, proposes a "partner" particle for every known particle, potentially offering clues about dark matter's identity.

From this theory, weakly interacting massive particles, or WIMPs, have become leading candidates for dark matter. These hypothetical particles barely interact with ordinary matter, yet experiments underground and at particle accelerators could possibly detect them.

Despite significant effort, WIMPs remain elusive. Experiments like DAMA have reported signals possibly tied to dark matter, but these findings are controversial. Attempts by other projects, such as COSINE-100, have not produced clear evidence to confirm DAMA's results.

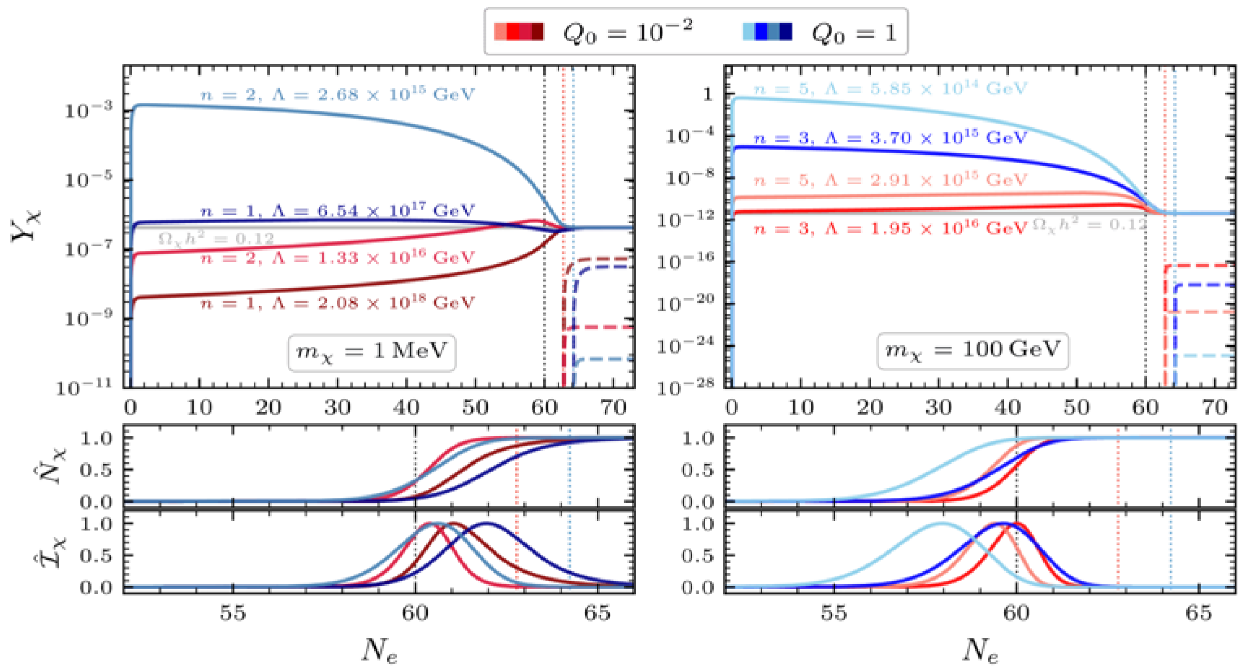
The powerful particle collisions at the Large Hadron Collider have also turned up empty-handed, finding no sign of the predicted SUSY particles. With this lack of evidence, the simplest WIMP-based theories now face serious doubts.

One such groundbreaking idea is the "Dark Big Bang" (DBB) theory, proposed in 2023 by Katherine Freese and Martin Winkler from the University of Texas at Austin. Unlike the conventional Big Bang, which explains the birth of ordinary matter, the DBB suggests that dark matter arose from a separate event.

This second Big Bang, occurring sometime after the first, would have generated dark matter through the decay of a quantum field trapped in a false vacuum state.

In this model, the early universe consisted of two sectors: the visible sector, filled with the familiar particles and forces, and a dark sector, which remained cold and decoupled. Eventually, the dark sector underwent its own phase transition, analogous to the visible sector's hot Big Bang.

This transition produced a thermal bath of dark particles, governed by a unique set of physical laws. The DBB model is particularly versatile, as it can accommodate a wide range of dark matter particle masses, from as light as a few keV to as heavy as 101210^{12}1012 GeV.



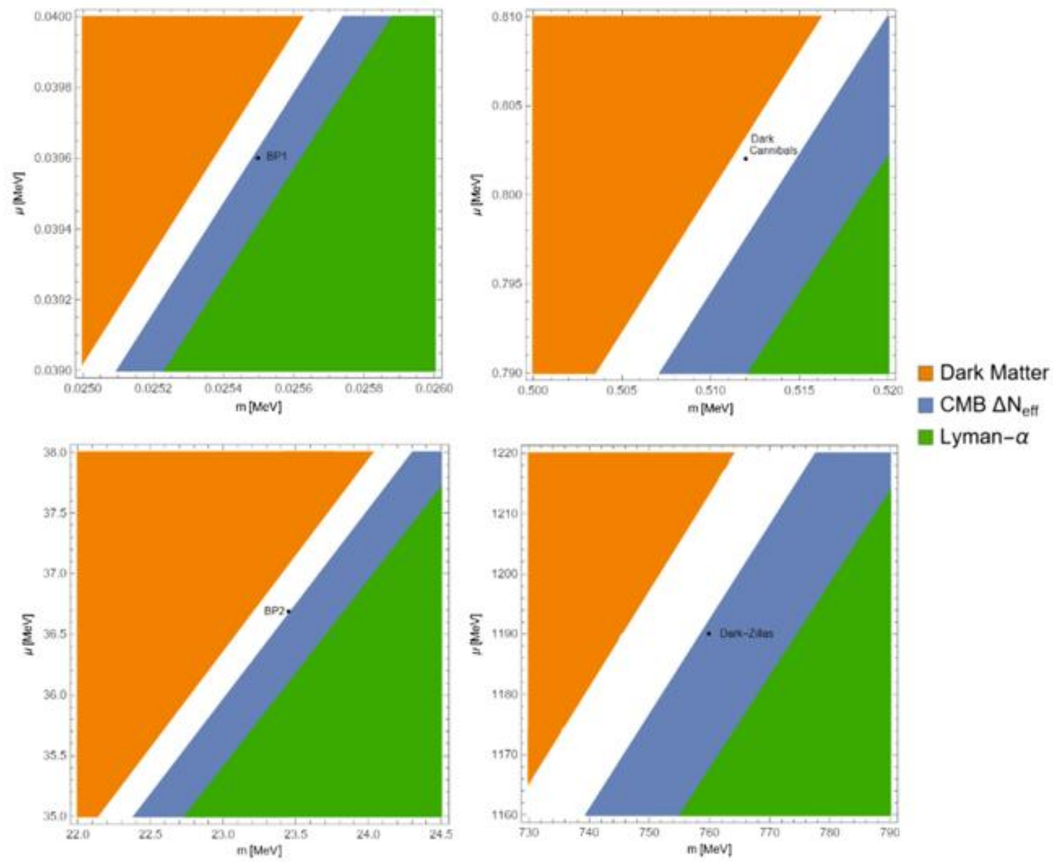
The DM yield Y χ as a function of the number of e-folds (solid lines), assuming vanishing initial DM abundance.

What sets the DBB model apart is its potential to leave observable traces. The phase transition in the dark sector could generate gravitational waves (GWs), ripples in the fabric of spacetime. These GWs would be distinct from those produced by black hole mergers or neutron star collisions and could be detected by next-generation observatories.

In particular, low-frequency GWs detectable by pulsar timing arrays (PTAs) such as the International Pulsar Timing Array (IPTA) and the Square Kilometer Array (SKA) could provide crucial evidence for the DBB.

Recent work by Cosmin Ilie, an Assistant Professor of Physics and Astronomy at Colgate University, and Richard Casey, a senior physics student, has further refined the DBB theory. Their study explores new parameter spaces for the dark sector's tunneling field, identifying scenarios that align with existing cosmological observations.

These scenarios predict not only the correct abundance of dark matter but also GW signals that could soon be within reach of PTA experiments.



The choices of parameters for BP1 (panel 1) and Dark-Zillas (panel 4) slightly violate the upper bound on α. These discrepancies do not significantly impact the results of [18], as the parameters can be adjusted slightly to produce the same phase transition characteristics used in their analysis.

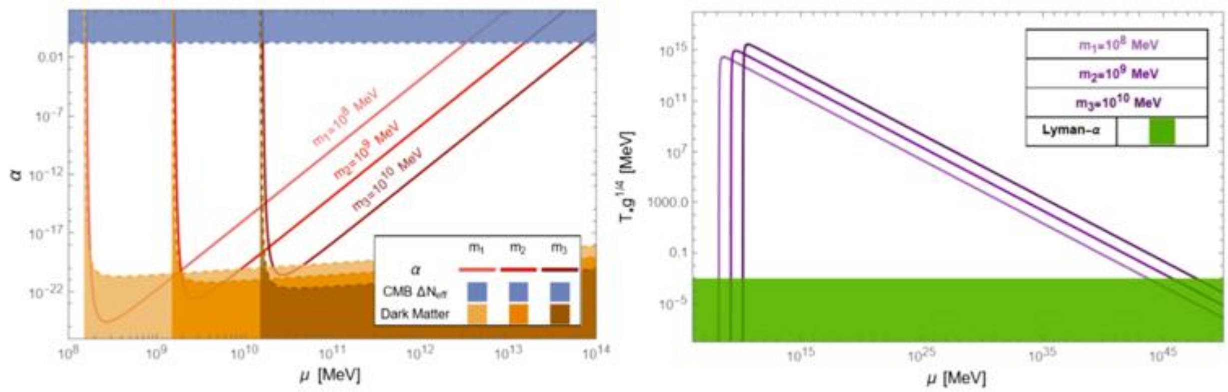
"Detecting gravitational waves generated by the Dark Big Bang could provide crucial evidence for this new theory of dark matter," says Ilie. Such detection would be groundbreaking, offering the first direct evidence of dark matter's distinct origin.

The 2023 detection of background GWs by the NANOGrav collaboration, a part of IPTA, adds an intriguing dimension to this research. While the exact source of these waves remains uncertain, they could potentially align with the DBB model's predictions.

Beyond its implications for dark matter, the DBB theory offers a fresh perspective on the early universe. Traditionally, cosmology has operated under the assumption that all matter, dark or otherwise, emerged from the same event.

The idea of a dual-origin universe challenges this notion, suggesting a more complex interplay of forces and fields in the universe's infancy. If confirmed, the

DBB model could reshape our understanding of cosmic evolution, from the formation of the first galaxies to the large-scale structure of the universe.



Left: values of α for fixed m. As before, α is bounded above by the CMB ΔNeff (blue) bound and below by the dark matter (orange) bounds. Right: temperature of the visible sector at the time of the DBB as a function of μ. (CREDIT: Phys.Rev.D)© The Brighter Side of News

The search for dark matter is a central pillar of modern physics, driving advancements in technology and theory. Direct detection experiments, such as those conducted deep underground, continue to push the boundaries of sensitivity, aiming to capture fleeting interactions between dark matter particles and ordinary matter.

Meanwhile, astrophysical observations, from the CMB to galactic rotation curves, provide indirect but compelling evidence for dark matter’s gravitational influence. The DBB model, with its unique predictions and testable consequences, adds a powerful new tool to this arsenal.

As observational capabilities advance, the prospect of detecting GWs from a DBB becomes increasingly plausible. Projects like SKA, expected to come online in the next decade, promise unprecedented sensitivity to low-frequency GWs. These efforts could finally lift the veil on dark matter's mysterious origins, answering questions that have puzzled scientists for generations.

In the broader context, understanding dark matter is not just a scientific pursuit but a quest to comprehend the fundamental nature of the universe. Whether through traditional particle physics or novel cosmological theories like the DBB, each discovery brings us closer to unveiling the full tapestry of existence.

The universe might have had a "secret life" before the Big Bang, a recent study has proposed.

Prior to the Big Bang, researchers say black holes were created as a result of the universe contracting, and this could possibly explain the enigmatic nature of dark matter.

The new study, which was recently published in the Journal of Cosmology and Astroparticle Physics, challenges the traditional belief that the universe originated from the Big Bang, which resulted in vast expansion.

Instead, after first contracting, the universe was in an extremely dense state and then began to "bounce" back in an expansion period, and it's this rebound that impacts what we understand about dark matter and black holes.

Density fluctuations may have brought about small black holes in the universe's contraction stage, which survived the expansion phase and can possibly make up the dark matter that adds up to around 80 per cent of the universe's total matter.

These findings could have major consequences on how we understand the universe, particularly where black holes and dark matter fit in all this.

It could provide a further understanding of the mystery of dark matter, as its lack of light interaction has baffled scientists.

"Small primordial black holes can be produced during the very early stages of the universe, and if they are not too small, their decay due to Hawking radiation [a hypothetical phenomenon of black holes emitting particles due to quantum effects] will not be efficient enough to get rid of them, so they would still be around now," said Patrick Peter, director of research at the French National Centre for Scientific Research (CNRS), who was not involved in the study.

"Weighing more or less the mass of an asteroid, they could contribute to dark matter, or even solve this issue altogether."

Now, researchers hope to find further evidence to support this cosmology theory with gravitational wave detectors, including the Laser Interferometer Space Antenna (LISA) and the Einstein Telescope, to find the waves produced when the primordial black holes were created.

Solving a 13-Billion-Year-Old Mystery: Scientists Recreate the Universe’s First Chemical Reaction

BY MAX PLANCK INSTITUTE FOR NUCLEAR PHYSICSAUGUST 2, 2025

Researchers have recreated key chemical reactions from the universe’s earliest moments with surprising results. Their findings may shed new light on how the first stars emerged from primordial darkness. (Artist’s concept). Credit: SciTechDaily.com

Researchers have uncovered new insights into the reaction pathways of the universe’s first molecule.

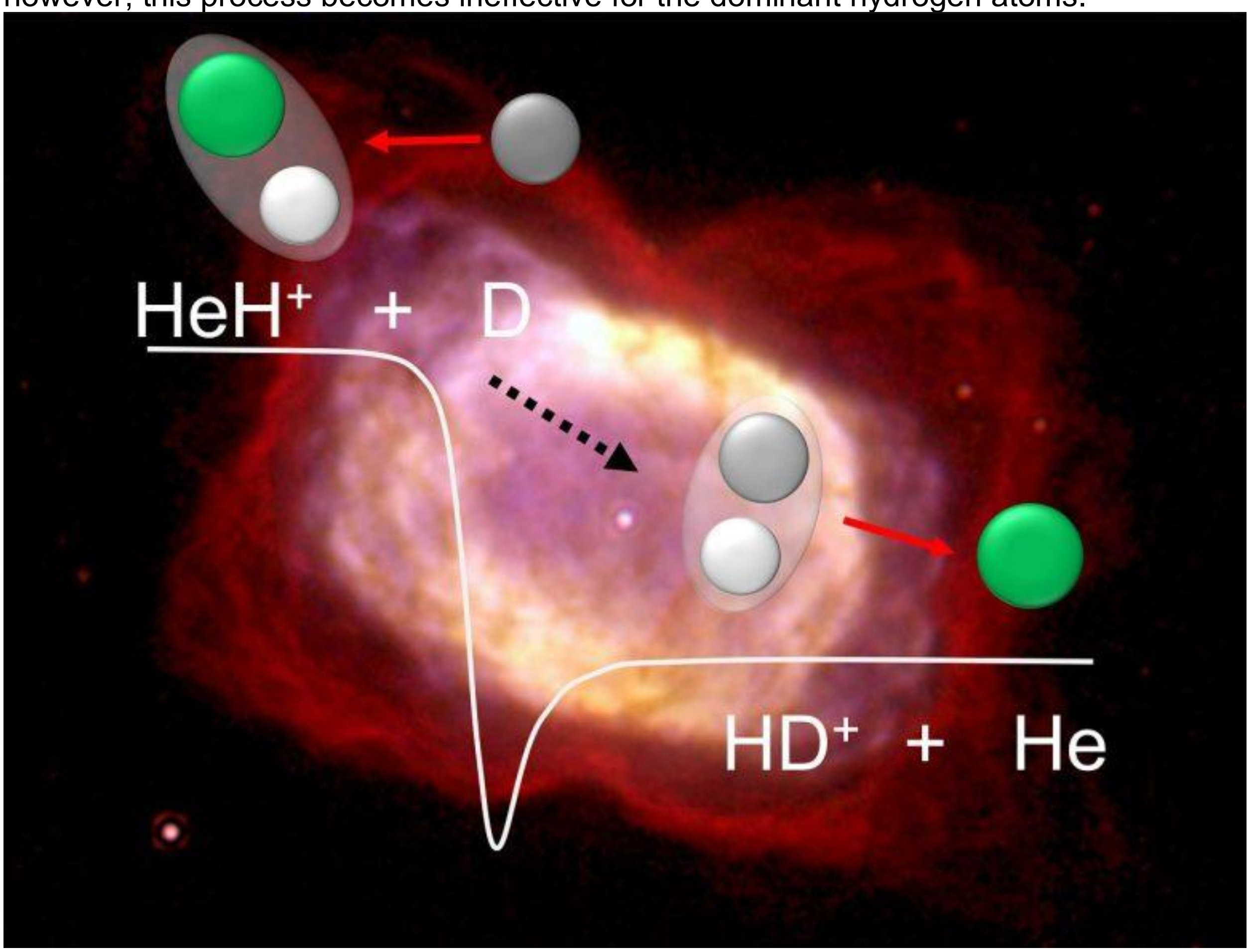
Shortly after the Big Bang, which took place around 13.8 billion years ago, the universe was a seething, dense expanse of extreme heat. In just a matter of seconds, it began to cool enough for the first atomic particles to come together, forming the lightest elements—hydrogen and helium. At this early stage, these elements were fully ionized, meaning their electrons were not yet bound to their nuclei. It would take another 380,000 years before the universe cooled sufficiently for neutral atoms to form. This process, known as recombination, allowed electrons to attach to nuclei, creating stable atoms and setting the stage for the first chemical interactions.

Among the earliest of these interactions was the creation of the helium hydride ion (HeH+), believed to be the first molecule ever to exist. This molecule formed when a neutral helium atom combined with a positively charged hydrogen nucleus. Its formation initiated a sequence of reactions that eventually led to molecular hydrogen (H_2), the most abundant molecule in the universe today.

After recombination, the universe entered what scientists call the "cosmic dark age." During this time, space had become transparent, as free electrons were now bound to atoms, but no stars or other light sources had yet emerged. It would be several hundred million years before the first stars lit up the cosmos.

Why Simple Molecules Mattered for Star Formation

During this early phase of the universe, however, simple molecules such as HeH^+ and H_2 were essential to the formation of the first stars. In order for the contracting gas cloud of a protostar to collapse to the point where nuclear fusion can begin, heat must be dissipated. This occurs through collisions that excite atoms and molecules, which then emit this energy in the form of photons. Below approximately 10,000 degrees Celsius, however, this process becomes ineffective for the dominant hydrogen atoms.



Reaction scheme and energetic level of the investigated reaction of the helium hydride ion with deuterium. It is a swift and barrierless reaction, contrary to earlier theories. Background: The planetary nebula NGC 7027, with molecular hydrogen visible in red. Credit: Schematic: MPIK; Background Image: W. B. Latter (SIRTF Science Center/Caltech) and NASA

Further cooling can only take place via molecules that can emit additional energy through rotation and vibration. Due to its pronounced dipole moment, the HeH^+ ion is particularly effective at these low temperatures and has long been considered a potentially important candidate for cooling in the formation of the first stars. Consequently, the concentration of helium hydride ions in the universe may significantly impact the effectiveness of early star formation.

During this period, collisions with free hydrogen atoms were a major degradation pathway for HeH^+, forming a neutral helium atom and an H_2^+ ion. These subsequently reacted with another H atom to form a neutral H_2 molecule and a proton, leading to the formation of molecular hydrogen.

Recreating the Early Universe in the Laboratory

Researchers at the Max-Planck-Institut für Kernphysik (MPIK) in Heidelberg have now successfully recreated this reaction under conditions similar to those in the early universe for the first time. They investigated the reaction of HeH^+ with deuterium, an isotope of hydrogen containing an additional neutron in the atomic nucleus alongside a proton. When HeH^+ reacts with deuterium, an HD^+ ion is formed instead of H_2^+, alongside the neutral helium atom.

The experiment was carried out at the Cryogenic Storage Ring (CSR) at the MPIK in Heidelberg — a globally unique instrument for investigating molecular and atomic reactions under space-like conditions. For this purpose, HeH^+ ions were stored in the 35-metre-diameter ion storage ring for up to 60 seconds at a few kelvins (-267 °C), and were superimposed with a beam of neutral deuterium atoms. By adjusting the relative speeds of the two particle beams, the scientists were able to study how the collision rate varies with collision energy, which is directly related to temperature.

They found that, contrary to earlier predictions, the rate at which this reaction proceeds does not slow down with decreasing temperature, but remains almost constant. “Previous theories predicted a significant decrease in the reaction probability at low temperatures, but we were unable to verify this in either the experiment or new theoretical calculations by our colleagues,” explains Dr. Holger Kreckel from the MPIK.

“The reactions of HeH^+ with neutral hydrogen and deuterium therefore appear to have been far more important for chemistry in the early universe than previously assumed,” he continues.

Implications for Star Formation and Cosmic Chemistry

This observation is consistent with the findings of a group of theoretical physicists led by Yohann Scribano, who identified an error in the calculation of the potential surface used in all previous calculations for this reaction. The new calculations using the improved potential surface now align closely with the CSR experiment.

Since the concentrations of molecules such as HeH^+ and molecular hydrogen (H_2 or HD) played an important role in the formation of the first stars, this result brings us closer to solving the mystery of their formation.

Reference: "Experimental confirmation of barrierless reactions between HeH+ and deuterium atoms suggests a lower abundance of the first molecules at very high redshifts" by F. Grussie, J. Sahoo, Y. Scribano, D. Bossion, L. Berger, M. Grieser, L. W. Isberner, Á. Kálosi, O. Novotný, D. Paul, A. Znotins, X. Urbain and H. Kreckel, 24 July 2025, *Astronomy & Astrophysics*.
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