Shining message about the end of the Dark Ages

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An international team, including researchers from the Centre for Astronomy of Heidelberg University (ZAH), has discovered three "cosmic Methusalems" from the earliest years of the universe. These unusual stars are about 13 billion years old and experts assign them to the first generations of stars after the "dark ages". The chemical qualities of these extremely rare stellar bodies enable new insights into the events that must have led to the origins of the stars. The first stars have been assumed to be high-mass and to shine especially brightly. However, the latest observations point to hitherto unknown phenomena in the young universe, allowing for the emergence of much smaller stars. This conclusion is suggested by analyses in part conducted at the State Observatory Königstuhl and at the Institute of Theoretical Astrophysics, both of which belong to the ZAH.

The universe emerged approximately 13.8 billion years ago through the big bang. The initially extremely hot gas of the "explosion cloud" expanded and grew colder and colder. As the cosmic expanses were completely empty of stars at the time, scientists talk of the "dark ages" of the universe. About 400 million years after the big bang, the first stars formed out of the gases created by the explosion. Due to the chemical composition of the initial gases – mainly hydrogen, helium and traces of lithium – the stars' mass must have been 10 to 100 times greater than that of the sun, and therefore they must have emitted an extremely brilliant light. They rapidly exhausted their nuclear fuel and so these stars only shone for a few million years. They disintegrated in gigantic explosions, during which heavy chemical elements were released and "recovered" by subsequent stellar generations. An exact chemical investigation of this second generation of stars can enable conclusions to be drawn regarding the properties of the very first stars.

The three original stars were discovered thanks to observations at the Paris observatory by a team of astronomers led by Dr. Piercarlo Bonifacio. Apart from hydrogen and helium they contain only extremely small quantities of other chemical elements, these include a striking amount of carbon. Astronomer Dr. Paolo Molaro from the Trieste observatory therefore suspects that they belong to a special – completely new – class of original stars. The programme at the European Southern Observatory (ESO) in Chile to observe such objects was initiated by Dr. Elisabetta Caffau during her time as Gliese Fellow of Heidelberg University at the Königstuhl Observatory. In order to be able to determine the extremely slight element frequencies with great accuracy, scientists use computer simulations of star atmospheres. These models are developed by Dr. Hans-Günter Ludwig, a researcher at the Königstuhl Observatory.

Events contributing to the formation of the first stars in the universe are being explored at the Institute of Theoretical Astrophysics by the Star Formation Group led by Prof. Dr. Ralf Klessen. He reports that carbon played a major role in the young universe as a "coolant" contributing to the contraction of interstellar gas into a star. The better the cooling, the smaller the stars that can form. Yet even with carbon the first stars should still have had at least ten times more mass than the newly discovered candidates. "Probably interstellar dust was the coolant contributing to the formation of these low-mass stars. We are now going to examine that in detail," says Prof. Klessen.

The current discoveries allow a fascinating new insight into the events surrounding the emergence of the first stars. Accordingly, these stars must not have arisen in isolation but in groups, Prof. Klessen underlines. The high-mass stars exploded after only a few million years, but far less violently than had been assumed. The Heidelberg scientist explains: "Only then could the lighter elements such as carbon or oxygen be projected far enough into

the cosmos to be of use to the new stars, which have a lower mass but a longer life." However, there is another puzzling question. The three newly discovered stars display no trace of lithium, although this chemical element is also contained in the original gas. For Dr. Marco Limongi from the Rome observatory, which is also part of the international research team, this is another mystery waiting to be elucidated.

More information: "TOPoS: II. On the bimodality of carbon abundance in CEMP stars." *Astronomy & Astrophysics* (in advance), dx.doi.org/10.1051/0004-6361/201425266

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