discovery, given the diversity of Ca^{2+} signals and behaviours exhibited by growth cones. ■

Timothy Gomez is in the Department of Anatomy, University of Wisconsin Medical School, 1300 University Avenue, Madison, Wisconsin 53706, USA.
e-mail: tmgomez@wisc.edu

1. Wang, G. X. & Poo, M. *Nature* **434,** 898–904 (2005).
2. Li, Y. *et al. Nature* **434,** 894–898 (2005).
3. Hong, K., Nishiyama, M., Henley, J., Tessier-Lavigne, M. & Poo, M. *Nature* **403,** 93–98 (2000).
4. Montell, C., Birnbaumer, L. & Flockerzi, V. *Cell* **108,** 595–598 (2002).
5. Greka, A., Navarro, B., Oancea, E., Duggan, A. & Clapham, D. E. *Nature Neurosci.* **6,** 837–845 (2003).
6. Jin, M. *et al. J. Neurosci.* **25,** 2338–2347 (2005).
7. Wen, Z. X., Guirland, C., Ming, G. L. & Zheng, J. Q. *Neuron* **43,** 835–846 (2004).
8. Robles, E., Huttenlocher, A. & Gomez, T. M. *Neuron* **38,** 597–609 (2003).
9. Henley, J. R., Huang, K. H., Wang, D. & Poo, M. M. *Neuron* **44,** 909–916 (2004).
10. Nishiyama, M. *et al. Nature* **423,** 990–995 (2003).

Astrophysics

Two's company

Roger Cayrel

The matter from which the first stars formed was that left behind by the Big Bang. Stars containing extremely small amounts of heavy elements such as iron provide clues to the chemical composition of this matter.

Identifying stars born at the beginning of the era of stellar formation proved a long and frustrating task. In 2002, however, Christlieb *et al.*[1] reported the discovery of the first such 'relic of the dawn of time'. Writing on page 871 of this issue, Frebel *et al.*[2] announce the discovery of a second. But why are these two objects so remarkable? And why does it help to have two instead of one?

Some 13.7 billion years ago, the Universe was much simpler than it is today. It consisted of a uniform, hot gas showing only small fluctuations in temperature and density, and containing no large structures — no galaxies, stars or planets. For the first 15 minutes of its existence, the temperature and density of this hot gas were high enough to allow the nuclear reactions necessary for the production of the lightest chemical elements. Heavier elements, such as the metals, were not produced in this first flurry of nucleosynthetic activity. After the first 15 minutes, the Universe's rapid expansion put an end to conditions that favoured nucleosynthesis and nothing more happened to the nuclear composition of the Universe for about 200 million years. The ingredients of this frozen primordial soup — principally, the light elements lithium and helium, as well as deuterium, a heavy isotope of hydrogen — are fairly well known from both theory and experiment[3].

A second opportunity for nuclear activity arose only when the original fluctuations of the early Universe had grown sufficiently large for haloes of dark matter to begin to form. This triggered gravitational instabilities and the collapse of conventional baryonic matter into clouds of gas, from which stars then formed[4]; in the cores of these stars, both the temperature and density reached values that again made nuclear reactions possible. Practically all the heavier elements, from carbon to uranium — the elements from which later solid planets and organic life formed — were synthesized in these first stars.

The search for stars with a composition reflecting that of these first stars has been going on for the past 25 years[5,6]. Before the discovery of the two 'relics' (HE0107−5240 by Christlieb *et al.*[1] and HE1327−2326 by Frebel *et al.*[2]), the lowest proportion, with respect to hydrogen, of stellar-made elements in the oldest stars was about a ten-thousandth of that observed in the Sun — a tiny amount, but, crucially, not zero. This finding seemed to support the theory that matter from the Big Bang was unable to fragment into stellar masses that were small enough for those stars still to be shining today: massive stars burn their fuel faster, and a star with a mass greater than around nine-tenths of the mass of the Sun would have exhausted its nuclear energy supply by now. Long-lived stars could thus be born only from interstellar gas already enriched in products of nucleosynthesis that had been expelled at the end of the evolution of earlier stars — either through a violent event such as a supernova, or through less dramatic mass loss, as is caused for example by stellar winds. If true, this would have ruled out any hope of finding a star with the primordial mix.

The discovery of HE0107−5240 and HE1327−2326, which have iron abundances respectively 200,000 and 300,000 times smaller than that of the Sun, is therefore of great significance. However, despite their impressively low iron content — well below the previous record, which stood for some 20 years before their discovery[7] — both stars contain a proportion of carbon that is only 25 times smaller than that of the Sun. And the deficiency of the various elements between carbon and iron in the periodic table increases steadily with increasing atomic number.

The main difference between the two relics is that, in the case of HE0107−5240, it proved impossible to determine whether lithium, carbon and nitrogen were still present in their original abundances. Frebel *et al.*[2], however, have been able to measure the abundance of lithium in HE1327−2326; surprisingly, it is far lower than that in other very old metal-poor stars. Other questions raised by HE1327−2326 are its abundance of nitrogen, which is 60 times larger than that of HE0107−5240; the shallower slope of the decrease of elemental abundances with atomic number; and the presence of strontium, not seen in HE0107−5240.

Previous work may help to unravel these mysteries. For example, it has been shown[8] that a supernova may expel only the upper layers of the nuclear matter of the pre-supernova star, enriching the carbon and oxygen content of the interstellar matter, whereas the iron falls back on to the remnant of the star. The abundance of iron in a star is irrelevant to the fragmentation process[9]: carbon and oxygen are thought to be the elements controlling the cooling of the interstellar matter, and it is their high abundance that allows the star to fragment into small masses.

Rotation can also produce devastating effects on the evolution of massive stars with low metal abundances[10]: if its initial rotation is sufficiently great, the star experiences a significant loss of mass, shedding great quantities of the first elements synthesized — helium, carbon, oxygen and magnesium. It is exactly these elements that are among the most abundant in HE0107−5240 and HE1327−2326. Rotation also triggers an efficient mixing mechanism that allows the synthesis of nitrogen as well as carbon and oxygen. This is of significance for HE1327−2326, in which — after hydrogen and helium, both of primordial origin — nitrogen is the most abundant element.

It is fascinating to see that, having taken 20 years to undercut the previous lowest iron abundance in a star, we have within two years found two stars containing more than an order of magnitude less iron. This is the reward for an enormous effort in observational work that is bringing new insights to the fragmentation process that occurred during the formation of the first stars. ■

Roger Cayrel is at the Observatoire de Paris-Meudon, 61 Avenue de l'Observatoire, 75014 Paris, France.
e-mail: roger.cayrel@obspm.fr

1. Christlieb, N. *et al. Nature* **419,** 904–906 (2002).
2. Frebel, A. *et al. Nature* **434,** 871–873 (2005).
3. Coc, A., Vangioni-Flam, E., Descouvemont, P., Adahchour, A. & Angulo, C. *Astrophys. J.* **600,** 544–552 (2004).
4. Bromm, V. & Larson, R. B. *Annu. Rev. Astron. Astrophys.* **42,** 79–118 (2004).
5. Beers, T. C., Preston, G. W. & Shectman, S. A. *Astron. J.* **103,** 1987–2034 (1992).
6. Christlieb, N. *et al.* in *ESO Astrophys. Symp.* (eds Weiss, A., Abel, T. G. & Hill, V.) 49–50 (Springer, Berlin, 2000).
7. Bessell, M. S. & Norris, J. *Astrophys. J.* **285,** 622–636 (1984).
8. Woosley, S. E. & Weaver, T. *Astrophys. Suppl. Ser.* **101,** 181–235 (1995).
9. Bromm, V. & Loeb, A. *Nature* **425,** 812–814 (2003).
10. Meynet, G., Maeder, A. & Ekström, S. preprint at www.arxiv.org/astro-ph/0408322 (2004).