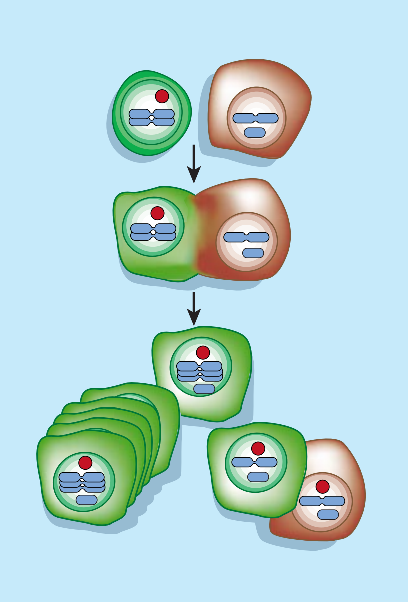

Figure 2 **Formation and reduction of hybrids. Cell fusion first produces a cell containing two nuclei; the exchange of specific molecules reprogrammes gene expression. The nuclei then fuse to generate a mononuclear hybrid cell that is polyploid (it has more than the usual chromosomal content). The hybrid divides to give identical polyploid daughters (lower left). Wang *et al.*[1] present evidence that hybrids can also generate daughters of normal ploidy, presumably through a reduction division (lower right). The expulsion of chromosomes can mask the fusion history of these cells. Blue shading indicates chromosomes. Red represents a specific gene product from the donor (in this case, the Fah enzyme).**

the first place? They seem to develop over time in culture, possibly because they become liberated from tissue-restricted gene expression. Could it be that fusion between distinct tissue-specific cell types in the starting population creates hybrids that reprogramme to become MAPCs?

Our new understanding of how blood cells produce liver[1,2] should have an impact on research into the use of bone-marrow transplantation for treating certain genetic disorders: gene transfer through *in vivo* fusion now seems a distinct possibility. But the major applications of regenerative medicine seem likely to be delivered through embryonic and tissue-specific adult stem cells. ■

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Astronomy

Telling the tale of the first stars

Timothy C. Beers

HE0107 − 5240 is a star in more than one sense of the word. Chemically, it is the most primitive object yet discovered, and it is at the centre of debate about the origins of the first elements in the Universe.

Late last year, the discovery of the most iron-deficient star yet identified, HE0107 − 5240, was announced. This star has a measured abundance of iron less than 1/200,000 that of the Sun[1]. Its significance is that it seems to be a relic from the early Universe, and astronomers are now busy considering how to interpret it.

In this issue, three groups — Bonifacio *et al.*[2], Umeda and Nomoto[3], and Schneider *et al.*[4] — present various interpretations of HE0107 − 5240. Each of these contributions centres on whether this star exhibits properties that might reveal the likely range of mass that should be associated with the so-called population III stars — objects that are presumed to have formed shortly after the Big Bang, and which are thought to have produced the first elements heavier than H, He and Li, as well as the 'first light' in the Universe. Population II stars are objects that formed after population III stars, and which incorporated the metals created by this previous generation. Our Sun, and other (younger) metal-rich stars in the Galactic disk, are referred to as population I objects.

To the astronomer, metals include all elements heavier than He, and they are thought to be produced only by nuclear reactions that take place during the lifetimes, or at the deaths, of stars. Stars such as our Sun have inherited the net production of metals by all of the previous generations that lived (and died) before it. Stars with the lowest observed abundances of heavy elements, such as HE0107 − 5240, must therefore have been born before other stars, because the gas clouds from which they formed had only the slightest traces of these heavy elements. So, regardless of the outcome of debate about the nature of the very first stars, HE0107 − 5240 remains chemically the most primitive object yet discovered, and is a crucial 'laboratory' for tests of the origins of the first elements in the Universe.

Despite the apparent simplicity of the composition of HE0107 − 5240, which to date has yielded the detection of nine elements (H, C, N, Na, Mg, Ca, Ti, Fe and Ni), the new papers[2–4] present a dizzying array of possible explanations for their origin. By comparison, other extremely low-metallicity stars, with Fe abundances near 1/1,000 the solar level, such as CS22892 − 052 (ref. 5) and CS31082 − 001 (refs 6, 7), show evidence of roughly 40–60 individual elements, most arising from the so-called rapid neutron-capture process, which accounts for the production of roughly half of all elements heavier than Fe. Beyond its Fe deficiency, the singular feature of HE0107 − 5240 is that its measured abundance of C, relative to Fe, is about 10,000 times the observed ratio of these elements in the Sun, the largest such 'over-abundance' ratio ever seen. The N abundance ratio is also greatly enhanced, though only by a factor of 200. The other detected elements exhibit ratios similar to those in previously identified metal-deficient stars.

Explanations put forward for the composition of HE0107 − 5240 fall into three main categories. First, that it is indeed a low-mass, population III star that formed out of gas of zero metallicity, and has had its present surface abundances altered. Possible mechanisms for changing the observed atmospheric abundances of HE0107 − 5240 include internal mixing of elements produced by nuclear burning in the star itself, and the acquisition of metals produced by later generations of stars during its passage through an already enriched interstellar medium[8], or — as now seems more likely — even in the cloud of its birth, from the contribution of material from later supernovae[9].

The second possible explanation is that it is a low-mass population II star, of an extreme form, and that the observed elemental abundances directly reflect the yields of species from supernova explosions of massive (more than 200 times the solar mass) population III stars that were incorporated into the gas from which HE0107 − 5240 formed.

Third, as above, except that the observed abundances reflect the yields of one or more supernova explosions of population III stars of 'normal' mass (20–25 solar masses) that were present shortly before its birth.

An important point here is that each of

Ecology

A liverwort cheat

Ghostwort — *Cryptothallus mirabilis* — is aptly named: it is a liverwort that lives beneath the surface layers in woodland, and rarely comes to human attention. Martin I. Bidartondo and colleagues tell how they have delved into the tangled details of its relationships with other organisms, and brought to light its cheating way of life (*Proc. R. Soc. Lond. B* **270,** 835–842; 2003).

Cryptothallus cannot carry out photosynthesis, and so must have a different energy source. It has long been known that it is associated with certain fungi. In a chain of experiment and inference, in part involving growth of the various players in microcosms, Bidartondo *et al.* now find that the fungi concerned belong to the *Tulasnella* group which, in turn, form mycorrhizae — close and mutually beneficial connections (pictured) — with the roots of trees such as birch and pine.

So far, so cosy. But from work with carbon isotopes it turns out that *Cryptothallus* is a cheat: it gets its carbon supply not from the soil, as once thought, but from the tree via *Tulasnella.* Instances of such complex relationships are known from other plants and other fungi, but this example greatly widens the field of organisms that can be involved.

MARTIN I. BIDARTONDO

Tim Lincoln

these options is consistent with the possibility that HE0107−5240 has 'locked up' the elemental clues required for understanding the nature of population III stars. Astronomers have long debated the form of the so-called 'initial mass function' of these objects, although recent theory has favoured the notion that it was dominated by stars of between several hundred and one thousand times the mass of the Sun. Such massive stars have extremely short lifetimes, so the elements they created provide one of the few lingering pieces of evidence that can be used to infer their properties.

Detailed observations of HE0107−5240, now under way, should help to discriminate between the three options. On page 834, for instance, Bonifacio *et al.*[2] propose that measurement of the element O may hold one key. They argue that this element should be detectable in the near-ultraviolet region of the spectrum of HE0107−5240. If it turns out to show a ratio, with respect to Fe, of more than about 1,000, this may be associated with production from high-mass, zero-metallicity stars. A value of less than 1,000 would suggest an origin from zero- (or low-) metallicity, lower-mass stars.

Bonifacio *et al.* also suggest that the presently observed metals in HE0107−5240 might have arisen from the yields of two supernova explosions of zero-metallicity progenitors with quite different masses — the high-mass progenitor producing the light elements now observed in the star (but little or none of the Fe), and the low-mass progenitor contributing the elements Mg and heavier (including Fe). Similar ideas, calling for a combination of supernovae to explain the observed elemental abundances of metal-poor stars, have already been proposed[10].

Umeda and Nomoto (page 871)[3] argue that the observed abundance pattern in HE0107−5240, including the large abundances of C and N, can be explained by the explosions of 20–130-solar-mass progenitors that underwent substantial 'mixing and fallback'. According to this view, most of the heavy elements (including Fe) that were created in the central regions of explosions were never ejected, but fell into the maw of a black hole that formed at the death of the progenitor. The lighter elements, such as C and N, which formed by pre-explosion nucleosynthesis in the progenitor, were ejected into the interstellar medium. Umeda and Nomoto also note that similar conditions might arise from aspherical supernova explosions, where jets of explosive nucleosynthesis might have been produced by a rapidly rotating progenitor star. These ideas are supported by the existence of other C-, N- (and O-) rich, extremely metal-poor stars, which have abundance patterns that are in some ways like that of HE0107−5240 and could be explained by a similar mechanism. Furthermore, the sort of low-luminosity supernova explosions envisaged by Umeda and Nomoto have already been observed — examples include SN1997D and SN1999br.

Both Umeda and Nomoto[3] and Schneider *et al.*[4] (page 869) point out that the great abundance of C, N (and presumably O) in HE0107−5240 may indicate that the gas cloud from which it formed was already quite metal-rich (even though the Fe abundance is low, the total abundance of metals is dominated by the lighter elements). That would allow efficient formation of low-mass stars from the 'cooling channels' supplied by the lighter elements. But these authors also note that, even if the abundances of C, N and O in the cloud from which HE0107−5240 formed were quite low, and were boosted only later from internal mixing processes, gas with metal abundance as low as that inferred from the Fe alone could still fractionate to form low-mass stars due to cooling from dust grains — if indeed such grains could have formed at sufficiently early times.

Schneider *et al.*[4] also argue that if the first population III stars had masses of 200–220 times the solar mass, their explosions might account for the abundances of the heavier elements in HE0107−5240, though not the lighter ones. Schneider *et al.* agree with Umeda and Nomoto that another possibility is the explosion of progenitors with masses 20–25 times that of the Sun, and point out that improved upper limits on the abundance of Zn, or the presence (or lack) of elements created in the rapid neutron-capture process in HE0107−5240, may be able to discriminate between the appropriate mass range of the progenitor object. From the data already in hand, however, Christlieb *et al.*[1] have argued that if the neutron-capture elements were indeed greatly enhanced, Ba and Sr might be expected to be detected in this star. But they are not.

Although we are left with a frustrating variety of possibilities, study of HE0107−5240 should allow us to address many questions about the formation and evolution of the first generations of stars in the Universe. One line of attack, not explicitly mentioned in these three papers, is analysis of the metallicity distribution function of stars with the lowest abundances of heavy elements[9]. If they apply in general, several of the explanations offered for the formation of a star with the observed properties of HE0107−5240 will produce stars with characteristic metallicities — which, given a large enough sample, might be detected as deviations from a continuous distribution of stellar metallicities. Hence, numerous additional stars with extremely low Fe abundances will need to be discovered to fully 'tell the tale' of early star formation and the creation of the first metals in the Universe. ■

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