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NEWS & VIEWS

SUPERNOVAE

A smashing success

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The progenitors of type Ia supernovae, the standard candles that lit the way to dark energy, have been elusive. A largely dismissed scenario has now produced one, but the results aren't what anyone expected.

For half a century, the origin of type Ia supernovae (SNe Ia) has been mired in a frustrating state of half-explanation. Part of the story is clear: they are the thermonuclear explosions of carbon–oxygen white dwarfs[1], the dense, spent cores of stars that were once like the Sun, but are now incapable of nuclear fusion. These balls of 'ash' can explode only if they gain mass, which compresses and heats them until carbon fusion is ignited. But to grow they must gorge on an orbiting companion, either by accreting the outer hydrogen layer of a still-burning star[2] or by entirely devouring another white dwarf by merging with it[3] (Fig. 1).

Unfortunately, there are serious problems with both of these ideas. In the first, it seems difficult to drizzle on enough hydrogen at just the right rate to avoid causing a nova — a surface eruption that results in white dwarfs losing, rather than gaining, mass. And if there is so much hydrogen around, why is it never seen in the supernova[4]? The merger scenario circumvents these shortcomings, but has its own issues — simulations show that the smaller white dwarf is shredded into a disk that falls rapidly onto the survivor. This should cause carbon ignition near the surface, where densities are too low to trigger a supernova[5] — a cosmic dud instead of celestial fireworks. However, on page 61 of this issue, Pakmor *et al.*[6] demonstrate that the oft-maligned merger proposal is viable after all, at least under certain conditions.

Figure 1 | Merging white dwarfs. If two white dwarf stars are close enough together in a binary system, the emission of gravity waves will cause them to spiral together and merge. This idea was proposed as one explanation for the production of type Ia supernovae, but was largely dismissed because simulations showed that the merger would result in a neutron star rather than a supernova. Pakmor *et al.*[6] find that, if the white dwarfs are equal in mass, a type Ia supernova does result, but contrary to expectation it is a sub-luminous Ia — one that is dimmer than normal and that has so far defied explanation.

Pakmor and colleagues show that the trick is to start with two white dwarfs of almost equal mass. When they violently merge, carbon ignition occurs deeper down, where densities are high enough to achieve a supernova. Most simulations of the merger would have stopped there, but here the authors use a series of different codes tailored to probe the physics inherent in each step of the process: the three-dimensional distortions in the merger, the expanding supernova ejecta and the photons that emerge out of the cataclysm.

The result is surprising. Even with the large amount of bomb fuel provided by two white dwarfs (in contrast to one in the alternative scenario), the explosion is fairly wimpy. In their simulations, Pakmor *et al.*[6] don't get a normal SN Ia but rather a sub-luminous one — a special class with distinct properties that has so far been even more resistant to explanation than normal SNe Ia (ref. 7). Their result may explain old mysteries, such as the inability of previous models to produce sub-luminous SNe Ia and the curiosity that the only sub-luminous SN Ia whose shape could be studied was found to be weirdly aspherical[8].

Can these mergers explain more normal or even over-luminous SNe Ia? In particular, some explosions seem to be so bright that they require two massive white dwarfs' worth of material to explain their properties[9]. Pakmor *et al.* considered only white dwarfs near 0.9 solar masses, although their scenario ought to be viable for a more massive pair, which would almost certainly produce a brighter explosion. But the requirement of nearly equal-mass stars, surely a rare occurrence, may mean that this scenario is better for explaining uncommon oddities than the larger Ia class.

There are caveats to be sure. The authors' predicted supernova light curves and spectra are close — but not perfect — matches to sub-luminous SNe Ia. And, as with any novel code, the findings must be checked by other groups using different approximations. Furthermore, a merger may be one way to get a sub-luminous SN Ia, although it may not be a unique solution. But the most serious concern is that Pakmor and colleagues' model[6] predicts a wide range of time delays, some shorter than a hundred million years, between the birth of the progenitor stars and their ultimate demise as supernovae. By contrast, sub-luminous SNe Ia generally don't show short time delays — they usually take a billion years or more to explode[10]. Reproducing this behaviour with the model is possible, but requires some fine-tuning.

Do these findings have implications for the use of SNe Ia as standard candles to measure the dark energy thought to be driving the accelerating expansion of the Universe? Yes and no. These sub-luminous SNe Ia are too dim to be seen at great distances, so are not useful in cosmological studies. However, one of the great worries about the use of SNe Ia, especially given their murky origins, is how their average properties may change with cosmic time[11]. Therefore, any understanding of their progenitors is progress. The dream is to one day understand what causes each subclass of SN Ia, so that we can model any change in supernova demographics as we look back in time through the Universe. Better yet, a separation of SNe Ia into different categories, arising from physically distinct processes, may make each subclass better standard candles.

Pakmor and colleagues' study is a big step forwards: after decades of modelling, it finally seems that white-dwarf mergers can make some supernovae. But it is an early step down a long path exploring where this scenario might take us. And if it can't explain all SNe Ia, what are the rest? ■

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