Title
Supernovae: The explosion in a bubble

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The story behind the supernova remnant RCW 86 might be one of the most wondrous ever told.

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Astronomers have long sought the progenitor systems of supernovae, since such discoveries provide the only direct checks of our understanding of the death throes of stellar evolution. Much of the work in this field over the past decade and a half has focused its attention on serendipitous pre-explosion imaging garnered by ground and space-based observations of nearby galaxies. With these data, astronomers have been able to place stringent constraints on the progenitor masses of a variety of hydrogen-rich Type II core-collapse supernovae (cc-SNe), upper limits on the mass of several more stripped-mass Type Ib/c supernovae as well as excellent upper limits on the companion stars for a couple of nearby Type Ia supernovae (1,2). Furthermore, in just the past few years, high-cadence optical surveys have provided several supernova discoveries within hours of their explosion. This has allowed astronomers a brief window (often less than 24 hours) to see the effects of the supernova explosion's shock-breakout on the surrounding environment before the rapidly-expanding ejecta completely overrun it. From such observations links have now been made between Wolf-Rayet-like winds and cc-SNe whose progenitors have suffered significant mass loss (3). These early observations have also been used to detect the potential signature of the ejecta of a thermonuclear (Type Ia) supernova slamming into, and shocking, its binary companion star (4).

Writing in *Nature Astronomy*, Vasilii Gvaramadze and collaborators tackle this problem from the other direction, not by looking at what happened before or during the supernova explosion, but rather at what was left behind hundreds of years later in the supernova's remnant. They have turned their attention to the supernova remnant RCW 86, located over 8,000 light years away and found between the constellations of Circinus and Centaurus. RCW 86 has had a long and rather convoluted history, with claims of it being the result of both a thermonuclear and core-collapse supernova. Associations with 10 nearby massive B-type stars, along with the fact that the supernova exploded into a "cavity", perhaps through a massive star's wind prior to explosion, favour the core-collapse progenitor (5). Recent studies focused on the X-ray and IR observations of the remnant, showing high iron abundances and strong hydrogen emission from non-radiative shocks, favour the thermonuclear origin (6). There is also a tentative association with the supernova seen by Chinese astronomers in 185 AD (SN 185).

What Gvaramadze *et al*. have added to the story is the detection of a solar-type star strongly polluted with calcium and iron among other elements. It is coincident with a candidate neutron star (NS) within the remnant RCW 86 (see Figure). Moreover, from radial velocity measurements, the G star is in a binary system. This is suggestive of a massive star going supernova, leaving behind a NS and the supernova ejecta polluting a companion. The G star/NS binary is offset from the centre of the RCW 86 remnant, in its own, smaller bubble. They believe that the supernova progenitor was a massive, moving star, which exploded near the edge of its wind bubble and lost most of its initial mass due to common-envelope evolution with this G star. It is a two-step process to manufacture this remnant: the first requiring mass loss during the main-sequence phase creating a large-scale bubble in the interstellar medium, and a second mass loss episode during the red supergiant phase producing a slow, dense wind creating a bow-shock-like structure at the edge of the bubble.

They further posit that due to the factor of 6 enhancement of calcium in the G star's spectrum, that perhaps this supernova is related to the rare calcium-rich subclass. Ca-rich supernovae are a recently identified class of explosions, which are relatively faint at peak and whose brightness drops rapidly. After a few months their spectra are dominated by calcium in emission – hence the moniker. The origins of these supernovae are up for debate. By and large they are associated with early-type galaxies, many of which show signs of recent merger activity, and are often separated by scores of kiloparsecs from the putative host (7). Proposed progenitor scenarios include the merger of a NS and a white dwarf (WD), WD-WD mergers and sub-Chandrasekhar thermonuclear explosions (8,9). Yet this link to Ca-rich supernovae is a bit murky as there are likely viable cc-SNe that could produce the observed abundances given their uncertainties. Overall the argument of Gvaramadze and collaborators is not completely convincing since much of it rests on the unlikely finding of such an odd G star next to a potential neutron star – but it is possible, and it is quite tantalizing.

While some may see this work as just adding to the pantheon of potential progenitors for this system, a smoking gun can, and likely will, be found in the next few years that could settle this debate once and for all. It will come to us through an indirect path in the form of a light echo. Just as sound can reflect off the face of a cliff, the light from a nearby supernova can reflect off a sheet of cosmic dust. And if the dust is situated several hundred light years away from the explosion, the light echo itself will be delayed by hundreds of years before it reaches us – giving us the opportunity to see the explosion as it happened – a cosmic DVR. With the advent of wide-field optical surveys, several of these light echoes have been discovered in the past few decades. Coupled with 8–10m-class telescopes, spectra of the echoes have been taken that reveal the underlying supernova subclass and, if there are echoes coming from a number of different directions, the three-dimensional nature of the supernova explosion itself (10). Such a discovery for RCW 86 would go a long way to clearing up this mystery and determining if this thermonuclear supernova bubble will burst.

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Figure 1 | Title. Text.