Supernova brightens the horizon

Astronomy, as opportunistic a discipline as can be imagined, has been electrified by the lucky appearance of a supernova in a nearby galaxy. The spirit of 1987 is reborn.

HUNTING supernovae requires the patience of a bird watcher in the Sahara. Although one or two may be discovered in any week, most are in distant galaxies and so are hard to observe. The circulars ('telegrams') of the International Astronomical Union (now distributed electronically) are full of announcements of discoveries of supernovae in anonymous or obscure galaxies. Despite their enormous intrinsic luminosity, outshining the Sun a billionfold, they barely register in astronomical images because they are so far away.

Another difficulty is that supernovae, despite their immense energy — or perhaps because of it — are over almost before they start. After countless millions of years of unrelieved obscurity, a star will exhaust its nuclear fuel, collapse and then explode in a matter of seconds. What we see is merely the aftermath as the excess heat from the remnant is radiated away over the subsequent years. Andy Warhol's 15 minutes of fame is more than most stars can aspire to.

But patience pays off. The appearance of supernova 1987A (SN1987A) a little over six years ago, although it was outside the Galaxy, showed how. That was the first nearby supernova that could be seen well since 1604; it was the first opportunity to confirm by observation theories of how stars explode. The detection of neutrinos from the supernova, part of that confirmation, inaugurated the field of neutrino astronomy (the solar version excepted) and also served as an unprecedented test of ideas about these ghostly particles.

Supernova 1987A also proved the value of the IAU circulars. Within a day, telescopes all over the Southern Hemisphere and also aboard astronomical satellites were trained on the Large Magellanic Cloud, with the data broadcast daily to astronomers. Something of that heady atmosphere has been recaptured in the past fortnight, with the discovery by Francisco Garcia, a Spanish amateur astronomer, of a supernova, SN1993J (the tenth recorded this year), in the spiral galaxy M81, in the constellation of the Great Bear (*Ursa major*).

Except for SN1987A, this is the brightest supernova at the Earth in more than 20, perhaps 50 years. SN1993J occurred in a galaxy that, like the Large Magellanic Cloud (host to SN1987A), is among the most closely watched in the sky: the 'M' in its name shows that it is conspicuous enough to have been included in the catalogue compiled by Charles Messier more than 200 years ago.

One of the immediate benefits was that old astronomical plates could be searched to find out which star had exploded. The supernova's field is crowded, but researchers are pretty satisfied that they have found the progenitor; ultraviolet observations in a few weeks should confirm that (or otherwise). Arguments about the progenitor of SN1987A rumbled on for much longer.

As most theories require, the progenitor was a red supergiant star, the typical inflated state of stars that have exhausted the hydrogen in their cores and are burning heavier elements. The progenitor was not as red as astrophysicists would really like, but neither was it as abnormal as the progenitor of SN1987A, which was a blue supergiant. Nor was it as difficult to identify, even though M81 is 70 times further away than the Large Magellanic Cloud. The condition of a star on the point of exploding is evidently not strictly constrained.

The popularity of M81 with astronomers also meant that photographs of this region of sky were available within hours before and after the supernova exploded. At about midnight on 27 March, there was no sign of a supernova on an image obtained by Jean-Claude Merlin, an amateur French astronomer; 9 hours later, it was there on an electronic image obtained by Bill Neely, another amateur, in New Mexico. Only rarely can astronomers pin down the moment of eruption so accurately. SN1987A was unique, of course, in that the neutrino pulse, produced at the precise moment of explosion, gave a precise time zero.

SN1993J has nicely conformed to the prescribed pattern of so-called type II supernovae. After the exhausted stellar core, no longer sustained by nuclear reactions, collapsed and then rebounded, a shock wave was driven out through the stellar envelope, raising the stellar surface to white heat (10^5–10^6 K) within a few hours. This is what the astronomers first saw. Over the next day or so, the star's brilliance increased to the point that it could be seen with a small telescope or even binoculars (10th magnitude).

The star soon started to fade as the old stellar surface started to cool. But as the shock wave ran into the tenuous wind that had been radiated by the progenitor star in its declining years, X-rays were detected on 3 April by Rosat, the astronomical satellite launched in 1990, and subsequently by the new Japanese satellite, ASCA. These betoken gas heated to 10^8 K or more. As material in front of the shock wave thinned out, radio waves from the shock could escape, to be detected on 5 April at the Mullard Radio Astronomy Observatory in Cambridge.

So SN1993J has now appeared over almost the full extent of the electromagnetic spectrum, although neutrinos have not been seen (unsurprisingly given the 3.2 megaparsec distance to M81). One day, gravitational waves from supernovae may be detected, but the appropriate antennae have yet to be built — the last frontier in observational astronomy has yet to be crossed. Curiously, the one player missing from the field is the Hubble Space Telescope: while amateurs and large projects alike have turned towards M81, Hubble, beset by technical problems (a computer glitch is hindering operations) and encumbered by a ponderous bureaucracy, has failed so far to take advantage of this 'target of opportunity'.

Even so, the interest in SN1993J involves a certain clutching at straws. What astronomers really need is to see a supernova in the Galaxy. Current estimates are that one appears every 40–50 years. But the last two to be seen appeared in 1604 and 1572. Before that, there were visible supernovae in 1006 and 1054. Unless the estimates are wrong, the others must have been hidden by the lanes of dust and gas that criss-cross the galactic disk.

What accurate observations beyond the Galaxy are showing is that the characteristics of type II supernovae are remarkably variable. All seem to be 'atypical', which begs the question: what is typical? Zwicky's inspired guess 60 years ago of the basic mechanism has proved to be remarkably accurate — right down to the prediction of neutron stars — but the details are turning out to be far more exciting. SN1987A has yet to reveal its neutron star, for example.

The other regret has been that nobody has yet seen a nearby type I supernova. Far brighter than type IIs, these explosions arise in white dwarf stars, possibly triggered by the accretion of a critical amount of mass. The preconditions seem so precisely tuned that many think that all type Is (or more specifically type Ias) have to be alike. For cosmologists, this offers the prospect of reliable beacons ('standard candles') to be seen far across the Universe, and a means to measure the cosmic distance scale and Hubble's constant, which gives the rate of cosmic expansion. Indeed, the catalogues are stuffed with the parameters of distant type I supernovae. The trouble is that none has been near enough to give an unequivocal calibration of the scale. As one astronomer remarked ruefully, had SN1993J been a type I, we would have known within days the answer to the most burning astronomical question.

Roland Pease