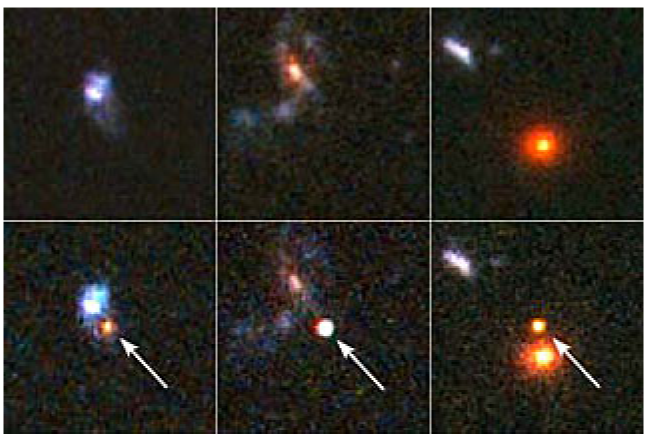
When Stars Go Bang

I mentioned briefly last time what happens when stars die, mentioning in passing that big stars often go off with a bang. The subject here though is the detail of what happens when stars of with a bang.

Firstly, the scale of these explosions are quite staggering. A star going supernova in our galaxy will be quite a sight, and there are several good candidates locally - Betelgeuse in Orion being a prime example. Supernovas tend to go off about once every 100 years per galaxy, and we haven't had a local one since 1604 (Kepler's supernova), and before that there were well observed ones in 1572, 1181, 1054, and 1006 - so we are well overdue for one. If it happens it may well be visible during the day, competing with the Sun. When we see them go off in nearby galaxies they are often brighter than the entire galaxy of 10 billion stars or more, for a short time.



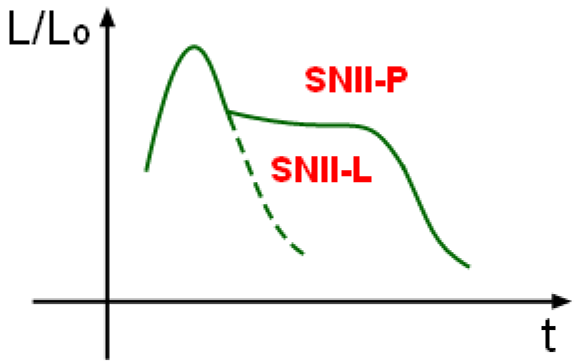
[Some before and after galaxies showing how bright supernovae are - NASA]

So first, there are 5 - or possibly 6, or maybe more, types of supernova. With a lot of astronomy we are stuck with history, annoyingly so in a lot of cases. I could go off on one about magnitudes, stellar classification, galaxy types and a number of other cases all of which made sense once, but now with more knowledge are either less useful or downright confusing.

So supernovas were first classified by their spectral signature. There were type I supernovae, which show no signs of hydrogen in the spectrum, and type II which show hydrogen.
So OK - that sounds fair enough so far, you'd expect hydrogen generally, its the most commonest thing around, so it is a reasonable thing to split on.

Next there were different sorts of lines that were apparent in type 1 supernovae spectra. Type 1a shows a line indicating the element silicon is involved, type 1b has a helium signature, and type 1c doesn't show much of either.

Type II's started to break ranks too. There are type IIp's which explode and then have a plateau in their light signature where the brightness fades, then stays the same for a while, before ultimately fading again. The type II-l has a linear decay (sort of constant de-lighting so to speak) in contrast. The type IIn shows narrow lines in the spectrum, and the type II-b starts off like the others but looks like a type I-b after a while. Confused yet??



[Type II-p and II-l light curves over time. (wikipedia)]

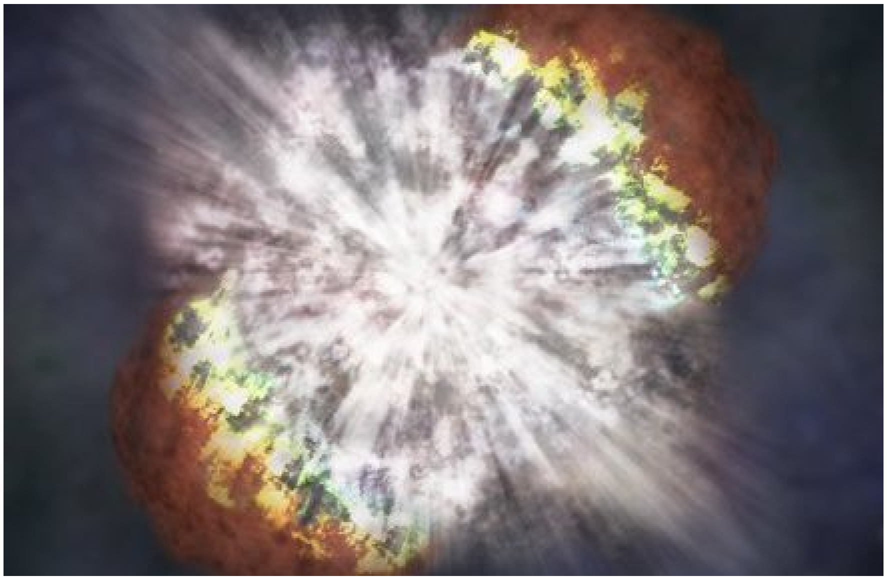
Well if you're not confused yet, then let me throw another confounding thing into the mix. All the above types have basically the same cause, except for the type I-a. All the others, the type I-b and type I-c and all the type II's are caused by a giant star collapsing at the end of its life.

These are massive stars, in hydrostatic equilibrium as it's known. This means that the star wants to collapse due to its gravity, but also wants to expand because of the heat produced from fusion. So it settles down to an uneasy equilibrium where the pressure outwards is exactly equal to the force of gravity inwards. Then the fire goes out, and gravity takes over. It takes over with a rush!

The star collapses inwards at a huge rate - a good fraction of the speed of light in fact.One second the core is maybe the size of the Earth, the next second it is the size of something just slightly bigger than the M25.

During this time energy is consumed rather than generated. Firstly lots of intense light is generated that splits up a lot of the heavy elements built up so far back into helium and hydrogen. The core collapses compressed by all this infalling material, getting squashed into huge density. Such a force actually pushes electrons into protons, turning them into neutrons, and so making a neutron star at the centre. This produces a huge number of neutrinos, those ghostly particles that hardly ever deign to interact with normal matter. However SO many neutrinos are made (maybe 10^{58} - yes that IS 1 with 58 0's after it) that even though they hardly ever interact with normal matter - with that number present they have an effect pushing out material.
The material then "bounces" off this solid core, exploding outward running into the gas that has started to fall in with a mighty collision. They tussle it out for a while, but the huge numbers of neutrinos passing through heat up the material. Perhaps heat up is the wrong word, they actively fry the material which means the outward forces now win. There is violent nuclear fusion, making new elements by the r-process whereby the newly free'd neutrons make up new

elements in fractions of a second (the r-process - r standing for rapid in comtrast to the slow s-process).



[Artists impression of a supernova - NASA]

Those watching (hopefully from afar!) would see first a blast of neutrinos (provided they had neutrino detectors!) and then a little later a blast of light, as the explosion finally makes its way out from the shrouding outer material.
There are a lot of short lived radioactive elements made during this process, and it’s these that keep the supernova shining for several weeks.
The brightness peaks, and then slowly diminishes. Over the subsequent years, a shell of expanding material can be seen, until it looks something like that of the next image - the crab nebula. Although it is the death of the star, it contains the seeds of rebirth. Firstly it scatters lots of heavy elements into the nearby environment, giving the building blocks for rocky planets and life itself. It also send shocks out that cause clouds of otherwise stable gas to start to collapse forming new stars. They are also important in regulating the life of galaxies as a whole. So - part of the circle of life.

I skipped over the type 1a supernova - they have a different process of going off, and one that is extremely useful for astronomers - so I’ll defer that to another article.

[Crab nebula - the remains of supernova that went off in 1054 - NASA]