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Overture to stellar swansong

Scientists have heard snatches of the first bars that usher the Supernova crescendo, says S.Ananthanarayanan.

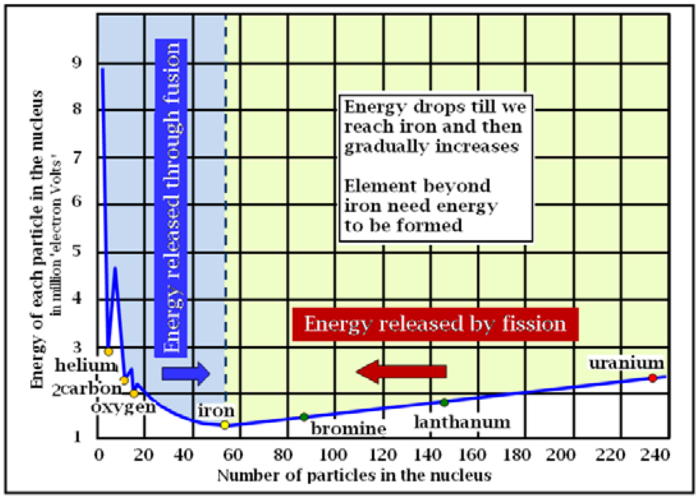
Supernovae are the most energetic of stellar explosions and they drive movement and change in the cosmos. The event can be as luminous as to outshine a galaxy and within a fleeting span, sometimes just a few weeks, it emits the energy the sun would send out in its lifetime. The supernova is usually the end of the life story of a star, with all the star's material being scattered through space, to merge with other star systems or with clouds of dust that form new stars.

As supernovae are short lived, there is not much information about what happens during their course and even less about the changes in the star that brings about the final explosion. A team of scientists from Israel, UK and USA report in the journal, ***Nature***, that they have documented changes and activity, which were suspected to precede supernovae, in a massive star just 40 days before the star exploded.

Star life cycle

Stars form when interstellar dust, or just hydrogen atoms, which is spread over millions of light years of space, gradually comes together because of mutual gravity. Squeezing the material of the mass of a star, which was spread out in the near vacuum of space, into the confines of the star itself, is an act of compression and this raises the temperature. In the process of increasing its mass by attracting more material, the star can heat up to millions of degrees – till it is so hot that nuclear reactions start between hydrogen atoms. The nuclei of hydrogen atoms, being positively charged, stay well apart, because of mutual repulsion. But at very high temperature, they move so rapidly that they could collide and come close enough for short-range attractive forces to get active, and pairs of hydrogen nuclei, along with two neutral particles called neutrons, merge to form nuclei of another element, helium. Helium is a more stable, or less energy state of the separate particles that make it up, and in the process of its formation, there is a release of the extra energy, which is stupendous – the source of the energy of the ***hydrogen bomb***!

Thus, while much of the hydrogen gets converted into helium, the gas in the star gets hotter still and rapidly expands. The expansion causes cooling, which draws the gas in, into another spell of compression and heating, which leads to more nuclear reactions and expansion, etc. In the course of this see-saw of pressure and temperature, other nuclear reactions take place and in many stars, helium nuclei get converted to nuclei of more massive elements, like lithium, which has three hydrogen nuclei and three neutrons, and so on. Each of these reactions releases energy and stars that are large enough go through innumerable cycles, till all the material in the star is converted usually as far as oxygen, but can continue till it reaches the element iron. The nucleus of iron, which has the mass of 56 hydrogen nuclei, is a low energy state and the more nuclear reactions cannot be self sustaining.

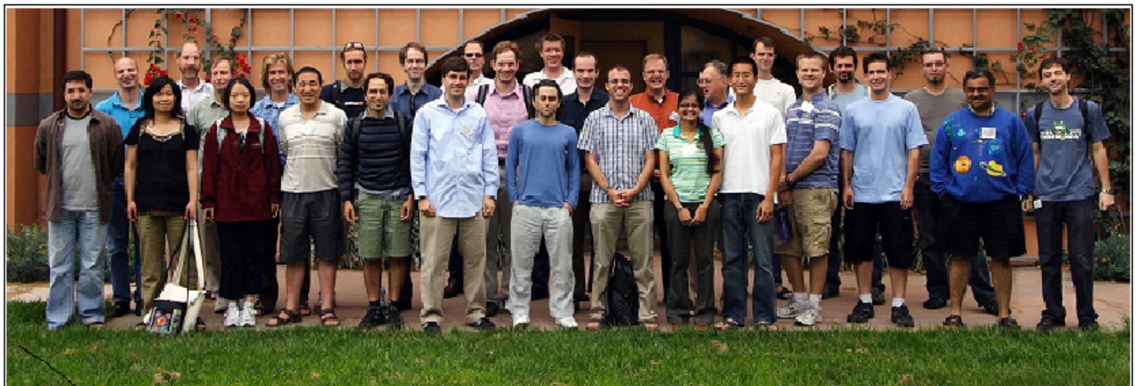


Many stars thus stop auto generation of elements at iron, or earlier, and as they do not have a source of energy, they begin to collapse under their own gravity. The intense compression that follows can have different results, depending on the mass of the stars. They may reduce to intensely hot '***white dwarfs'*** or cool '***red giants'***. As a sequel, the positive and negative parts of atoms may merge and the stars further collapse as '***neutron stars***', stars of the greatest density possible. And if the stars have sufficient mass, the gravity at their surface may be so high that it holds back the light that they emit, as '***black holes***

But larger stars, or more likely, white dwarfs that grab more material or merge with another white dwarf, continue with processes that lead to sudden release of energy. The increased mass raises temperatures and brings about fusion of carbon nuclei. This fusion reaction is so energetic that in seconds, a substantial part of the white dwarf could get consumed, leading to a shock wave of expansion. These high temperatures and pressures lead not only to huge luminosity – supernovae are billions of times brighter than the sun – but also to the generation of elements with more nuclear particles than iron. Supernovae, in fact, are the source of these elements in the universe.

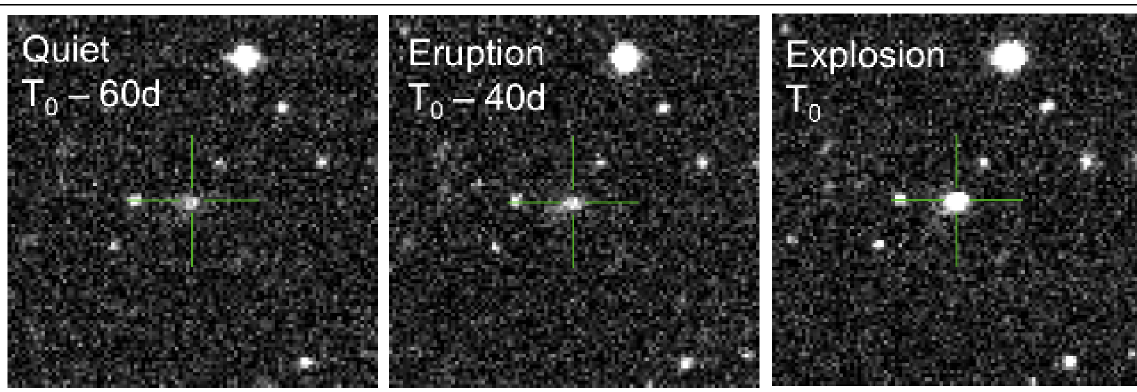
The final stage

Very little has been known of the stages of a star's final progress to a supernova. It was first thought that the fate of larger stars was to become red super giants and then explode. Tracing the available past data of the progenitor of a supernova discovered in 1987, the nearest supernova since the last, and celebrated, near one seen in 1604, showed that its parent star was a ***blue supergiant***. This was a departure from the model of ***red giant progenitors***. Through other observations since then, it is found that supernova progenitors can be of lesser mass and a feature of the 1987 supernova was that showers of very light, neutral particles, called ***neutrinos*** had been detected a few hours before the explosion. It is now considered that massive stars lose energy in the final stages not in the form of light but by neutrino emission. But neutrinos are elusive and almost undetectable and the final stages of stars have remained unknown territory.



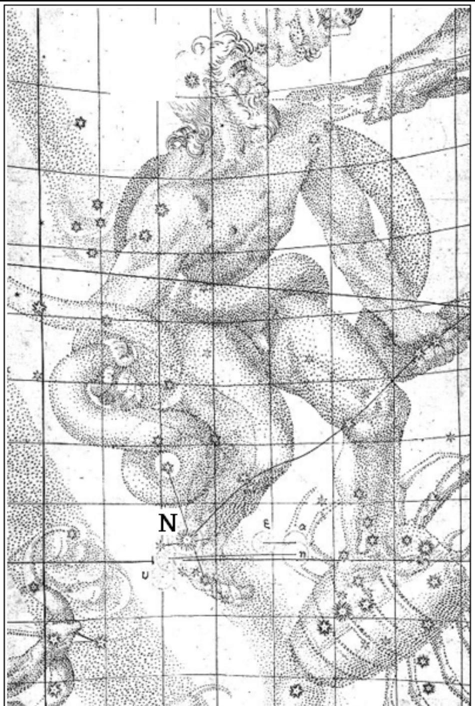
The team at PTF - Palomar Transient Factory, the automated star image and data aquiring facility

In the study now reported in ***Nature***, ***E O Ofek, of the Benoziyo Center for Astrophysics, Weizmann Institute of Science, Israel*** and colleagues scanned data of mass loss in a class of objects called ***luminous blue variables*** (***LBV***) and observed an outburst of material, about 1/100 of the mass of the sun, from a giant star, just over a month before it exploded. So far, the study of stars that go supernova has been based on the remnants of the supernova, which is after the event. Here, Ofek and others have stepped back, to the parent star, which they estimate to have had about 50 solar masses. And, based on statistical analysis of the images and data collected by the ***Palomar Transient Factory***, an automated survey of the night sky, they suggest that the pair of events – (i) eruption of material from the star and (ii) its explosion soon after - cannot be unrelated. If this turns out to be the case, this becomes one of the few cases where there is information about the late stages of a star that becomes a supernova.



60 days before | 40 days before | the day of the explosion

Stars with more than some 25 solar masses are known to have eruptions of extreme loss of matter. Why they occur and what drives them is not known, but a number of supernova models provide for such mass loss. The present study, of the eruptions in a star that went supernova soon after such loss, affords a chance to compare eruption behaviour of candidate supernovae and to propose possible mechanisms that lead to their evolution. Ofek and colleagues find that the timing and the matter ejected best fits a supernova model that is based on the instabilities in the flow of material in the star – a finding that may be refined with more work.



Kepler's original illustration - the supernova is at 'N', on the right foot of the 'serpernt bearer'

Kepler's supernova

Nova means new, and denotes a new star, or one that suddenly comes into view, as a result of getting brighter. The more luminous ones are visible to the naked eye and many stand out brighter than any of the other stars for the few days or months that they last.

Kepler's Star, which was 'brighter than all in the sky' for 3 weeks, was seen in Italy in 1604 and was documented by ***Johannes Kepler***. The supernova has been named after him because he tracked the object for a year and wrote a book, entitled ***De Stella nova in pede Serpentarii*** ("On the new star in Ophiuchus's foot", Prague 1606.

Keepler's star is the nearest supernova, at 20,000 light years, seen so far. It is in our own galaxy, in the constellation, ***Ophiuchus,*** or the ***serpent gatherer***.