ASTROPHYSICS

Cosmic explosions under scrutiny

Stellar explosions known as type Ia supernovae are a significant tool in cosmology, but their exact nature is unknown. Two studies bring an understanding of these cosmic blasts a step closer. SEE LETTERS P.344 & P.348

MARIO HAMUY

Type Ia supernovae are exploding stars characterized by an absence of hydrogen, the most abundant chemical element in the Universe. There is a general consensus that their progenitors are white-dwarf stars in two-star systems. But the type of star that is the companion to the white dwarf remains an open question. To date, no progenitor of a type Ia supernova has ever been directly observed before its explosion. The recently discovered[1] supernova SN 2011fe in the galaxy Messier 101, at a distance of only 6.4 million parsecs (20.9 million light years) from Earth, is the closest and brightest found in 25 years. As such, it provides a unique opportunity to search in discovery data and pre-discovery archive images for the presence of a progenitor system. Such a search is the subject of two papers in this issue, one by Nugent *et al.*[2] (page 344) and the other by Li *et al.*[3] (page 348) .

Type Ia supernovae are so powerful that they can outshine an entire galaxy such as the Milky Way, with its 200 billion stars, for several weeks. White dwarfs are the final evolutionary state of a star such as the Sun. They are Earth-sized 'diamonds' made of carbon and oxygen (one tablespoon of white dwarf weighs ten tonnes) and result from the slow but steady nuclear fusion of hydrogen and helium over millions of years. After exhausting their nuclear fuel, white dwarfs gradually emit their stored thermal energy, at a rate of 1/10,000th the luminosity of the Sun.

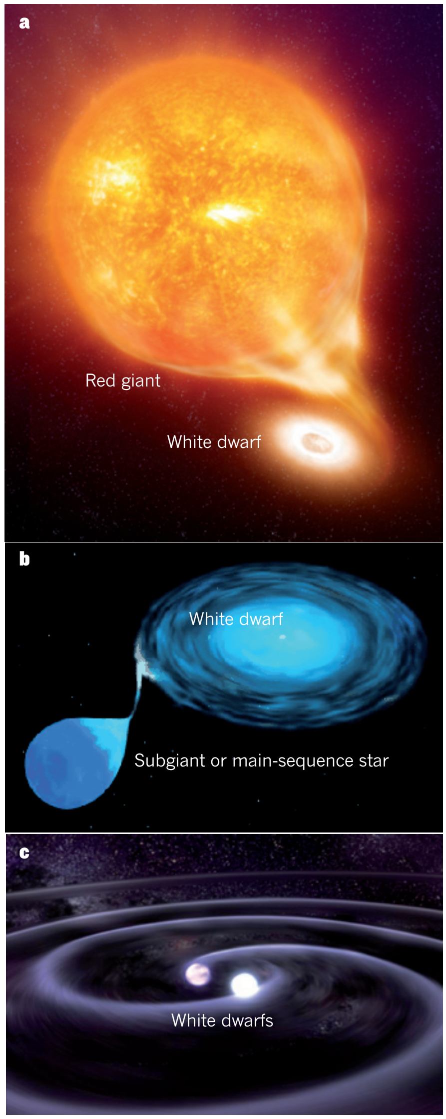
Under normal circumstances, white dwarfs do not explode. Instead, they slowly cool down, releasing their internal heat over billions of years. However, a dramatically different outcome can occur if a white dwarf gains weight by stealing matter from a nearby companion star. In such a case, the white dwarf contracts (the ideal diet!) and gets hotter. When the star reaches a critical mass (1.4 times the mass of the Sun), sparks of nuclear reactions begin to release heat, thereby increasing the conditions for further nuclear reactions. This is a runaway situation, and in only one second the whole white dwarf explodes as a colossal nuclear bomb (equivalent to about 10^{28} megatonnes of TNT), transforming its carbon and oxygen mainly into radioactive nickel, cobalt and iron.

According to theoretical models, there are three possible types of companion star to a white dwarf: a red giant, which is about 100 times more luminous than the Sun; a subgiant star or a main-sequence star, which are a few times more luminous than the Sun; and another white dwarf, which is 10,000 times less luminous than the Sun (Fig. 1). Because these possible companion stars span such a wide range of luminosity, examination of the explosion site on pre-discovery images of type Ia supernovae should, in principle, allow researchers to discriminate between these possibilities and ascertain the nature of the progenitor.

In their study, Li *et al.*[3] examined pre-discovery images of SN 2011fe obtained by the Hubble Space Telescope and found no evidence for an object seen before the explosion. If a red giant was the companion star, it should have been detected. This observation allowed the authors to exclude a red-giant progenitor — at least in this case. Unfortunately, the depth of the pre-discovery images was not sufficient to allow them to exclude a subgiant, main-sequence or white-dwarf companion. Nevertheless, this result represents a major advance in our understanding of the progenitor stars of type Ia supernovae.

Supernova 2011fe was discovered[1] on 24 August 2011 by the Palomar Transient Factory (PFT) project[4] with the 1.2-metre Samuel Oschin Telescope at the Palomar Observatory in California. The members of the PTF team spotted it just over 11 hours after explosion — the earliest detection ever obtained for a type Ia supernova. Their prompt reaction to the discovery allowed them to analyse the light of the object using a spectrograph mounted on the robotic Liverpool Telescope in the Canary Islands barely 16 hours after detection.

If you were to watch the explosion of a house in slow motion, the earlier you could observe the blast the clearer would be the picture you could infer of the building's initial structure, before the debris had destroyed the evidence. Likewise, at only about 28 hours after explosion, the spectrum of SN 2011fe revealed, as Nugent and colleagues[2] show, the elusive outermost layers of the exploding star before they became invisible because of the dilution caused by their rapid expansion (7% of the speed of light). The authors' analysis[2] of the spectrum uncovers light emerging from clouds of oxygen and carbon from the surface of the supernova. This result confirms the theoretical belief that the exploding star is indeed a carbon–oxygen white dwarf, and demonstrates that a small amount of the white dwarf's outermost material managed to expand and escape the burning front coming from the centre. Although traces of carbon have been observed[5,6] in other type Ia supernovae, the detection of oxygen is unprecedented. In addition, the authors' study[2] of the supernova's early period of rising luminosity shows that the secondary star is most consistent with being a main-sequence star.



A, ESO; B, STSCI, NASA; C, NASA/T. STROHMAYER (GSFC)/D. BERRY (CHANDRA X-RAY OBSERV.)

Figure 1 | Possible progenitors of type Ia supernovae. This class of supernova is thought to originate from a white-dwarf star that accretes matter from a companion star and explodes. The companion might be: **a**, a red-giant star; **b**, a subgiant or main-sequence star; **c**, a second white dwarf. Li *et al.*[3] exclude the red-giant hypothesis for supernova 2011fe. Nugent *et al.*[2] find that the companion was probably a main-sequence star.

Type Ia supernovae are not only important astrophysical objects in their own right; they also provide the most precise means of measuring distances to remote galaxies. The calibration of their luminosities in the early 1990s through the Calán/Tololo project[7] allowed two groups of astronomers, headed by Brian Schmidt and Saul Perlmutter, to discover in 1998–99 that, contrary to expectation, the Universe is undergoing an accelerated expansion owing to a mysterious dark energy that constitutes 70% of the Universe's content[8,9]. This amazing discovery has been recognized with this year's Nobel Prize in Physics. Not knowing the exact nature of type Ia supernovae, which have such a crucial place in cosmology, is an embarrassing situation. Although the studies of Nugent *et al.*[2] and Li *et al.*[3] on SN 2011fe do not yet provide a definitive answer to this question, they are a reassuring step forward — one that lends support to our ideas about the nature of type Ia supernovae.

A conclusive answer to this fascinating question will have to await the discovery of other type Ia supernovae in galaxies closer to Earth than Messier 101. Because such supernovae are rare events — they occur once every two centuries in a typical galaxy such as our own[10] — and because there are only a handful of galaxies closer than Messier 101, we might have to wait 30 years for another such event. With patience and luck, we might even be rewarded in our lifetimes with a supernova in the Milky Way. ■

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CANCER

A drug-resistant duo

The efficacy of the anticancer drug vemurafenib, which is used to treat metastatic melanoma, is plagued by acquired resistance. A picture of how such resistance develops is emerging. See Letter p.387

HUGO LAVOIE & MARC THERRIEN

Vemurafenib (also known as PLX4032) is a promising drug. Newly approved by the US Food and Drug Administration, it is currently the best prospect against metastatic melanoma, the deadliest form of skin cancer[1,2]. The drug selectively inhibits an oncogenic form of B-RAF, a protein that drives cell proliferation. Unfortunately, most patients acquire resistance to vemurafenib within a year of treatment[3]. All modes of resistance discovered so far involve circumvention of this mutant B-RAF. But on page 387 of this issue, Poulikakos and colleagues[4] report a new mechanism of resistance — enhanced dimerization of the kinase domain of mutant B-RAF. Dimerization normally activates the wild-type protein.

'Gain-of-function' mutations in the *B-RAF* gene are found in about 50% of human melanomas, and its sustained expression is required for tumour-cell proliferation and survival[5]. Therefore, extensive efforts have been devoted to developing selective B-RAF inhibitors, especially those that, like vemurafenib, target its most prevalent oncogenic variant, B-RAF^{V600E}.

In normal cells, B-RAF functions in the RAS/ERK molecular signalling pathway, which has a prominent role in regulating proliferation and survival[6]. The minimum components of this pathway are a cell-membrane-associated protein, RAS, and three protein kinases — a RAF family member (such as B-RAF), MEK and ERK — which convey RAS signals along the pathway (Fig. 1a). On association with signal-activated RAS, the kinase domains of two RAF proteins form a dimer, resulting in their activation[7].

When activated by a gain-of-function mutation, B-RAF induces ERK activity independently of the normal signals, leading to the development of multiple cancers (Fig. 1b)[5]. In melanoma, inhibition of the mutant molecule B-RAF^{V600E} by vemurafenib shuts down ERK activity and rapidly leads to tumour regression[1–3]. However, acquired resistance to vemurafenib is a serious limitation, and several laboratories are hard at work investigating the underlying causes.

Previous efforts have uncovered four mechanisms that counteract vemurafenib effectiveness, all of which bypass B-RAF^{V600E}. In three cases, ERK signalling is reactivated through alternative entry points in the pathway, whereas the fourth mechanism involves

50 Years Ago

For more than one hundred years, the Royal Greenwich Observatory has been responsible for providing exact time signals for a wide variety of users both in Britain and abroad. In recent years this service has become increasingly important in various fields of scientific research where extreme accuracy is essential. In order to provide the various users with more frequent opportunities for checking the time, the present twice-daily transmissions from Rugby were increased to four as from December 1 … As long ago as 1833, the Royal Greenwich Observatory provided hourly time signals for the operation of 'time balls', which were devices consisting of a large ball secured to the top of a mast and released by a special catch at a precise time. One such ball is still in use in the grounds of the old Observatory at Greenwich.
From *Nature* 16 December 1961

100 Years Ago

In the volume on mammals in the "Fauna of British India," the late Dr. W. T. Blanford stated that the black-buck (*Antilope cervicapra*) living on a spit of sand between the Chilka Salt Lake, in Orissa, and the sea, never drank, as there is no water on the spit except in deep wells. The statement has been strongly controverted by various writers, one at least of whom has suggested that the antelopes obtain water from sheep-troughs. Of late years it has, however, been conclusively shown that giraffes, kudu, and gemsbok live for a considerable portion of the year in the Kalahari Desert without drinking, obtaining such moisture as they require from the succulent roots of certain plants … The case of the Chilka black-buck accordingly requires reinvestigation in order to ascertain whether they too may be able to obtain moisture from plants.
From *Nature* 14 December 1911