Strongly magnetic pulsar could explain anomalous supernovas

Magnetars may drive super-luminous supernovas in the local Universe.

by Matthew Francis - Oct 16 2013, 6:00pm BST

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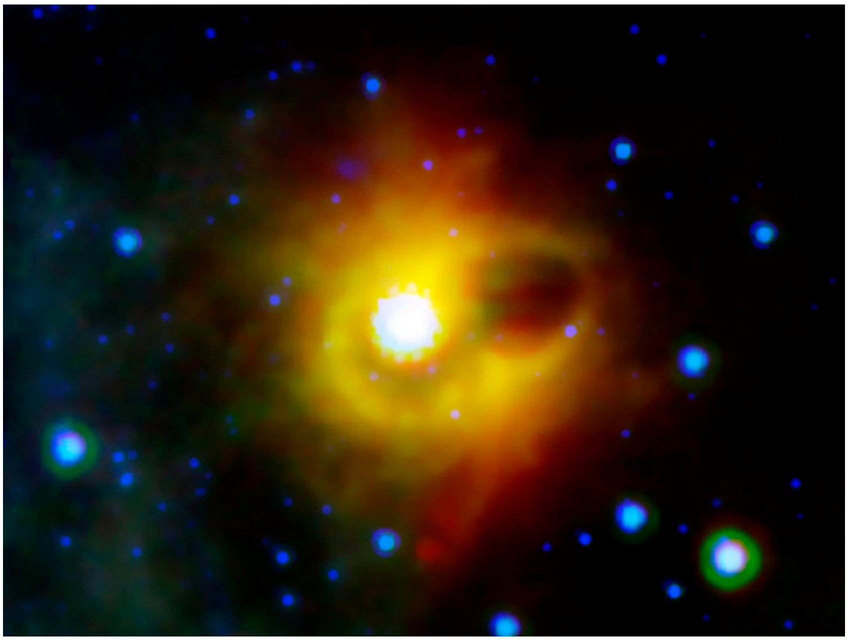

Infrared image of dust swathing a magnetized pulsar—a magnetar—known as SGR 1900+14.

NASA/JPL-Caltech/S. Wachter (Spitzer Science Center)

Supernovae are among the brightest events in the Universe, outshining whole galaxies at their peak. Even so, some are exceptional—these are called super-luminous supernovae. These events are typically the explosions of immense stars more than a hundred times the mass of the Sun, but two recently identified examples didn't quite fit the mold. They reached peak brightness too quickly before fading, and they exhibited uncharacteristic blue color.

These two super-luminous supernovae could instead be powered by magnetars, intensely magnetized neutron stars born in the collapse of the progenitor stars' cores. Analysis of the data by M. Nicholl and colleagues showed consistency between the explosions and observations of material heated by magnetars. Additionally, they found the behavior of the two supernovae to be completely unlike that of other super-luminous supernovae. While magnetar-driven explosions are rare, their existence could explain why some of the brightest supernovae don't match expectations.

Most super-luminous supernovae are driven by "pair instability," the production of electron-positron pairs during the death throes of a very massive star. The creation of these particles produces a rapid contraction in the dying star, resulting in a powerful nuclear explosion that blows everything apart, possibly leaving nothing behind. Pair-instability supernovae only occur if the star is more than about 140 times the mass of the Sun, so they are extremely rare.

Since a star's chemistry reflects the environment in which it was born, the supernova explosion does as well. Massive stars formed in the early Universe are relatively lacking in "metals"—heavier chemical elements such as oxygen, carbon, and iron—while stars of a more recent vintage contain higher abundances of those nuclei. Pair-instability supernovae can only occur in low-metal stars; high-mass stars that formed later leave behind black holes instead.

For that reason, the observation of two super-luminous supernovas in the nearby Universe was anomalous. These explosions were low in the heavier elements, consistent with the early birth required for a pair-instability supernova but inconsistent with the life cycle of a high-mass star. Additionally, the light emission peaked more quickly and contained more blue light than expected from pair-instability supernovae, which are distinctly red. The slow fade of pair-instability supernovae is due to the emissions from a decay of radioactive nickel (^{56}Ni), an element produced during the explosion.

However, the two supernovae—known by their catalog designations PTF 12dam and PS1-11ap—

showed a high level of ionization. That in turn indicates a high temperature in the ejected material. The authors of the present study compared the behavior of the supernovae to emissions from matter surrounding highly active pulsars known as magnetars. As their name suggests, magnetars have especially strong magnetic fields, in addition to rapid rotation.

Magnetars generate powerful outflows of particles, called winds. When these particles strike the surrounding gas, they compress and heat it, forming a hot, dense shell that glows brightly. The researchers found a strong resemblance between PTF 12dam, PS1-11ap, and supernovae that generate magnetars, known as core-collapse supernovae. Specifically, they realized that all these events could be classed together as type Ic, including an event known as supernova 2007bi that had previously been considered a pair-instability supernova.

This study implies that super-luminous supernovae in the nearby Universe are more likely to be magnetar-driven rather than pair-instability explosions—which makes sense, given that they're the progeny of stars that formed relatively recently. It also enables these supernovas to be included in the type Ic class, meaning that perhaps all supernovas of this class involve magnetars.

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