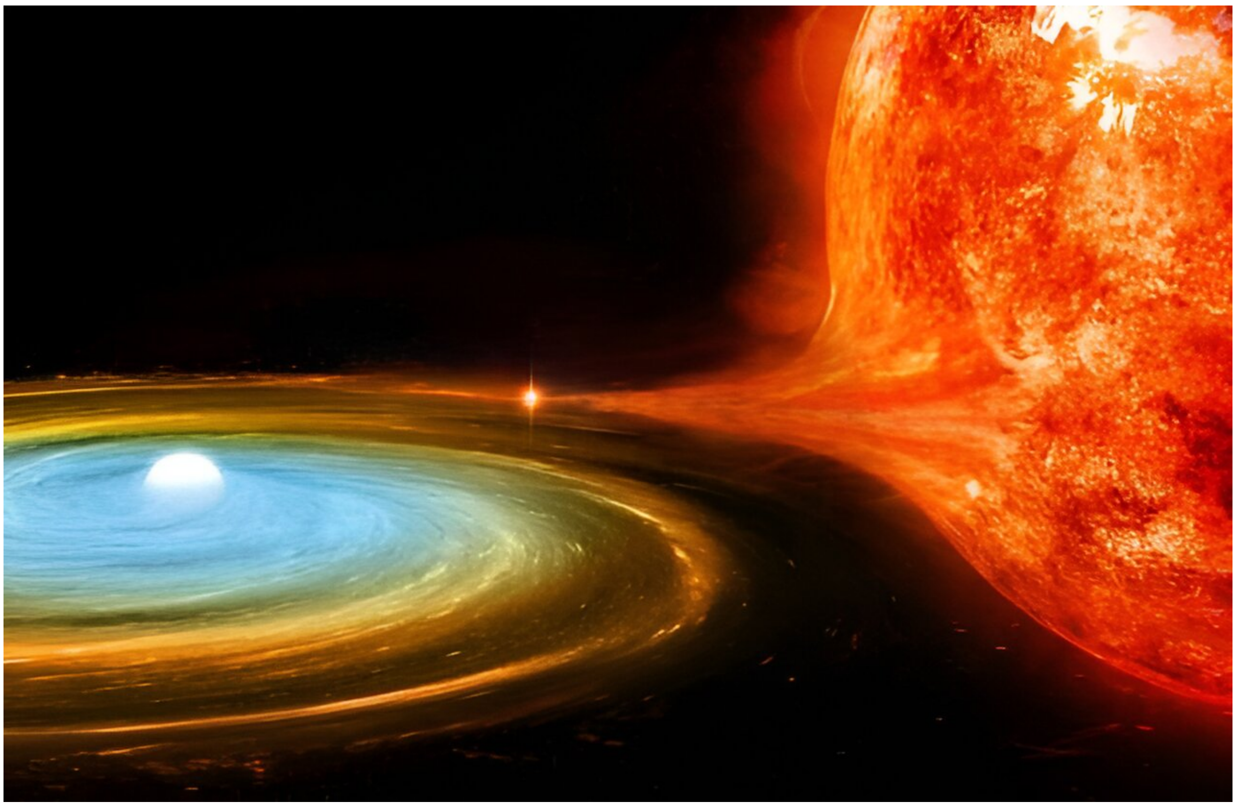
Did this supernova explode twice?

September 1 2023, by Evan Gough



Artist view of a binary system before a type Ia supernova. Credit: Adam Makarenko/W. M. Keck Observatory

All supernovae are exploding stars. But the nature of a supernova explosion varies quite a bit. One type, named Type 1a supernovae, involves a binary star where one of the pair is a white dwarf. And while supernovae of all types usually involve a single explosion, astronomers have found something that breaks that mold: A Type 1a supernova that may have detonated twice.

Type 1A supernovae occur in binary stars where one star is a white dwarf, and the other star is anything from a massive star to another white dwarf. As the primary white dwarf siphons material away from its secondary companion, it eventually gathers enough mass and exceeds the Chandrasekhar limit. When that happens, it triggers a cataclysmic explosion.

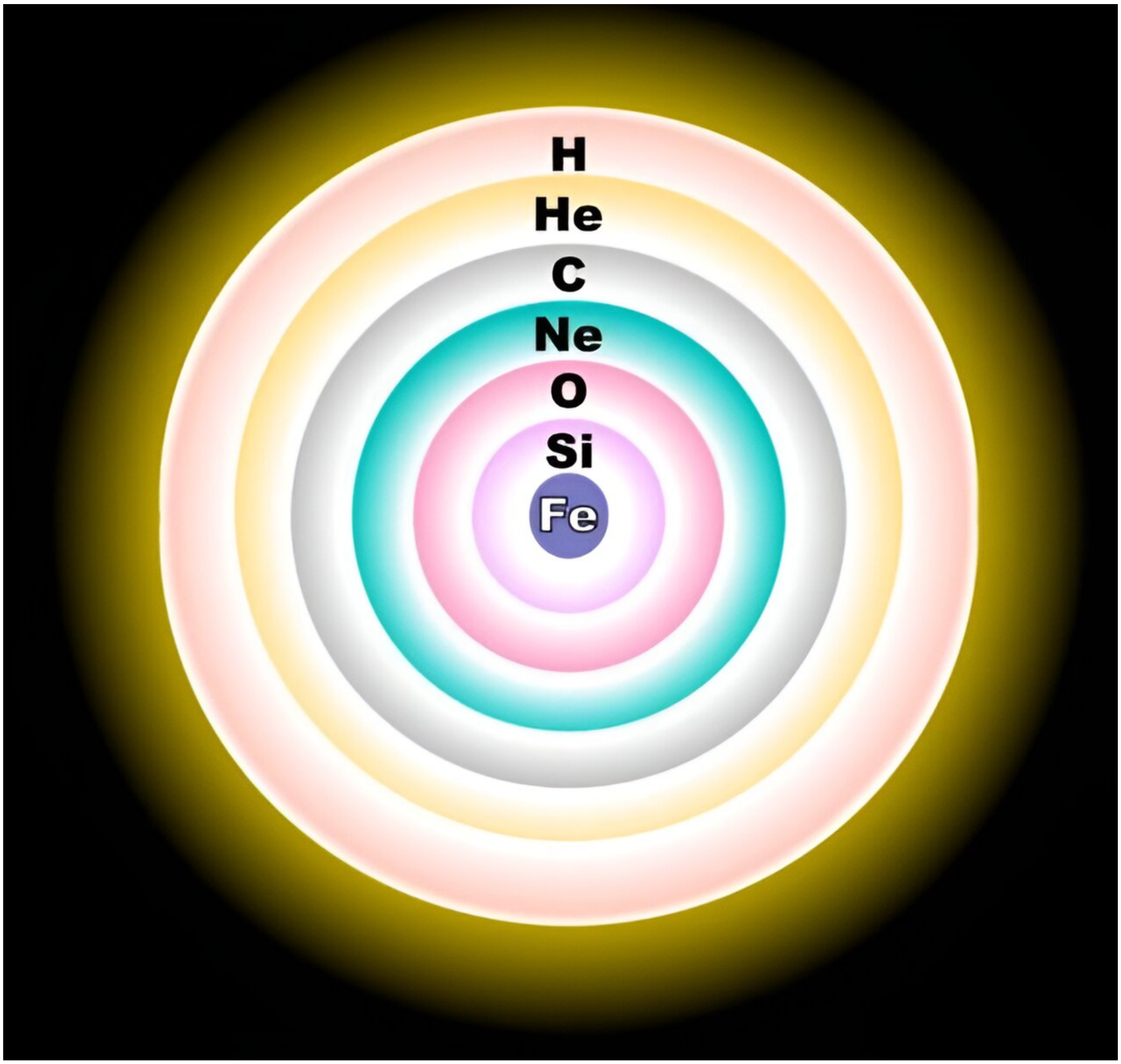
But a Type 1a supernova named SN 2022joj is exhibiting some peculiar behavior. This led the authors of a new paper to consider that the supernova may have exploded twice. Moreover, it didn't have to exceed the Chandrasekhar limit to detonate.

The paper is "SN 2022joj: A Potential Double Detonation with a Thin Helium Shell." It hasn't been published yet and is available on the pre-print server *arXiv*. The lead author is Estefania Padilla Gonzalez from the Department of Physics at UC Santa Barbara and the Las Cumbres Observatory.

Double-detonation stars are rare but not unheard of. They happen when the white dwarf accretes a layer of helium that ignites. In these types of explosions, the white dwarf doesn't exceed the Chandrasekhar limit, and the explosion is relatively dim. These types of twice-exploding supernovae are called sub-luminous supernovae.

But it's not just the dimness that signals a double-detonation supernova. It has an unusual light curve where red light manifests 11 days prior to its maximum brightness. After that peak, it resembles a more typical Type 1a supernova. That, combined with other aspects of its spectroscopy, led the authors of the new paper to consider that Sn 2202joj might have experienced a double detonation.

At different stages of their evolution, different types of stars can have layers or shells of different chemical elements. White dwarfs are no different and can have outer shells of either helium or hydrogen. The large majority of white dwarfs have a hydrogen shell or atmosphere.

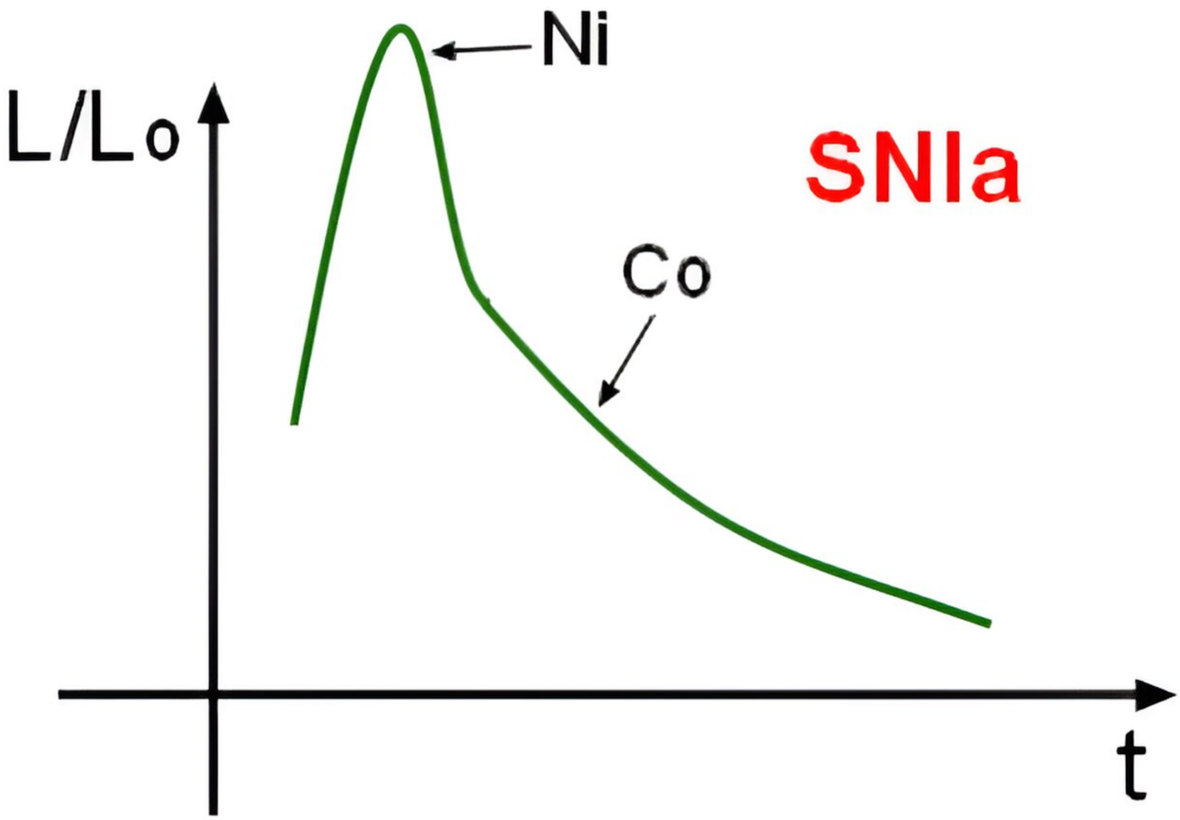


It's not to scale, but this schematic shows the onion-like layers of a massive evolved star just before it collapses. Each concentric shell of plasma is burning inside the star. Credit: By User: Rursus—R. J. Hall, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=2565862

The authors of this study suggest that Sn 2202joj has an outer shell of helium. In this case, the white dwarf's companion star has an outer shell of helium and 2202joj has siphoned off some of that helium to form its own helium shell. That can trigger a helium detonation, even though the star hasn't exceeded the well-known Chandrasekhar limit. An important point is that this helium explosion creates another element: an isotope of Nickel called 56Ni. All that nickel is visible in the star's spectrometry.

When the helium shell detonates, it not only synthesizes 56Ni. It drives a powerful shock wave into the white dwarf. That shock can trigger another detonation inside the star, and that's how nature creates a double-detonation supernova.

The spectroscopy from the supernova supports this explanation, according to the authors. "Spectroscopically, we find strong agreement between SN 2022joj and double-detonation models with white dwarf masses around 1 $M_{\odot}$ and thin He-shell between 0.01 and 0.02 $M_{\odot}$," they write.

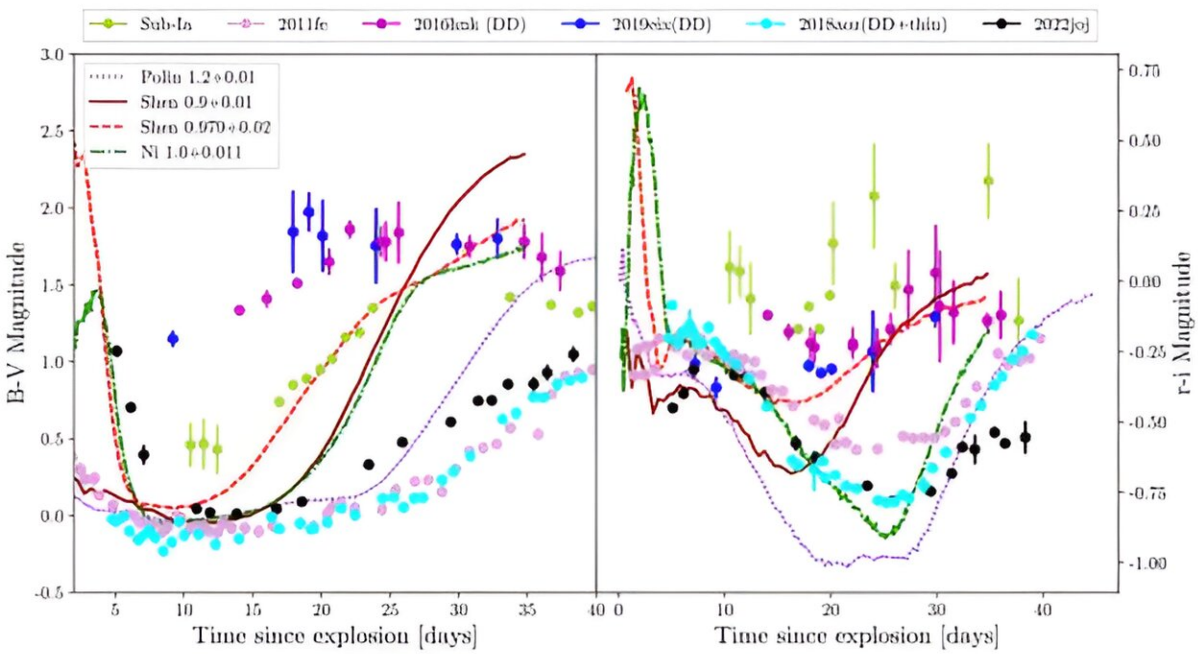


This light curve is typical of Type 1a supernova. The nickel produced by the explosion decays rapidly and creates a peak in brightness, then the luminosity decreases and is dominated by the decay of Cobalt. Credit: The *Astrophysical Journal* 547 (2): 988. DOI:10.1086/318428., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=308666

Light curves tell astrophysicists a lot about what's going on with a star. This one is no different, and SN 2202joj's light curve revealed a lot to the team of astronomers who studied it. Typically, a Type 1a supernova's light curve looks like this.

But SN 2202joj's light curve is different than a regular Type 1a SN. It has two separate peaks, and the first one is exceedingly red before quickly declining and shifting toward blue.

The following image compares SN 2202joj's light curve with light curves from other SNe as well as different models of double detonation SNe. There's a lot of data in this image, but it's worth a look.



This figure from the study shows the colour evolution of SN 2022joj plotted against other SNe and Sne models in colour and time since explosion. Dashed lines are what different models of double detonation SNe predict. Black is 2202joj, while the other colours are other stars that astrophysicists have studied. Notice that the magenta and the blue stars are both other double detonation SN, while 2202joj is a thin helium shell double detonation SN. It’s particularly interesting that 2202joj is much redder in its early phases than the other supernovae. Credit: Gonzalez et al. 2023

The researchers aren't 100% certain that this is a double detonation SN.

The early red colors indicated that two explosions occurred, but other evidence doesn't agree. "However, the nebular spectra composition in SN 2022joj deviates from expectations for double detonation," they write. The nebular spectra contain strong Fe III emissions, which a double detonation can't explain.

"More detailed modeling, e.g., including viewing angle effects, is required to test if double detonation models can explain the nebular spectra," they conclude.

Supernovae, though rare, play an important role in nature. They synthesize metals and spread them out into space when they explode. Without them, there would be no rocky planets like ours. Type 1a supernovae are important because of the specific role they play in the universe. Scientists think that they synthesize the majority of the elements in the iron group, from titanium to zinc.

Nature creates all kinds of fascinating things in space, and exploding stars are some of the most awe-inspiring. Stars contain an enormous amount of matter, and when one explodes, the supernova releases a massive amount of energy in a short period of time. It's only natural that these objects attract our attention.

More information: E. Padilla Gonzalez et al, SN 2022joj: A Potential Double Detonation with a Thin Helium shell, *arXiv* (2023). DOI: 10.48550/arxiv.2308.06334

Provided by Universe Today