Newly discovered supernova may rewrite exploding star origin theories

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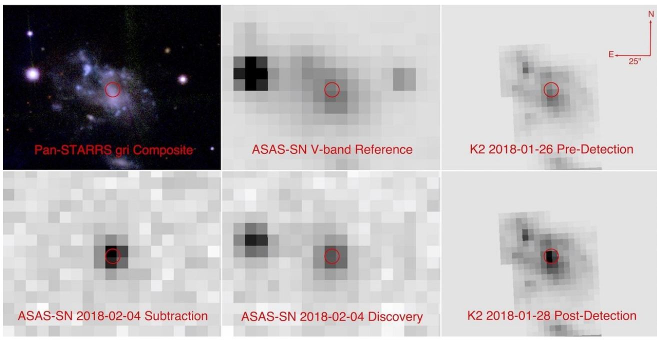

The top left panel shows a color composite image of the galaxy in which the supernova occured, taken with the Pan-STARRS1 telescope on Haleakal?. The top middle panel is the "reference" image of the same galaxy, without the supernova emission, from the ASAS-SN survey, and the top right panel shows a similar image from NASA's Kepler Space Telescope. The bottom middle and right panels are the corresponding ASAS-SN and Kepler images with the supernova. The bottom left panel is the difference between the two ASAS-SN images, showing only the light from the supernova. Credit: Ben Shappee/ASASSN/NASA

A supernova discovered by an international group of astronomers has provided an unprecedented look at the first moments of a violent stellar explosion. The team, led by the University of Hawai?i (UH) Institute for Astronomy's (IfA) Ben Shappee and Carnegie Observatories' Tom Holoien, found a mysterious signature in the light from the explosion's first hours. Their findings are published in a trio of papers in the *Astrophysical Journal*.

This category of supernova, called "Type Ia," is fundamental to our understanding of the cosmos. Their nuclear furnaces are crucial for generating many of the elements around us, and they are used as cosmic rulers to measure distances across the universe. Despite their importance, the actual mechanism that sets off a Type Ia supernova explosion has remained elusive for decades.

That's why catching them in the act is crucial.

Astronomers have long tried to get detailed data at the initial moments of the explosions, with the hope of figuring out how these phenomena are triggered. For the first time, they succeeded in February of this year, with the discovery of a Type Ia supernova called ASASSN-18bt (also known as SN 2018oh).

ASASSN-18bt was discovered by the All-Sky Automated Survey for Supernovae (ASAS-SN), an international network of telescopes headquartered at the Ohio State University, that routinely scans the sky for supernovae and other explosive events. NASA's Kepler Space Telescope was simultaneously able to take complementary data on this event. Kepler was designed to be extremely sensitive to small changes in light for its main mission of detecting extrasolar planets, so it was able to obtain especially detailed information about the explosion's genesis.

"ASASSN-18bt is the nearest and brightest supernova yet observed by Kepler, so it offered an excellent opportunity to test the predominant theories of supernova formation," said Shappee, who is lead author on the discovery and early-time paper. "The Kepler light curve is amazing. We can probe the explosion just hours after it happened."

In addition to the discovery and pre-discovery data from ASAS-SN, two IfA sky surveys also played crucial roles. Pre-discovery data from the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) and the Asteroid Terrestrial-impact Last Alert System (ATLAS) helped provided critical information about the color of the brightening supernova. Pan-STARRS even caught ASASSN-18bt within the first day after its explosion.

Combining data from ASAS-SN, Kepler, Pan-

STARRS, ATLAS, and telescopes from around the world, the astronomers realized that ASASSN-18bt looked unusual during its first couple of days. "Many supernovae show a gradual increase in the light they put out," said Maria Drout, assistant professor at the University of Toronto and third author on the discovery paper. "But for this event, you could clearly see something unusual and exciting happening in the early times—some unexpected additional emission."

Type Ia supernovae are thought to originate from the thermonuclear explosion of a white dwarf star—the dead core left over by a sun-like star after it exhausts its nuclear fuel. Material must be added to the white dwarf from a companion star to trigger the explosion, but the nature of the companion star and how the fuel is transferred has long been debated.

One possibility is that this additional light seen during the supernova's early times could be from the exploding white dwarf colliding with the companion star. Although this was the initial hypothesis, detailed comparisons with theoretical models and follow up observation from the Keck telescope demonstrated that this extra light has a different, unexplained origin.

"While the steep increase in ASASSN-18bt's early brightness could indicate that the explosion collides with another star, the data doesn't quite fit predictions for how this should appear," Holoien said. "Other possibilities, such as an unusual distribution of radioactive isotopes in the exploded star, could also explain what we saw."

Indeed, recent Keck observations looked for the outer layers that would have been stripped from a nearby star by the violent supernova explosion. "If the donor star was there, we would have seen it," says Michael Tucker, a graduate student at the Institute for Astronomy and lead author on the Keck paper. "But we just don't see anything."

This supports a recent hypothesis put forth by visiting-IfA astronomer Maximilian Stritzinger of Aarhus University that there may be two distinct populations of Type Ia supernovae—those that show early emission and those that do not—without the need for a nearby star.

"We are finding that supernovae explosions are more complicated than we previously thought, and that's half the fun," said Shappee.

Thanks to ASAS-SN, ATLAS, Pan-STARRS, and other surveys, we are now monitoring the sky every night, so astronomers will find even more new supernovae and catch them at the moment of explosion. As more of these events are found and studied, they will home in on the solution to the longstanding mystery of how these stellar explosions originate.

More information: "No Stripped Companion Material in the Nebular Spectrum of the "Two-Component" Type Ia Supernova ASASSN-18bt," M. A. Tucker, B. J. Shappee & J. P. Wisniewski, 2018 Nov. 30, to appear in the *Astrophysical Journal Letters* arxiv.org/abs/1811.09635

"K2 Observations of SN 2018oh Reveal a Two-Component Rising Light Curve for a Type Ia Supernova," G. Dimitriadis et al., 2018 Nov. 30, to appear in the *Astrophysical Journal Letters* arxiv.org/abs/1811.10061

"Photometric and Spectroscopic Properties of Type Ia Supernova 2018oh with Early Excess Emission from the Kepler 2 Observations," W. Li et al., 2018 Nov. 30, to appear in the *Astrophysical Journal* arxiv.org/abs/1811.10056

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