The Supernova Impostor With a Hidden Partner

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Mojgan Aghakhanloo (Credit: Mojgan Aghakhanloo)

We are pleased to welcome our guest blogger, Mojgan Aghakhanloo, who leads a new paper that is the subject of our latest Chandra press release. She is currently a VITA–Origins Fellow in the Department of Astronomy at the University of Virginia (UVA), and before joining UVA, she was a postdoctoral researcher at the University of Arizona. She earned her Ph.D. from Florida State University in 2020 and her bachelor's degree in Iran, where she is originally from. Her research focuses on non-terminal outbursts of massive stars, which she studies at optical, X-ray, and radio wavelengths.

Stars that fake their own deaths

When astronomers search the sky for supernovae (that is, explosions of stars), they sometimes find outbursts that look like the death of a massive star. However, some turn out to be something even stranger. These events are fainter and less energetic than true supernovae, and the star is expected to survive. Astronomers call them "supernova impostors": non-fatal outbursts from some of the most massive stars in the Universe.

Supernova impostors are often associated with stars known as luminous blue variables (LBVs). These are hot, bright, and massive stars that can undergo dramatic changes in brightness and shed enormous amounts of material into space. The most famous LBV in our Galaxy is Eta Carinae. During its "Great Eruption" in the 1840s, Eta Carinae expelled more than

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ten times the mass of the Sun and briefly became one of the brightest stars in the night sky.

Why LBVs matter, and why they are a puzzle

LBVs matter because their outbursts may help massive stars shed their outer hydrogen layers and become Wolf-Rayet stars, a late stage of evolution for huge stars when they have lost much of that hydrogen-rich envelope and expose their hot interiors. The expelled material may also form the dense surroundings of gas that some supernovae encounter when they eventually explode. In the traditional single-star picture, the LBV phase is a brief transitional stage that should not end in a supernova. But nature has complicated that picture. The supernova known as SN 2009ip, for example, was associated with an LBV-like star that erupted repeatedly before producing an event widely interpreted as a supernova in 2012.

What drives LBV outbursts remains one of the major open questions in astrophysical studies of massive stars. Increasing evidence points to stellar companions as possible key players. Most massive stars form in multiple-star systems, and many have companions close enough to interact with them as they evolve. LBVs also tend to be found farther from other young massive stars than expected, and some move unusually fast relative to their surroundings. These clues suggest that interactions with a companion may shape their evolution. The challenge is that detecting such companions directly is extremely difficult: an LBV can outshine its companion, while a close companion may be impossible to resolve separately in images.

A star on a schedule

This is where AT 2016blu comes in. It lies in the galaxy NGC 4559, about 30 million light-years away from Earth. Earlier observations with the Hubble Space Telescope showed that AT 2016blu is at least 33 times as massive as the Sun, making it unusually massive compared with the stars around it. It seems almost too young for its neighborhood, as though it had been rejuvenated by gaining mass from, or merging with, a companion.

Between 2012 and June 2026, AT 2016blu erupted at least 27 times, roughly every 113 days. Such roughly periodic outbursts point to an orbital connection. In our earlier study of AT 2016blu, we proposed that

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the star has a companion moving along an elongated, oval-shaped orbit, triggering an outburst each time the two approach one another. Its spectra revealed another surprise: the star remains hot during its outbursts, unlike many LBVs, which cool as they brighten.

But light curves and spectra alone could not tell us what the companion is. In Eta Carinae, the companion is another massive star. The two stars' powerful stellar winds collide, producing X-rays. A compact companion, such as a neutron star or black hole, would produce a very different X-ray signal. Material drawn from the LBV could form an accretion flow around the compact object, heating to millions of degrees and producing much brighter X-ray emission than colliding winds. By observing AT 2016blu in X-rays, we could test whether its companion is another massive star or a compact object.

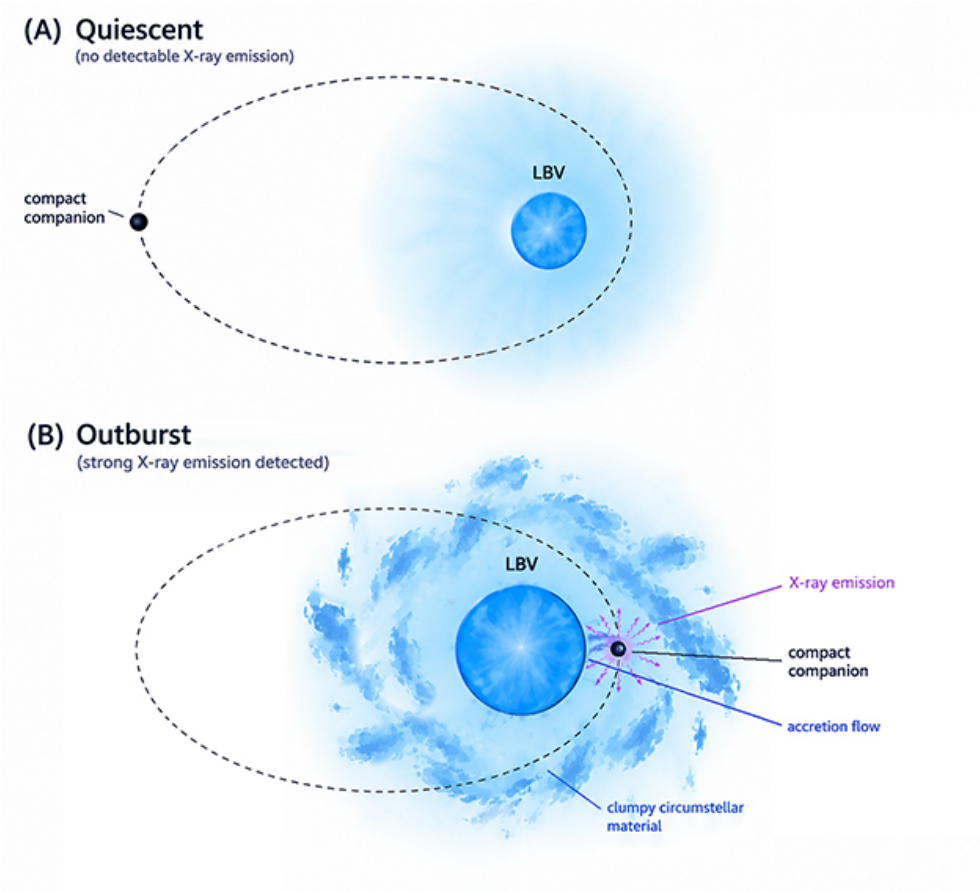


Figure 1. A schematic of the AT 2016blu system (not to scale). The LBV and its compact companion follow an oval-shaped orbit. When the two are far apart, the system is quiet and no X-rays are detected (A). Roughly every 113 days, the companion swings closest to the LBV and pulls in material from it. This material heats up to millions of degrees and shines in X-rays, which in turn heat the dense surrounding gas and make it glow in visible light, producing the outburst we see (B). **Credit:** NASA/SAO/CXC/Univ. of Virgina/M. Aghakhanloo et al.

Catching the star in the act

Timing was everything. AT 2016blu erupts roughly every 113 days, but the timing is not exact. To catch an outburst, we needed to monitor the star closely and trigger Chandra to observe it at just the right moment. That took a team effort. Our collaborators at UC Berkeley monitored AT 2016blu using the Katzman Automatic Imaging Telescope (KAIT) at Lick Observatory, while the Las Cumbres Observatory Global Supernova Project (GSP) followed it with telescopes around the world. In 2024, we also launched a campaign through the American Association of Variable Star Observers (AAVSO), bringing more than 30 amateur astronomers into the effort. They observed the star night after night. When KAIT and GSP observations showed AT 2016blu brightening in March 2026, we triggered Chandra.

AT 2016blu was detected in every Chandra observation. Its X-ray emission was at least 100 times brighter than in archival Chandra observations from 2001 and 2002, before the recurring outbursts began. Its X-ray luminosity is thousands of times greater than that of any other known LBV, far exceeding what colliding stellar winds can plausibly explain. The most compelling explanation is that material from the LBV is being pulled onto a neutron star or black hole as the two objects approach each other. AT 2016blu thus provides the first X-ray evidence for a compact companion with an LBV, placing the system among the high-mass X-ray binaries: systems containing a massive star and a compact stellar remnant.

AT 2016blu is also bright enough in X-rays to be classified as an ultraluminous X-ray (ULX) candidate, a class of exceptionally bright and still poorly understood X-ray sources. Another supernova impostor, SN 2010da, is also classified as a ULX, hinting at a link between these two mysterious groups of objects.

What comes next

One system can reveal a new phenomenon; a population can tell us how common it is. We now want to observe more repeating supernova impostors with Chandra to determine how often LBVs have compact companions. The Vera C. Rubin Observatory is expected to uncover more of these erupting stars, including some that are distant and faint for detailed study with current X-ray telescopes. Following up on those discoveries will require X-ray observatories that combine Chandra-like sharp vision with greater sensitivity.

AT 2016blu offers a tantalizing possibility: some of the most dramatic outbursts of massive stars may be driven not by an unstable star acting alone, but by an unseen companion drawing matter from it.

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