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James Webb Space Telescope Reconstructs a Seven-Year Stellar Merger in the Andromeda Galaxy

Environment * Climate Change * Atmospheric Physics

Most binary star systems evolve over millions or billions of years, making their brief, catastrophic mergers extraordinarily difficult to catch in action. In a landmark study published in Nature on November 18, 2026, an international team led by Viraj Karambelkar, a NASA Hubble Fellow at Columbia University, reported the first real-time, frame-by-frame reconstruction of a complete common-envelope stellar merger . Located on the outer fringes of the neighboring Andromeda Galaxy (M31) roughly 2.5 million light-years from Earth, the binary system -- formally designated AT 2025abao and nicknamed "Bao" -- consisted of an aging supergiant primary star that engulfed and merged with a smaller solar-type companion.

Crucially, NASA's James Webb Space Telescope (JWST) executed rapid-response mid-infrared observations of Bao in late December 2025, just 47 days after its merger eruption peaked. By pairing JWST's dust-penetrating infrared spectra with archival optical monitoring from surveys such as the Zwicky Transient Facility (ZTF), the team traced gas and dust ejected before, during, and after the collision -- demonstrating that the final inspiral unfolded over roughly seven years rather than the millennia once assumed by classical models.

Meet Big Bao and Little Bao in Andromeda's Outer Disk

Prior to its 2025 outburst, the binary system combined two starkly mismatched stars. The primary component ("Big Bao") was an evolved, bloated supergiant containing roughly 7 times the mass of the Sun and swollen to approximately 350 times the Sun's radius . Orbiting alongside it was a much smaller companion ("Little Bao") weighing roughly 0.7 solar masses .

As the massive primary expanded into its supergiant phase, tidal interactions and mass transfer destabilized the binary orbit. Archival photometry indicates that the two stars orbited steadily for millennia until orbital decay brought the companion into direct physical contact with the supergiant's outer envelope around 2018. Once Little Bao plunged inside Big Bao's tenuous outer atmosphere, aerodynamic drag stripped orbital angular momentum at an accelerating rate, driving the smaller star inward through roughly seven final orbits before culminating in a luminous red nova eruption on October 17, 2025.

| System / Event Parameter | | Observed Value (AT 2025abao / "Bao") |

| Host Galaxy & Distance | | Andromeda Galaxy (M31), ~2.5 million light-years away |

| Primary Star ("Big Bao") | | Evolved supergiant, ~7 solar masses, ~350 solar radii |

| Companion Star ("Little Bao") | | Main-sequence companion, ~0.7 solar masses |

| Inspiral Duration | | ~7 years (~7 final orbits from ~2018 contact to 2025 merger)

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| Peak Eruption & JWST Follow-Up | | Eruption on October 17, 2025; JWST mid-IR capture 47 days post-peak |

How JWST Mapped the Common-Envelope Dust Shells

Common-envelope evolution -- reviewed extensively by Ivanova and colleagues (2013) -- is one of the most important yet least constrained phases in stellar astrophysics . Whenever a giant star expands to engulf a companion, gravitational friction heats and expels the shared gaseous envelope, leaving behind either a tight compact binary (precursors to Type Ia supernovae, X-ray binaries, and gravitational-wave-emitting black hole or neutron star mergers) or a single coalesced star.

Because thick clouds of newly condensed silicate and carbonaceous dust rapidly shroud the merger site at optical wavelengths, ground-based telescopes quickly lose sight of the inner engine. Triggered just 47 days after maximum light, JWST's mid-infrared instruments pierced that opaque veil to map concentric shells of warm and cool dust. Those layered shells act as a fossilized velocity and timing record: outer shells trace pre-merger mass loss during the 2018-2025 inspiral, while dense inner ejecta preserve the shock heating and angular-momentum shedding of the October 2025 core coalescence.

A Seven-Year Inspiral Challenges Theoretical Timescales

One of the central surprises of the Bao reconstruction is how cleanly the pre-eruption lightcurve and post-eruption JWST dust architecture constrain the plunge timescale. Many hydrodynamical models struggled to bridge the gap between slow, secular tidal decay and dynamical plunge-in, often predicting prolonged common-envelope phases lasting centuries or millennia.

In AT 2025abao, however, the transition from initial envelope contact around 2018 to core unification in late 2025 required only about seven years. That rapid seven-orbit spiral provides quantitative calibration for 3D radiation-hydrodynamic simulations, helping astrophysicists refine the efficiency parameter alpha CE that governs how much orbital energy goes into unbinding stellar gas versus radiating away.

A Rejuvenated Remnant Star and Future Merger Demographics

Following the ejection of its outer common envelope, the merged remnant left behind by Big Bao and Little Bao is predicted to settle into a single, rapidly rotating, chemically mixed star -- effectively "rejuvenated" by fresh hydrogen drawn inward from its ingested companion. Detecting and modeling this process in real time within M31 establishes a template for interpreting future luminous red novae across the Local Universe.

As wide-field optical surveys such as ZTF and the Vera C. Rubin Observatory continue flagging transient outbursts in nearby galaxies , pairing immediate ground-based alerts with rapid-response JWST infrared spectroscopy will turn common-envelope mergers from rare theoretical mysteries into an empirically calibrated pillar of binary stellar evolution .

References & Primary Sources

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