

Astronomers witness a dying star reach its explosive end

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An artist's impression of a red supergiant star in the final year of its life emitting a tumultuous cloud of gas. This suggests at least some of these stars undergo significant internal changes before going supernova. Credit: W. M. Keck Observatory/Adam Makarenko

For the very first time, astronomers have imaged in real time the dramatic end to a red supergiant's life, watching the massive star's rapid self-destruction and final death throes before it collapsed into a Type II

supernova.

Using two Hawai'i telescopes—the University of Hawai'i Institute for Astronomy Pan-STARRS on Haleakalā, Maui and W. M. Keck Observatory on Maunakea, Hawai'i Island—a team of researchers conducting the Young Supernova Experiment (YSE) transient survey observed the [red supergiant](#) during its last 130 days leading up to its deadly detonation.

"This is a breakthrough in our understanding of what [massive stars](#) do moments before they die," says Wynn Jacobson-Galán, an NSF Graduate Research Fellow at UC Berkeley and lead author of the study. "Direct detection of pre-supernova activity in a red supergiant star has never been observed before in an ordinary Type II supernova. For the first time, we watched a red supergiant star explode!"

The discovery is published in today's issue of *The Astrophysical Journal*.

Pan-STARRS first detected the doomed massive star in Summer of 2020 via the huge amount of light radiating from the red supergiant. A few months later, in Fall of 2020, a supernova lit the sky.

The team quickly captured the powerful flash and obtained the very first spectrum of the energetic explosion, named supernova 2020tlf, or SN 2020tlf, using Keck Observatory's Low Resolution Imaging Spectrometer (LRIS). The data showed direct evidence of dense circumstellar material surrounding the star at the time of explosion, likely the same exact gas that Pan-STARRS had imaged the red supergiant star violently ejecting earlier in the summer.

"Keck was instrumental in providing direct evidence of a massive star transitioning into a supernova explosion," says senior author Raffaella Margutti, an associate professor of astronomy at UC Berkeley. "It's like

watching a ticking time bomb. We've never confirmed such violent activity in a dying red supergiant star where we see it produce such a luminous emission, then collapse and combust, until now."

The team continued to monitor SN 2020tlf after the explosion; based on data obtained from Keck Observatory's DEep Imaging and Multi-Object Spectrograph (DEIMOS) and Near Infrared Echellette Spectrograph (NIRES), they determined SN 2020tlf's progenitor [red supergiant star](#), located in the NGC 5731 galaxy about 120 million light-years away as seen from Earth, was 10 times more massive than the Sun.

The discovery defies previous ideas of how red supergiant stars evolve right before blowing up. Prior to this, all red supergiants observed before exploding were relatively quiescent: they showed no evidence of violent eruptions or luminous emission, as was observed prior to SN 2020tlf. However, this novel detection of bright radiation coming from a red supergiant in the final year before exploding suggests that at least some of these stars must undergo significant changes in their internal structure that then results in the tumultuous ejection of gas moments before they collapse.

Margutti and Jacobson-Galán conducted most of the study during their time at Northwestern University, with Margutti serving as an Associate Professor of Physics and Astronomy and member of CIERA (Center for Interdisciplinary Exploration and Research in Astrophysics), and Jacobson-Galán as a graduate student.

The team's discovery paves a path forward for transient surveys like YSE to hunt for luminous radiation coming from red supergiants, and gather more evidence that such behavior could signal the imminent, supernova demise of a massive star.

"I am most excited by all of the new 'unknowns' that have been unlocked

by this discovery," says Jacobson-Galán. "Detecting more events like SN 2020tlf will dramatically impact how we define the final months of stellar evolution, uniting observers and theorists in the quest to solve the mystery on how massive [stars](#) spend the final moments of their lives."

More information: Final Moments. I. Precursor Emission, Envelope Inflation, and Enhanced Mass Loss Preceding the Luminous Type II Supernova 2020tlf, *Astrophysical Journal* (2022).

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Provided by W. M. Keck Observatory

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