Hubble Space Telescope gives unprecedented, early view of a doomed star's destruction

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Astronomers recently witnessed supernova SN 2020fqv explode inside the interacting Butterfly galaxies, located about 60 million light-years away in the constellation Virgo. Researchers quickly trained NASA's Hubble Space Telescope on the aftermath. Along with other space- and ground-based telescopes, Hubble delivered a ringside seat to the first moments of the ill-fated star's demise, giving a comprehensive view of a supernova in the very earliest stage of exploding. Hubble probed the material very close to the supernova that was ejected by the star in the last year of its life. These observations allowed researchers to understand what was happening to the star just before it died, and may provide astronomers with an early warning system for other stars on the brink of death. Credit: NASA, ESA, Ryan Foley (UC Santa Cruz), Joseph DePasquale (STScI)

Like a witness to a violent death, NASA's Hubble Space Telescope recently gave astronomers an unprecedented, comprehensive view of the first moments of a star's cataclysmic demise. Hubble's data, combined with other observations of the doomed star from space- and ground-based telescopes, may give astronomers an early warning system for other stars on the verge of blowing up.

"We used to talk about supernova work like we were crime scene investigators, where we would show up after the fact and try to figure out what happened to that star," explained Ryan Foley of the University of California, Santa Cruz, the leader of the team that made this discovery. "This is a different situation, because we really know what's going on and we actually see the death in real time."

Telescope teamwork

The supernova, called SN 2020fqv, is in the interacting Butterfly Galaxies, which are located about 60 million light-years away in the constellation Virgo. It was discovered in April 2020 by the Zwicky Transient Facility at the Palomar Observatory in San Diego, California. Astronomers realized that the supernova was simultaneously being observed by the Transiting Exoplanet Survey Satellite (TESS), a NASA satellite designed primarily to discover exoplanets, with the ability to detect an assortment of other phenomena. They quickly trained Hubble and a suite of ground-based telescopes on it.

Together, these observatories gave the first holistic view of a star in the very earliest stage of destruction. Hubble probed the material very close to the star, called circumstellar material, mere hours after the explosion. This material was blown off the star in the last year of its life. These observations allowed astronomers to understand what was happening to the star just before it died.

"We rarely get to examine this very close-in circumstellar material since it is only visible for a very short time, and we usually don't start observing a supernova until at least a few days after the explosion," explained Samaporn Tinyanont, lead author on the study's paper to be published in the *Monthly Notices of the Royal*

Astronomical Society. "For this supernova, we were able to make ultra-rapid observations with Hubble, giving unprecedented coverage of the region right next to the star that exploded."

Telling the star's story

The team looked at Hubble observations of the star going back to the 1990s. TESS provided an image of the system every 30 minutes starting several days before the explosion, through the explosion itself, and continuing for several weeks. Hubble was used again starting only hours after astronomers first detected the explosion. And from studying the circumstellar material with Hubble, the scientists gained an understanding of what was happening around the star in the previous decade. By combining all of this information, the team was able to create a multi-decade look at the star's final years.

"Now we have this whole story about what's happening to the star in the years before it died, through the time of death, and then the aftermath of that," said Foley. "This is really the most detailed view of stars like this in their last moments and how they explode."

The rosetta stone of supernovas

Tinyanont and Foley called SN 2020fqv "the Rosetta Stone of supernovas." The ancient Rosetta Stone, which has the same text inscribed in three different scripts, helped experts learn to read Egyptian hieroglyphs.

In the case of this supernova, the science team used three different methods to determine the mass of the exploding star. These included comparing the properties and the evolution of the supernova with theoretical models; using information from a 1997 archival Hubble image of the star to rule out higher-mass stars; and using observations to directly measure the amount of oxygen in the supernova, which probes the mass of the star. The results are all consistent: around 14 to 15 times the mass of the Sun. Accurately determining the mass of the star that explodes in a supernova is crucial to understanding how massive stars live and die.

"People use the term 'Rosetta Stone' a lot. But this is the first time we've been able to verify the mass with these three different methods for one supernova, and all of them are consistent," said Tinyanont. "Now we can push forward using these different methods and combining them, because there are a lot of other supernovas where we have masses from one method but not another."

An early warning system?

In the years before stars explode, they tend to become more active. Some astronomers point to the red supergiant Betelgeuse, which has recently been belching significant amounts of material, and they wonder if this star will soon go supernova. While Foley doubts Betelgeuse will imminently explode, he does think we should take such stellar outbursts seriously.

"This could be a warning system," said Foley. "So if you see a star start to shake around a bit, start acting up, then maybe we should pay more attention and really try to understand what's going on there before it explodes. As we find more and more of these supernovas with this sort of excellent data set, we'll be able to understand better what's happening in the last few years of a star's life."

More information: The research paper is available as a PDF at stsci-opo.org/STScI-01FH8PXT7J03QWHH2JAZYN79DK.pdf

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