Astronomers uncover new clues to the star that wouldn't die

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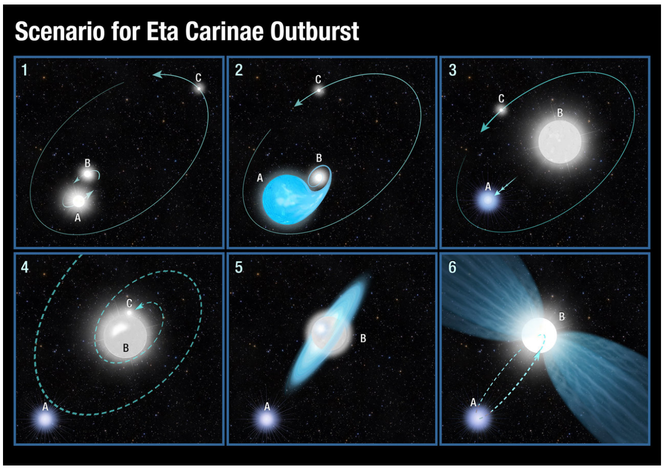

This six-panel graphic illustrates a possible scenario for the powerful blast seen 170 years ago from the star system Eta Carinae. 1. Eta Carinae initially was a triple-star system. Two hefty stars (A and B) in the system are orbiting closely and a third companion C is orbiting much farther away. 2. When the most massive of the close binary stars (A) nears the end of its life, it begins to expand and dumps most of its material onto its slightly smaller sibling (B). 3. The sibling (B) bulks up to about 100 solar masses and becomes extremely bright. The donor star (A) has been stripped of its hydrogen layers, exposing its hot helium core. The mass transfer alters the gravitational balance of the system, and the helium-core star moves farther away from its monster sibling. 4. The helium-core star then interacts gravitationally with the outermost star (C), pulling it into the fray. The two stars trade places, and the outermost star gets kicked inward. 5. Star C, moving inward, interacts with the extremely massive sibling, creating a disk of material around the giant star. 6. Eventually, star C merges with the hefty star, producing an explosive event that forms bipolar lobes of material ejected from the monster sibling. Meanwhile, the surviving companion, A, settles into an elongated orbit around the merged pair. Every 5.5 years it passes through the giant star's outer gaseous envelope, producing shock waves that are detected in X-rays. Credit: NASA, ESA, and A. Feild (STScI)

What happens when a star behaves like it exploded, but it's still there?

About 170 years ago, astronomers witnessed a major outburst by Eta Carinae, one of the brightest known stars in the Milky Way galaxy. The blast unleashed almost as much energy as a standard supernova explosion.

Yet Eta Carinae survived.

An explanation for the eruption has eluded astrophysicists. They can't take a time machine back to the mid-1800s to observe the outburst with modern technology.

However, astronomers can use nature's own "time machine," courtesy of the fact that light travels at a finite speed through space. Rather than heading straight toward Earth, some of the light from the outburst rebounded or "echoed" off of interstellar dust, and is just now arriving at Earth. This effect is called a light echo. The light is behaving like a postcard that got lost in the mail and is only arriving 170 years later.

By performing modern astronomical forensics of the delayed light with ground-based telescopes, astronomers uncovered a surprise. The new measurements of the 1840s eruption reveal material expanding with record-breaking speeds up to 20 times faster than astronomers expected. The observed velocities are more like the fastest material ejected by the blast wave in a supernova explosion, rather than the relatively slow and gentle winds expected from massive stars before they die.

Based on this data, researchers suggest that the eruption may have been triggered by a prolonged stellar brawl among three rowdy sibling stars, which destroyed one star and left the other two in a binary system. This tussle may have culminated with a violent explosion when Eta Carinae devoured one of its two companions, rocketing more than 10 times the mass of our Sun into space. The ejected mass created gigantic bipolar lobes resembling the dumbbell shape seen in present-day images.

The results are reported in a pair of papers by a team led by Nathan Smith of the University of Arizona in Tucson, Arizona, and Armin Rest of the Space Telescope Science Institute in Baltimore, Maryland.

The light echoes were detected in visible-light images obtained since 2003 with moderate-sized telescopes at the Cerro Tololo Inter-American Observatory in Chile. Using larger telescopes at the Magellan Observatory and the Gemini South Observatory, both also located in Chile, the team then used spectroscopy to dissect the light, allowing them to measure theejecta's expansion speeds. They clocked material zipping along at more than 20 million miles per hour (fast enough to travel from Earth to Pluto in a few days).

The observations offer new clues to the mystery surrounding the titanic convulsion that, at the time, made Eta Carinae the second-brightest nighttime star seen in the sky from Earth between 1837 and 1858. The data hint at how it may have come to be the most luminous and massive star in the Milky Way galaxy.

"We see these really high velocities in a star that seems to have had a powerful explosion, but somehow the star survived," Smith explained. "The easiest way to do this is with a shock wave that exits the star and accelerates material to very high speeds."

Massive stars normally meet their final demise in shock-driven events when their cores collapse to make a neutron star or black hole. Astronomers see this phenomenon in supernova explosions where the star is obliterated. So how do you have a star explode with a shock-driven event, but it isn't enough to completely blow itself apart? Some violent event must have dumped just the right amount of energy onto the star, causing it to eject its outer layers. But the energy wasn't enough to completely annihilate the star.

One possibility for just such an event is a merger between two stars, but it has been hard to find a scenario that could work and match all the data on Eta Carinae.

The researchers suggest that the most straightforward way to explain a wide range of observed facts surrounding the eruption is with an interaction of three stars, where the objects exchange mass.

If that's the case, then the present-day remnant binary system must have started out as a triple system. "The reason why we suggest that members of a crazy triple system interact with each other is because this is the best explanation for how the present-day companion quickly lost its outer layers before its more massive sibling," Smith said.

In the team's proposed scenario, two hefty stars are orbiting closely and a third companion is orbiting farther away. When the most massive of the close binary stars nears the end of its life, it begins to expand and dumps most of its material onto its slightly smaller sibling.

The sibling has now bulked up to about 100 times the mass of our Sun and is extremely bright. The donor star, now only about 30 solar masses, has been stripped of its hydrogen layers, exposing its hot helium core.

Hot helium core stars are known to represent an advanced stage of evolution in the lives of massive stars. "From stellar evolution, there's a pretty firm understanding that more massive stars live their lives more quickly and less massive stars have longer lifetimes," Rest explained. "So the hot companion star seems to be further along in its evolution, even though it is now a much less massive star than the one it is orbiting. That doesn't make sense without a transfer of mass."

The mass transfer alters the gravitational balance of the system, and the helium-core star moves farther away from its monster sibling. The star travels so far away that it gravitationally interacts with the outermost third star, kicking it inward. After making a few close passes, the star merges with its heavyweight partner, producing an outflow of material.

In the merger's initial stages, the ejecta is dense and expanding relatively slowly as the two stars spiral closer and closer. Later, an explosive event occurs when the two inner stars finally join together, blasting off material moving 100 times faster. This material eventually catches up with the slow ejecta and rams into it like a snowplow, heating the material and making it glow. This glowing material is the light source of the main historical eruption seen by astronomers a century and a half ago.

Meanwhile, the smaller helium-core star settles into an elliptical orbit, passing through the giant star's outer layers every 5.5 years. This interaction generates X-ray emitting shock waves.

A better understanding of the physics of Eta Carinae's eruption may help to shed light on the complicated interactions of binary and multiple stars, which are critical for understanding the evolution and death of massive stars.

The Eta Carinae system resides 7,500 light-years away inside the Carina nebula, a vast star-forming region seen in the southern sky.

The team published its findings in two papers, which appear online Aug. 2 in The *Monthly Notices of the Royal Astronomical Society*.

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