NASA’s James Webb Space Telescope offers dramatically different views of the Southern Ring Nebula. Each image combines near- and mid-infrared light from three filters. At left, Webb’s image of the Southern Ring Nebula highlights the very hot gas that surrounds the two central stars. At right, Webb’s image traces the star’s scattered molecular outflows that have reached farther into the cosmos. In the image at left, blue and green were assigned to Webb’s near-infrared data taken in 1.87 and 4.05 microns (F187N and F405N), and red was assigned to Webb’s mid-infrared data taken in 18 microns (F1800W). In the image at right, blue and green were assigned to Webb’s near-infrared data taken in 2.12 and 4.7 microns (F212N and F470N), and red was assigned to Webb’s mid-infrared data taken in 7.7 microns (F770W). Credit: NASA, ESA, CSA, and O. De Marco (Macquarie University). Image processing: J. DePasquale (STScI)
Around 2,500 years ago, a star ejected most of its gas, forming the beautiful Southern Ring Nebula, NGC 3132, chosen as one of the first five image packages from the James Webb Space Telescope (JWST).

A team of nearly 70 astronomers from 66 organizations across Europe, North, South and Central America, and Asia have used the JWST images to piece together the messy death of this star.

"It was nearly three times the size of our sun, but much younger, about 500 million years old. It created shrouds of gas that have expanded out from the ejection site, and left a remnant dense white dwarf star, with about half the mass of the sun, but approximately the size of the Earth," says Professor Orsola De Marco, lead author on the paper, from Macquarie University's Research Center for Astronomy, Astrophysics and Astrophotonics.

"We were surprised to find evidence of two or three companion stars that probably hastened its death as well as one more 'innocent bystander' star that got caught up in the interaction," she says.

The study was based on the JWST images supplemented by data from the ESO Very Large Telescope in Chile, the San Pedro de Mártir Telescope in Mexico, the Gaia Space Telescope, and the Hubble Space Telescope.
Examine the straight, brightly-lit lines that pierce through the rings of gas and dust around the edges of the Southern Ring Nebula in the James Webb Space Telescope’s image. These “spokes” appear to emanate from one or both of the central stars, marking where light streams through holes in the nebula. A research team projects that the straight lines may have been shot out hundreds of years earlier and at greater speeds than those that appear thicker and curvy. It’s possible the second set is a mix of material that slowed, creating less linear shapes. In this image, blue and green were assigned to Webb’s near-infrared data taken in 2.12 and 4.7 microns (F212N and F470N), and red was assigned to Webb’s mid-infrared data taken in 7.7 microns (F770W). Credit: NASA, ESA, CSA, and O. De Marco (Macquarie University). Image processing: J. DePasquale (STScI)

It paves the way for future JWST observations of nebulae, providing
insight into fundamental astrophysical processes including colliding winds, and binary star interactions, with implications for supernovae and gravitational wave systems.

The paper is published today in *Nature Astronomy*.

"When we first saw the images, we knew we had to do something, we must investigate! The community came together and from this one image of a randomly chosen nebula we were able to discern much more precise structures than ever before. The promise of the James Webb Space Telescope is incredible," says De Marco, who is also president of the International Astronomical Union Commission on Planetary Nebulae.

Astronomers gathered online and developed theories and models around the mid-infrared image to reconstruct just how the star had died.
How did up to five stars create the Southern Ring Nebula? Panel 1 shows a wider field with stars 1, 2, and 5, the last of which orbits star 1 far more tightly than star 2 does. Panel 2 zooms way in on the scene, and two other stars (3 and 4) appear in view; star 3 is emitting jets. Panel 3 shows star 1 expanding as it ages. Both stars 3 and 4 have sent off a series of jets. In panel 4 we zoom out to see how light and stellar winds are carving out a bubble-like cavity. Star 1 is surrounded by a dusty disk. In the fifth panel, star 5 is interacting with the ejected gas and dust, generating the system of large rings seen in the outer nebula. The sixth panel portrays the scene as we observe it today. Credit: NASA, ESA, CSA, E. Wheatley (STScI)

Shining at the center of the nebula is an ultra-hot central star, a white dwarf that has burned up its hydrogen. "This star is now small and hot, but is surrounded by cool dust," said Joel Kastner, another team member, from the Rochester Institute of Technology USA. "We think all that gas and dust we see thrown all over the place must have come from that one star, but it was tossed in very specific directions by the companion stars."

There are also a series of spiral structures moving out from the center. These concentric arches would be created when a companion orbits the central star while it is losing mass. Another companion is further out and is also visible in the picture.

Looking at a three-dimensional reconstruction of the data, the team also saw pairs of protuberances that may occur when astronomical objects eject matter in jet form. These are irregular and shoot out in different directions, possibly implying a triple star interaction at the center.

De Marco says. "We first inferred the presence of a close companion because of the dusty disk around the central star, the further partner that created the arches and the super far companion that you can see in the image. Once we saw the jets, we knew there had to be another star or
even two involved at the center, so we believe there are one or two very close companions, an additional one at middle distance and one very far away. If this is the case, there are four or even five objects involved in this messy death."


Provided by Macquarie University

Citation: The messy death of a star, as observed by Webb (Update) (2022, December 8) retrieved 21 December 2022 from [https://phys.org/news/2022-12-messy-death-star-webb.html](https://phys.org/news/2022-12-messy-death-star-webb.html)

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