Supernova remnant Cassiopeia A gets the JWST treatment

April 11 2023, by Carolyn Collins Petersen

A closeup of the "Green Monster" (named after Boston's Fenway Park). The JWST view shows incredible detail in this and other filaments at the heart of Cas A. Credit: NASA, ESA, CSA, D. D. Milisavljevic (Purdue), T. Temim (Princeton), I. De Looze (Ghent University). Image Processing: J. DePasquale (STScI)

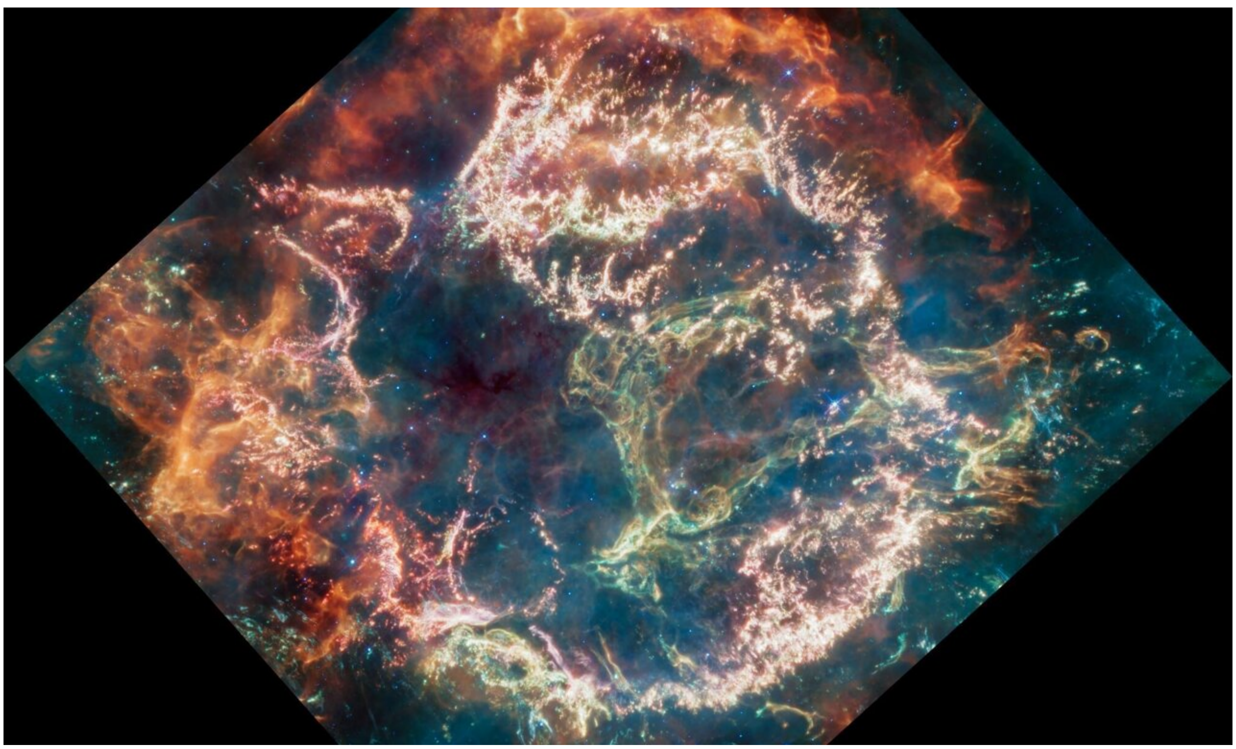
Ready for another stunning image from JWST? How about a peek inside a supernova remnant? Not just any stellar debris, but a highly detailed view of the leftovers from the explosion that created Cassiopeia A. The latest image is giving astronomers an up-close and personal look at what happened to a supermassive star some 11,000 light-years away from us. It may also help answer questions about the existence of cosmic dust, particularly in the early universe.

The Cassiopeia A supernova remnant has been studied a lot. But, the new JWST view shows a great deal more detail that astronomers haven't seen in other observations. And, that detail is opening up new windows on this stellar event. "Cas A represents our best opportunity to look at the debris field of an exploded star and run a kind of stellar autopsy to understand what type of star was there beforehand and how that star exploded," said Danny Milisavljevic. He's the principal investigator of the observing program that captured this view.

Exploring the damage

This image tells a tale of sequential destruction when the supermassive star at the heart of Cas A died. First, as the aging star began its death process, it consumed heavier and heavier fuels in its core. That heated it up and the star expanded. It also ejected clouds of warm dust. They expanded slowly outward from the event. Then, when the star's core began to consume iron, it took more energy than the star could supply. Burning stopped and the core collapsed. That brought the rest of the star inward. Then, it all rebounded, sending tendrils of stellar material racing away from the core. Eventually, that material collided with the slower-expanding dust shell.

All the colors in the image indicate the various parts of the explosion. The scene is pretty confusing at first. Astronomers are still working to figure out all the different sources of emissions in the remnant. The orange and red-hued material indicates emission from the warm outer shell. The tendrils are the starstuff rushing away from the collapsed core. They are bright pink and studded with knots and clumps. There's a mix of elements generated in the star and by the explosion—including oxygen, neon, and argon. There is a collection of wispy star material closer to the center of the explosion site. The most prominent is a giant green loop that the team nicknamed the "Green Monster." It's an unexpected feature and nobody's quite sure how or why it formed.



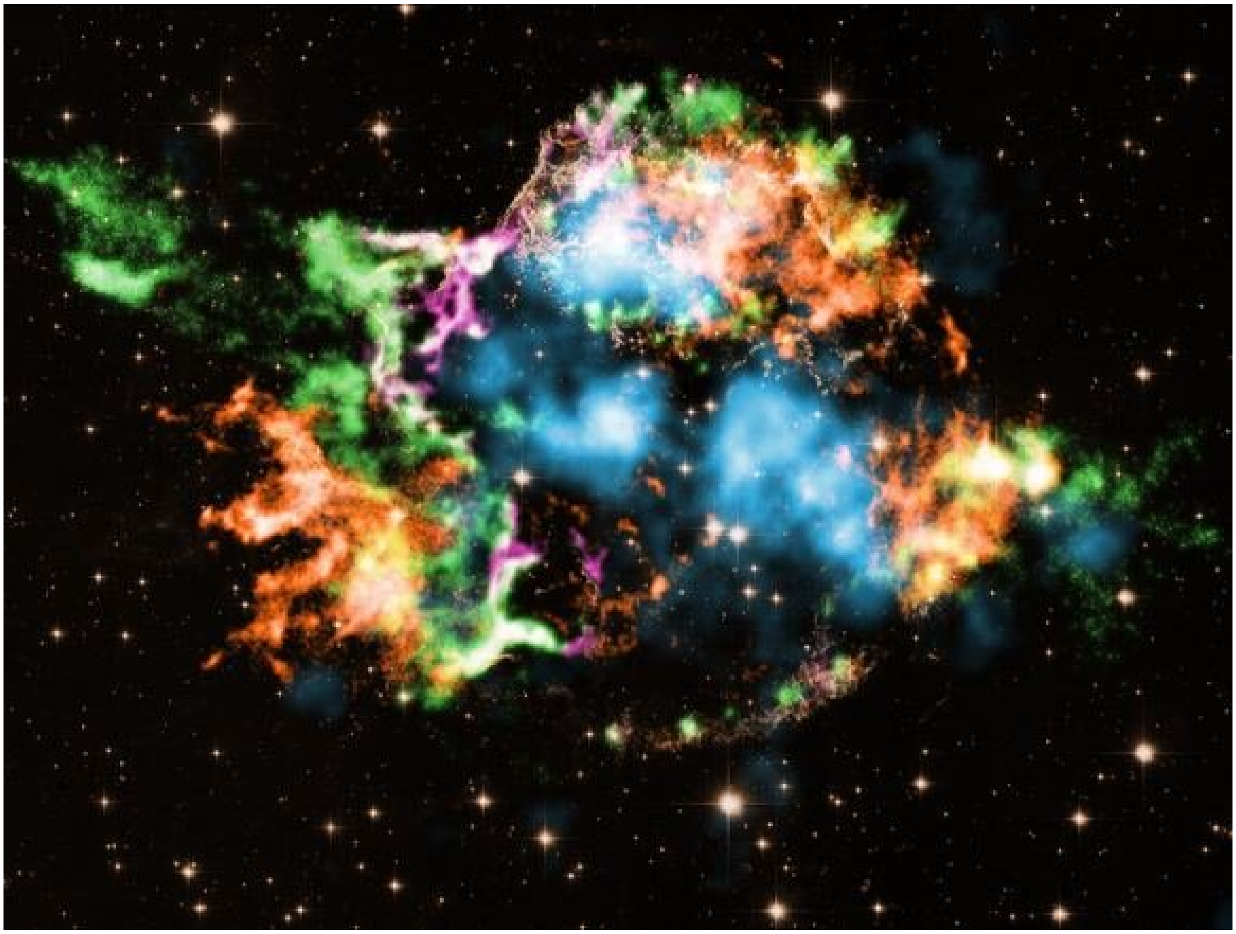
Cassiopeia A (Cas A) is a supernova remnant. It has been observed many times. This new image uses data from Webb's Mid-Infrared Instrument (MIRI) to reveal Cas A in a new light. Credit: NASA, ESA, CSA, D. D. Milisavljevic (Purdue), T. Temim (Princeton), I. De Looze (Ghent University). Image Processing: J. DePasquale (STScI)

The Cas A supernova remnant and cosmic dust

Supernovae scatter huge amounts of dust in their wakes. So, this raises a question. Since astronomers see dusty galaxies in the early universe, did supernovae make them that way? The answer is complicated. Certainly, the first supermassive stars existed pretty early in cosmic history. And, they died in supernova explosions. So, it might make sense to assume that they'd scatter dust as they died. Yet, observations of more "modern" supernovae and their dust output don't always explain the huge amounts of dust in early times. So, where did the early dust come from, if not from supernovae?

The answer may be that they did provide all that dust. We just need the high-resolution infrared views that JWST is able to provide to find the evidence for that. "In Cas A, we can spatially resolve regions that have different gas compositions and look at what types of dust were formed in those regions," said Temim. That means JWST can "see" what astronomers haven't been able to detect using many other telescopes in the past.

Exploring supernova remnants like Cas A gives astronomers more than a view of what a dying star does to its environment. Doing it in high-resolution detailed infrared views allows astronomers to "see inside" dusty objects such as Cas A. Not only that, but it provides a window to the past. "By understanding the process of exploding stars, we're reading our own origin story," said Milisavljevic. "I'm going to spend the rest of my career trying to understand what's in this data set."



This Chandra X-ray Observatory image of Cas A shows chemical elements in the supernova remnant. The different colors mostly represent iron (orange), oxygen (purple), and the amount of silicon compared to magnesium (green). Titanium (light blue) detected previously by NASA's NuSTAR telescope at higher X-ray energies is also shown. These Chandra and NuSTAR X-ray data have been overlaid on an optical-light image from the Hubble Space Telescope (yellow). Credit: Chandra: NASA/CXC/RIKEN/T. Sato et al.; NuSTAR: NASA/NuSTAR; Hubble: NASA/STScI

Past views of supernova remant of Cas A

Cassiopeia A lies only about 11,000 light-years from us and stretches across 10 light-years of space. It was probably first observed in the late 1600s from Earth. With the advent of modern telescopes, it has been seen in visible light from the ground, as well as through radio observations, and from space by the Hubble Space Telescope, the Chandra X-ray Observatory, NuSTAR, and others.

This lopsided stellar remnant itself is speeding out from the explosion site at a velocity between 4,000 and 6,000 kilometers per second. HST images showed knots and other ejecta moving away at up to 14,500 kilometers per second. Spitzer Space Telescope and the Infrared Astronomical Satellite (both predecessors to JWST) detected an infrared echo from the explosion on nearby gas clouds.

All of these observations point to Cas A being a perfect target for further studies of supernova explosions and their role throughout cosmic time.

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