# Using James Webb Space Telescope to study supernovae as source of heavy elements in the universe

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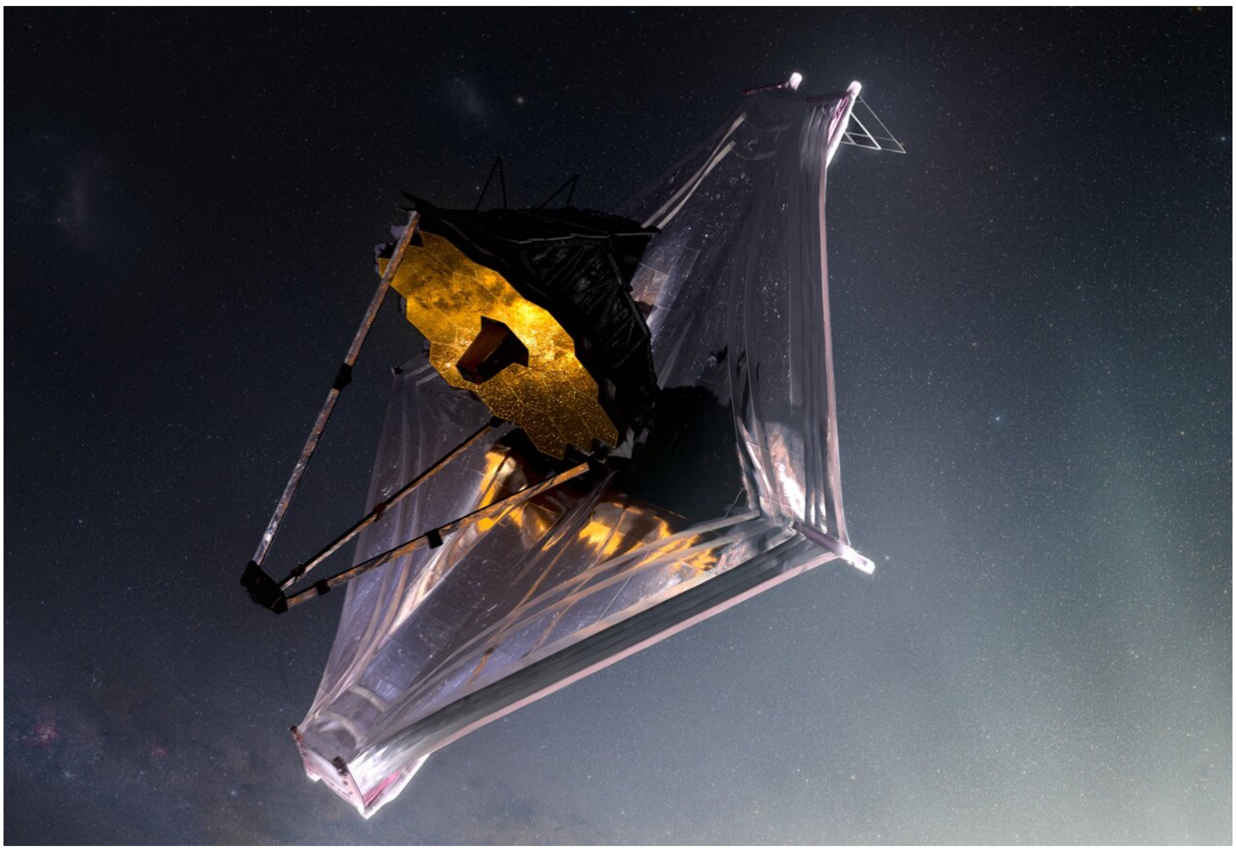

An illustration of the James Webb Space Telescope. Credit: NASA Godard Space Flight Center/Conceptual Image Laboratory by Adriana Manrique Gutierre

In 1980's popular book "Cosmos," Carl Sagan wrote of what makes us: "All the elements of the Earth except hydrogen and some helium have been cooked by a kind of stellar alchemy billions of years ago in stars, some of which are today inconspicuous white dwarfs on the other side of the Milky Way galaxy. The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, the carbon in our apple pies were made in the interiors of collapsing stars. We are made of 'starstuff.'"

Chris Ashall, an assistant professor of astrophysics in the Virginia Tech College of Science's Department of Physics, wants to know more about where and how this "starstuff" is made.

This week, Ashall began using NASA's James Webb Space Telescope to collect data on the presence of heavy elements in exploding dying stars, or supernovae. As James Webb's Baltimore-based mission operations center relays commands to the distant telescope to gather observations on supernovae targeted by Ashall, his team at Virginia Tech will study the collected data alongside more than 30 other scientists from around the world as part of the Mid-Infrared Supernova Collaboration that Ashall leads.

Ashall is one of the few scientists selected to use the telescope for two projects during the mission's first cycle. The projects will study two types of supernovae: type Ia supernovae, which describe exploding carbon-oxygen white dwarf stars, and core-collapse supernovae.

"Pretty much everything around us comes from dying stars," Ashall said. "We're made of stardust. Being able to study that fact—what we're made out of—in detail, and to understand where the elements around us come from, is truly amazing."

Stars produce heavy elements through the process of stellar nucleosynthesis. As stars burn, die, and explode, thermonuclear reactions take place inside them.

Supernovae are one of the highest-temperature and highest-density places in the universe, Ashall said. The material in stars burns and burns to form heavier and heavier elements, from hydrogen to helium, helium to carbon, carbon to oxygen, and so forth, all the way through the Periodic Table to iron.

When the stars finally explode, they throw all of this material back out into the universe at speeds up to 30 percent of the speed of light to make the next generation of stars and planets. "That's how the planet and everything around us can have all of these heavy elements," Ashall said. "They were made in dying stars."

It's widely accepted that most of the heavy elements in the universe are made by way of stellar nucleosynthesis, but Ashall wants to know more—to trace particular elements to the varieties of supernovae out there and to measure at what levels those elements are made by the stars.

In his first project, Ashall will look for elements commonly found on Earth, such as manganese, chromium, cobalt, and nickel, by focusing the James Webb Telescope on one Ia supernova in particular: a third-generation white dwarf titled SN2021aefx, which exploded a year ago in the spiral galaxy NGC1566, also known as the Spanish Dancer.

"A year after it has exploded, you can look and see right through to the center of the supernova," Ashall said. "That's where all this high-density burning happens. The nucleosynthesis happens in only a few seconds, but we see the central high-density region a year after the explosion."

Ashall will use the telescope to collect imaging and spectroscopy data on elements inside SN2021aefx. Spectroscopy involves looking at spectra produced by material when it interacts with or emits light by breaking the light into its component colors, per NASA. "Spectroscopy tells us about different elemental lines," Ashall said. "If there's a line, we know the element is there."

NASA's new telescope is the first that's capable of collecting the kind of data Ashall needs. James Webb can observe in wavelength regimes that Hubble just couldn't, Ashall said.

"Hubble could mainly observe in the ultraviolet, optical, and a tiny bit in the near-infrared, but James Webb was made to observe in the near-infrared and the mid-infrared," he said. "It opens up a whole new wavelength window to do astrophysics."

Ashall's second project will focus on detecting carbon monoxide and silicon monoxide, also building blocks for life in the universe, in core-collapse supernovae. Core-collapse supernovae are massive dying stars more than eight times the mass of our sun. The supernova's name comes from the kind of explosion that occurs, Ashall said: When the massive star dies, it collapses in on itself and makes an explosion more than 100 billion times brighter than the sun.

Using the observations made by the James Webb Space Telescope, Ashall will work to not only source heavy elements, but to investigate when they were ejected by the exploding supernova. His team will study how supernovae explode by pairing the data with computer simulations of explosions.

"When we measure these lines, we can figure out velocities of the explosion," Ashall said. "So then we'll understand how fast these elements are thrown out into the universe."

Starting with the single type Ia supernova, Ashall hopes to build a sample of different varieties of supernovae to produce meaningful statistics on their role as element-makers. He's open to whatever they'll find.

"If we don't find those elements coming from supernovae, then we have to reassess what we know about how stars die and how these elements are released into the universe," Ashall said. "It's interesting either way."

Provided by Virginia Tech

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