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Out with a Bang

A nearby supernova gives stunning details of a dying star's last days

International Gemini Observatory/NOIRLab/NSF/AURA

EVERY 10 SECONDS, somewhere in the universe, a star explodes. These cataclysms spew the radiation, dust and gas that help to sculpt galaxies, form new stars and planets, and enrich the universe with heavy elements. The light from a minuscule fraction of these supernovae reaches Earth to be pored over by astronomers. Most such events are so distant that scientists have only a handful of photons to use in their attempts to learn more.

Earlier this year, however, astronomers spotted a supernova erupting a mere 21 million light-years away—a stone's throw compared with the vastness of the observable universe and one of the closest to Earth seen in a decade. Thanks to this proximity, astronomers are now piecing together its final days in lavish detail and gaining fresh insights into how these astrophysical spectacles unfold and shape the cosmos at large.

Japanese amateur astronomer Koichi Itagaki was the first to spot this supernova, known as SN 2023ixf, on May 19. Professional observers sprang into action. "The whole supernova community got on it as soon as they could," says Griffin Hosseinzadeh of the University of Arizona. The astronomers used facilities that included the Hubble Space Telescope, the International Gemini Observatory in Hawaii and the Lick Observatory in California.

Itagaki had seemingly seen the supernova erupting within the Pinwheel Galaxy, also called M101—an initial assessment that follow-up observations confirmed. From there astrophysicists wanted to identify the individual star that exploded—a difficult thing to determine with supernovae. Thankfully, Joanne Pledger of the University of Central Lancashire in England had studied the galaxy in the early 2010s using new and archival images from the Hubble Space Telescope. By zooming in on those archival images, Pledger managed to identify the exact star that had exploded.

The star was a red supergiant about 420 times the radius and about 10 times the mass of our sun. It had undergone a so-called type II supernova, in which a massive star exhausts its nuclear fuel, collapses in on itself and explosively ejects its outer layers after they bounce off its durable core, leaving behind a neutron star or a black hole. Red supergiants can grow puffy late in life and blow off shells of gas and dust from their outer atmosphere before they explode. When the supernova even-

ADVANCES

tually erupts, it expands outward and crashes into those lingering shells, producing a discernible shock wave, which teams of astronomers detected coming from 2023ixf. "It's not the first time we've seen this happen," Hosseinzadeh says. "But the detail has never been this good."

From those observations, Wynn Jacobson-Galán of the University of California, Berkeley, and his colleagues calculated that the star lost almost 1 percent of its mass in the years before the explosion. That's actually "more than we would expect from a red supergiant star," Jacobson-Galán says. "It points, maybe, to our ignorance about how red supergiants evolve and die in the last few years before [their] explosion."

Red supergiants' dying days are crucial for understanding how supernovae enrich galaxies. How these stars lose mass "has a big influence on how galaxies evolve," says Azalee Bostroem of the University of Arizona, who has co-authored multiple studies of 2023ixf. "And it's telling us a little bit about which stars explode as which type of supernovae." Researchers also want to know where the bright burst of energy seen during a supernova comes from—whether it's entirely from the explosion or partly from the impact of the supernova shock wave on the surrounding debris. "All these things are linked with how much material is left on the star when it explodes," Bostroem says.

Supernova 2023ixf has also given astrophysicists their earliest-ever detailed glimpse of the intricate interactions between a supernova's shock wave and the material the star had previously shed. Specifically, scientists had debated whether the ejected gas and dust would form a sphere or some more asymmetrical shape—such as a flattened disk—around the star. The results for 2023ixf suggest the latter, says Sergiy Vasylyev of U.C. Berkeley. The exploding star's ejecta then expands in an hourglass shape as it impacts this disk. The varied orientations of debris disks with respect to their exploding host star suggest a surprising number of ways that type II supernovae can evolve. "It tells you that these events are diverse," Vasylyev says.

The nearby supernova could also help scientists predict when other red supergiants will explode. Before 2023ixf went supernova, it had been pulsating. Monika Soraisam of the National Science Foundation's National Optical-Infrared Astronomy Research Laboratory and her colleagues showed that the star had substantially swelled and shrunk in size over a period of about 1,000 days before bursting. Red supergiants are known to pulsate in this way in the denouement of their life; take Betelgeuse, a red supergiant in the constellation Orion, which has been flickering dramatically in recent years.

Astrophysicists consider these fluctuations to be a murky omen of an eventual explosion, but theoretically a star's pulsa-

ANIMAL BEHAVIOR

A Hell of a Meal

Why giant salamanders just keep eating their young

An eastern hellbender swims in the Hiwassee River in Tennessee.

Pete Oxford/Minden Pictures

MALE HELLBENDER SALAMANDERS usually make doting dads, guarding eggs and shaking them free of silt. But in some troubled populations, they are cannibalizing their entire brood every year, further jeopardizing the vulnerable giant salamander species.

Eastern hellbenders once swam in at least 570 streams in the eastern and central U.S., says Bill Hopkins, an ecologist at Virginia Tech. But numbers of the craggy, beady-eyed amphibians have plummeted in recent decades, with only about 126 streams now harboring healthy populations—and scientists didn't know why.

To solve the mystery, Hopkins's team placed hundreds of concrete nest boxes in streams in southwestern Virginia. For eight years they snooped on 182 nests, checking them every few days during the breeding season. In 60 percent of those nests not a single larva survived, most commonly because of whole-clutch cannibalism: the male had gobbled up hundreds of eggs. These cannibal dads had bulging bellies and a tendency to regurgitate the eggs when handled, the team reported in the *American Naturalist.*

The researchers' documentation of egg survival rates across time is "incredibly impressive," says Hope Klug, a behavioral ecologist at the University of Tennessee at Chattanooga, who wasn't part of the study. Cannibalism of offspring isn't unusual among animals, Klug says, explaining that parents may nutritionally benefit from consuming some offspring that they suspect won't survive. And desperately hungry parents in some species may eat their young during lean times, banking on reproducing later. Changes to the hellbenders' environment may have turned this once beneficial adaptation into a harmful evolutionary trap, Klug says.

Deforestation of the salamanders' woodland habitat may be to blame, the study findings suggest. Whole-clutch cannibalism was three times more common in areas with low upstream forest cover than in those with greater coverage. Vegetation helps to prevent streambank erosion, keeping back salt-filled silt that changes the water chemistry and fills the gaps between gravel—where hellbender larvae live. Trees also shade the streams, keeping the water cooler and more oxygen-rich.

Cannibalism isn't the only human-influenced cause of death threatening hellbender populations; anglers sometimes snag adults, and a silt-filled habitat itself can harm larvae. "This is a species that's been around for millions of years," surviving the extinction event that wiped out the dinosaurs, Hopkins says. "And now we humans are driving it to extinction."

Restoring forest cover and putting in protections around streams will take decades, Hopkins says. In the short term, conservationists could keep the numbers up by rearing hellbender larvae for release and avoiding this danger at the nest.

—Carolyn Wilke

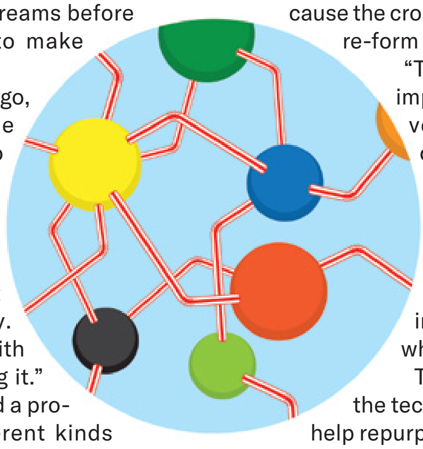
tions should have nothing to do with its going supernova. The two phenomena are caused by "totally different" mechanisms, Soraisam says. Yet such instabilities remain poorly understood, leaving the possibility that there may indeed be some kind of link. "That's the intriguing thing about 2023ixf," Soraisam says. "Very close to the explosion, we are still seeing very regular variability." If scientists can determine a link between the size shifts and the explosion, it could help them predict when other red supergiant stars will explode.

Short of seeing a supernova in our own galaxy—every modern astronomer's dream—this bright, brief spectacle in the Pinwheel Galaxy may be the best opportunity for many years to come to test current models for type II supernovae and to better see the creative destruction unleashed on the cosmos. "This is being studied in such detail and with such precision," Jacobson-Galán says. "It really is going to be one of the best-studied supernovae of the 21st century."

—*Jonathan O'Callaghan*

Linked Up A new process recycles mixed plastics

PLASTICS Soda bottles, sour cream containers and disposable cutlery—these plastics (and many others) typically arrive at recycling plants mixed together in the same bin. But because they are made of different molecular building blocks, called monomers, they must be sorted into different streams before they can be melted to make new products.



"Until about a year ago, everybody thought the only thing you could do is take a plastic, break it back down to a monomer and then re-form it," says Sanat Kumar, a chemical engineer at Columbia University. "Now we've come up with a different way of doing it." His team has developed a process that allows different kinds of plastic to be recycled together. Their findings, reported recently in *Nature*, could give new life to many items that end up in landfills.

A disturbingly small portion of our plastic waste is recycled, and production of new plastic—made from fossil fuels—continues to increase. The worsening situation has prompted scientists to seek new solutions to old recycling problems, including the difficulty of recycling mixed plastics. But they have faced a fundamental chemical hurdle: when different plastics are melted together, their various monomers tend to separate from one another like oil and water.

The new process solves this problem by adding chemicals called universal dynamic cross-linkers to the mix. Just as soap brings together oil and water, these cross-linkers (when applied under heat) form covalent molecular bonds that tether the diverse monomers together. This process creates polymers that can retain certain useful properties of each constituent plastic, such as keeping oxygen or ultraviolet light from passing through. These materials can then be melted and remade again and again because the cross-linkers can break and re-form their bonds.

"This chemistry is a really important step," says University of Washington chemical engineer Julie Rorrer, who works on plastics recycling and was not a part of the study. "They're demonstrating that this was industrially processable, which is very exciting."

The researchers hope the technique could eventually help repurpose more plastic waste, and Kumar says the process consumes less energy than breaking plastics down into their original monomers—but it's not yet cheap enough to be widely used at existing recycling facilities. Still, showing that it works could lead to lucrative markets for less expensive recycled plastics, which Kumar says would be one way to help recyclers eventually address the plastic waste crisis. "The plastics problem is huge," he says, "and you're going to have to look for multiple solutions."

—*Susan Cosier*

Illustrations by Thomas Fuchs