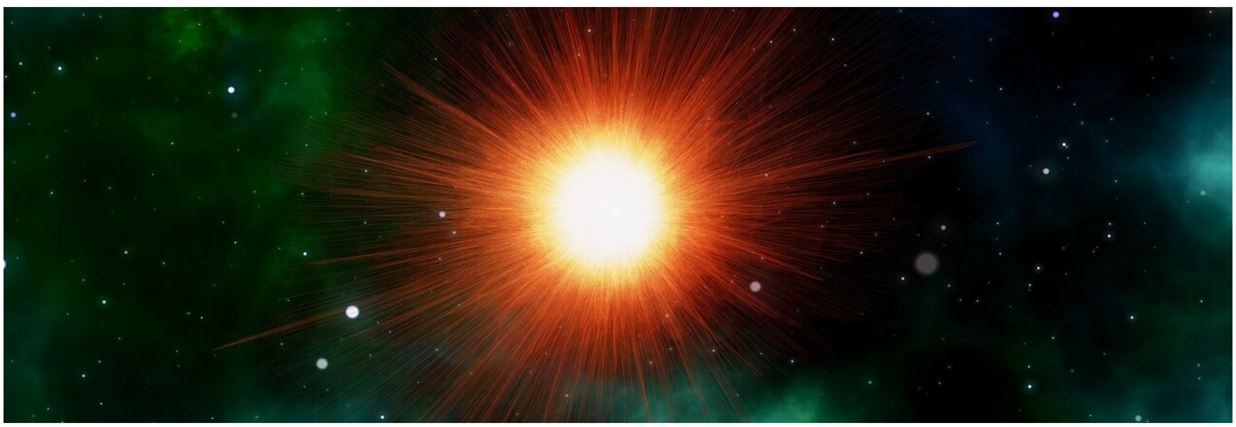
# Exploding stars are rare but emit torrents of radiation—one close enough to Earth could threaten life on the planet

April 1 2024, by Chris Impey



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Stars like the sun are remarkably constant. They vary in brightness by only 0.1% over years and decades, thanks to the fusion of hydrogen into helium that powers them. This process will keep the sun shining steadily for about 5 billion more years, but when stars exhaust their nuclear fuel, their deaths can lead to pyrotechnics.

The sun will eventually die by growing large and then condensing into a type of star called a white dwarf. But stars more than eight times more massive than the sun die violently in an explosion called a supernova.

Supernovae happen across the Milky Way only a few times a century, and these violent explosions are usually remote enough that people here on Earth don't notice. For a dying star to have any effect on life on our planet, it would have to go supernova within 100 light years from Earth.

I'm an astronomer who studies cosmology and black holes.

In my writing about cosmic endings, I've described the threat posed by stellar cataclysms such as supernovae and related phenomena such as gamma-ray bursts. Most of these cataclysms are remote, but when they occur closer to home they can pose a threat to life on Earth.

## The death of a massive star

Very few stars are massive enough to die in a supernova. But when one does, it briefly rivals the brightness of billions of stars. At one supernova per 50 years, and with 100 billion galaxies in the universe, somewhere in the universe a supernova explodes every hundredth of a second.

The dying star emits high energy radiation as gamma rays. Gamma rays are a form of electromagnetic radiation with wavelengths much shorter than light waves, meaning they're invisible to the human eye. The dying star also releases a torrent of high-energy particles in the form of cosmic rays: subatomic particles moving at close to the speed of light.

Supernovae in the Milky Way are rare, but a few have been close enough to Earth that historical records discuss them. In 185 A.D., a star appeared in a place where no star had previously been seen. It was probably a supernova.

Observers around the world saw a bright star suddenly appear in 1006 A.D. Astronomers later matched it to a supernova 7,200 light years away. Then, in 1054 A.D., Chinese astronomers recorded a star visible in the daytime sky that astronomers subsequently identified as a supernova 6,500 light years away.

Johannes Kepler observed the last supernova in the Milky Way in 1604, so in a statistical sense, the next one is overdue.

At 600 light years away, the red supergiant Betelgeuse in the constellation of Orion is the nearest massive star getting close to the end of its life. When it goes supernova, it will shine as bright as the full moon for those watching from Earth, without causing any damage to life on our planet.

## Radiation damage

If a star goes supernova close enough to Earth, the gamma-ray radiation could damage some of the planetary protection that allows life to thrive on Earth. There's a time delay due to the finite speed of light. If a supernova goes off 100 light years away, it takes 100 years for us to see it.

Astronomers have found evidence of a supernova 300 light years away that exploded 2.5 million years ago. Radioactive atoms trapped in seafloor sediments are the telltale signs of this event. Radiation from gamma rays eroded the ozone layer, which protects life on Earth from the sun's harmful radiation. This event would have cooled the climate, leading to the extinction of some ancient species.

Safety from a supernova comes with greater distance. Gamma rays and cosmic rays spread out in all directions once emitted from a supernova, so the fraction that reach the Earth decreases with greater distance. For example, imagine two identical supernovae, with one 10 times closer to Earth than the other. Earth would receive radiation that's about a hundred times stronger from the closer event.

A supernova within 30 light years would be catastrophic, severely depleting the ozone layer, disrupting the marine food chain and likely causing mass extinction. Some astronomers guess that nearby supernovae triggered a series of mass extinctions 360 to 375 million years ago. Luckily, these events happen within 30 light years only every few hundred million years.

## When neutron stars collide

But supernovae aren't the only events that emit gamma rays. Neutron star collisions cause high-energy phenomena ranging from gamma rays to gravitational waves.

Left behind after a supernova explosion, neutron stars are city-size balls of matter with the density of an atomic nucleus, so 300 trillion times denser than the sun. These collisions created many of the gold and precious metals on Earth. The intense pressure caused by two ultradense objects colliding forces neutrons into atomic nuclei, which creates heavier elements such as gold and platinum.

A neutron star collision generates an intense burst of gamma rays. These gamma rays are concentrated into a narrow jet of radiation that packs a big punch.

If the Earth were in the line of fire of a gamma-ray burst within 10,000 light years, or 10% of the diameter of the galaxy, the burst would severely damage the ozone layer. It would also damage the DNA inside organisms' cells, at a level that would kill many simple life forms like bacteria.

That sounds ominous, but neutron stars do not typically form in pairs, so there is only one collision in the Milky Way about every 10,000 years. They are 100 times rarer than supernova explosions. Across the entire universe, there is a neutron star collision every few minutes.

Gamma-ray bursts may not hold an imminent threat to life on Earth, but over very long time scales, bursts will inevitably hit the Earth. The odds of a gamma-ray burst triggering a mass extinction are 50% in the past 500 million years and 90% in the 4 billion years since there has been life on Earth.

By that math, it's quite likely that a gamma-ray burst caused one of the five mass extinctions in the past 500 million years. Astronomers have argued that a gamma-ray burst caused the first mass extinction 440 million years ago, when 60% of all marine creatures disappeared.

## A recent reminder

The most extreme astrophysical events have a long reach. Astronomers were reminded of this in October 2022, when a pulse of radiation swept through the solar system and overloaded all of the gamma-ray telescopes in space.

It was the brightest gamma-ray burst to occur since human civilization began. The radiation caused a sudden disturbance to the Earth's ionosphere, even though the source was an explosion nearly 2 billion light years away. Life on Earth was unaffected, but the fact that it altered the ionosphere is sobering—a similar burst in the Milky Way would be a million times brighter.

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