

Stars collided in galactic “demolition derby,” produced oddball gamma-ray burst

Enlarge / Astronomers studying a powerful gamma-ray burst (GRB) may have observed a never-before-seen way to destroy a star.

Int’l Gemini Observatory/NOIRLab/NSF/AURA/M. Garlick/M. Zamani

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When astronomers spotted a powerful gamma-ray burst (GRB) in October 2019, the most likely explanation was that it was produced by a massive dying star in a distant galaxy exploding in a supernova. But data from subsequent observations showed that the burst originated with the collision of stars (or their remnants) in a densely packed area near the supermassive black hole of an ancient galaxy, according to a new paper published in the journal *Nature Astronomy*. Such a rare event has been hypothesized, but this is the first observational evidence for one.

As we’ve reported previously, gamma-ray bursts are extremely high-energy explosions in distant galaxies lasting between mere milliseconds to several hours. There are two classes of gamma-ray bursts. Most (70 percent) are long bursts lasting more than two seconds, often with a bright afterglow. These are usually linked to galaxies with rapid star formation. Astronomers think that long bursts are tied to the deaths of massive stars collapsing to form a neutron star or black hole (or, alternatively, a newly formed magnetar). The baby black

hole would produce jets of highly energetic particles moving near the speed of light, powerful enough to pierce through the remains of the progenitor star, emitting X-rays and gamma rays.

Those gamma-ray bursts lasting less than two seconds (about 30 percent) are deemed short bursts, usually emitting from regions with very little star formation. Astronomers think these gamma-ray bursts result from mergers between two neutron stars or a neutron star merging with a black hole, comprising a “kilonova.”

The gamma-ray burst detected by NASA’s Neil Gehrels Swift Observatory back in 2019 fell into the long category. But astronomers were puzzled because they found no evidence of a corresponding supernova. “For every hundred events that fit into the traditional classification scheme of gamma-ray bursts, there is at least one oddball that throws us for a loop,” said co-author Wen-fai Fong, an astrophysicist at Northwestern University. “However, it is these oddballs that tell us the most about the spectacular diversity of explosions that the universe is capable of.”

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Intrigued, Fong and his co-authors followed the burst’s fading afterglow using the International Gemini Observatory, augmented with data collected by the Nordic Optical Telescopes and the Hubble Space Telescope. The afterglow enabled them to nail down the GRB’s location to a region just 100 light-years away from the nucleus of an ancient galaxy—i.e., very near the supermassive black hole at its center. They concluded that the burst had originated with the collision of two stars or stellar remnants.

That’s significant because there are three well-known processes for a star to die, depending on its mass. Massive stars explode in a supernova, while a star with the mass of our own Sun will discard its outer layers and eventually fade

to become a white dwarf. And the stellar remnants created from supernovae—neutron stars or black holes—can form binary systems and eventually collide.

Now we have a fourth alternative: stars in densely packed areas of ancient galaxies can collide—an occurrence that is very rare in active galaxies, which aren't as dense. An ancient galaxy could have a million stars packed into an area just a few light-years across. And in this case, the gravitational effects of being so near a supermassive black hole would have altered the motions of those stars so that they moved in random directions. A collision would be bound to happen eventually.

In fact, the authors suggest that these kinds of collisions might not even be that rare; we just don't detect the telltale GRBs and afterglows because of all the dust and gas obscuring our view of the centers of ancient galaxies. If astronomers could pick up a gravitational wave signature in conjunction with such a GRB in the future, that could tell them more about this kind of stellar death.

"These new results show that stars can meet their demise in some of the densest regions of the Universe where they can be driven to collide," said co-author Andrew Levan, an astronomer with Radboud University in The Netherlands. "This is exciting for understanding how stars die and for answering other questions, such as what unexpected sources might create gravitational waves that we could detect on Earth."

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