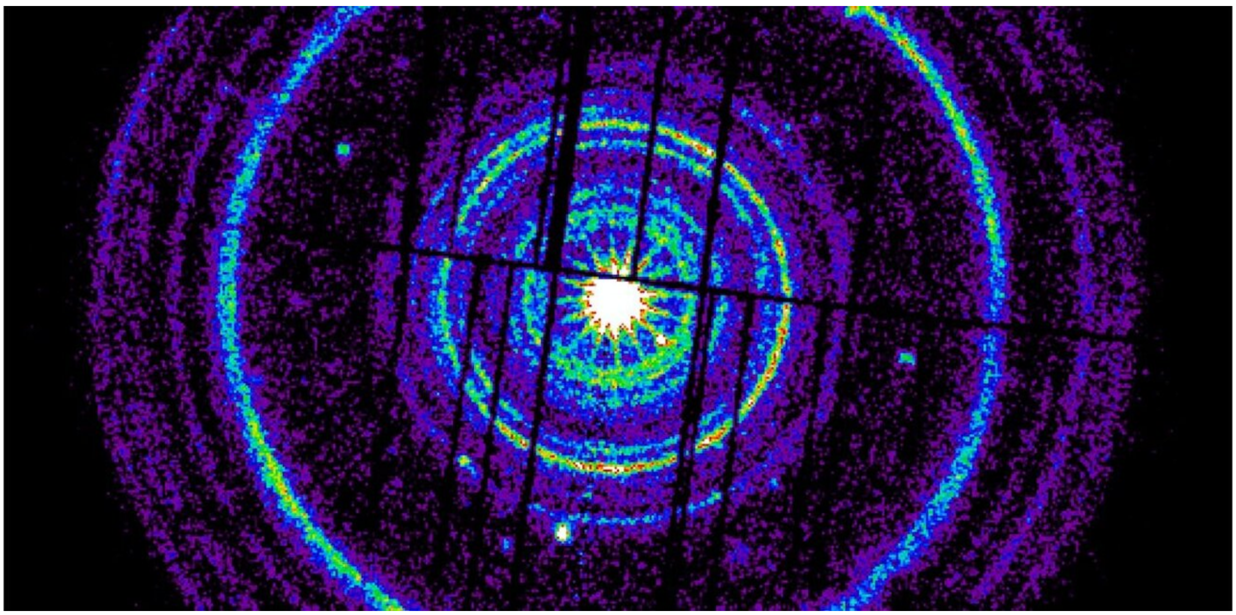
Brightest cosmic explosion of all time: How we may have solved the mystery of its puzzling persistence

June 10 2023, by Hendrik Van Eerten



An x-ray of the brightest ever gamma ray burst reflected off dust layers, creating extended 'light echoes' of the initial blast. Credit: NASA

First detected accidentally by US military satellites in the late 1960s, cosmic explosions known as gamma ray bursts (GRBs) have come to be understood as the brightest explosions in the universe.

Typically, they are the result of the cataclysmic birth of a black hole in a distant galaxy. One way this can happen is through the collapse of a single, massive star.

Astronomers such as myself working in the field are well aware of the massive energy scales involved in GRBs. We know they can release as much energy in gamma rays as the Sun does throughout its lifetime. But every once in a while, an event is observed that still gives us pause.

In October 2022, gamma-ray detectors on the orbital satellites Fermi and the Neil Gehrels Swift Observatory noted a burst known as GRB 221009A (the date of detection).

This quickly turned out to be a record-setter. It was dubbed the Brightest Of All Time, or the "Boat," as convenient shorthand among astronomers studying and observing the event. Not only did the Boat start out bright, it refused to fade away like other bursts.

We still do not fully know why the burst was so exceptionally bright, but our new study, published in *Science Advances*, provides an answer for its stubborn persistence.

The burst originated from a distance of 2.4 billion light years—relatively nearby for a GRB. But even when accounting for relative distance, the energy of the event and the radiation produced by its aftermath were off the charts. It is decidedly not normal for a cosmically distant event to deposit about a gigawatt of power into the Earth's upper atmosphere.

Observing narrow cosmic jets of gas

GRBs such as the Boat launch a stream of gas moving at very close to light speed into space. How exactly the jet is launched remains something of a puzzle—but most likely, it involves magnetic fields near where the black hole is being formed.

It is the early emission from this jet that we see as the burst. Later, the jet slows down and produces additional radiation, a fading afterglow of light—from radio waves up to (in exceptional cases) gamma rays.

We do not observe jets directly. Instead, like distant stars, we see GRBs as points in the sky. Nevertheless, we have good reason to believe that GRBs do not explode in all directions equally. For GRB 221009A, this would certainly be unreasonable, as it would involve multiplying the amount of energy detected on Earth by all other directions—amounting to much more energy than any star would have available.

Another indication that GRBs come from jets pointing roughly at us is due to special relativity theory. Relativity teaches us that the speed of light is constant, no matter how fast a source moves at us. But that still allows for the direction of light to become distorted. Thanks to this fun-house mirror effect, light emitted in all directions from the surface of a fast-moving jet will end up focused strongly along its direction of motion.

That said, the edges of a jet heading in our direction will be very slightly curved away, meaning their light is focused away from our direction. Only later, when the jet slows down, do the edges normally come into view and does the afterglow start to fade faster.

But here again, GRB 221009A broke the rules. Its edges never showed, and it joined a select group of very bright bursts that refuse to fade normally. Rather than starting to fade slowly and then disappearing quickly, it is steadily fading over time.

In our work, we demonstrate how the appearance of the jet edges can be obscured in a way that matches the observations of the Boat. The key idea is as follows: yes, a narrow jet was launched, but it had a difficult time escaping the collapsing star, leading to a lot of mixing with stellar gas along the sides of the jet.

From simulation to observation

To test whether this was indeed the case, we took a computer simulation result showing this mixing and implemented it in a model that could actually be compared to the Boat data directly. And it showed that what would normally be a quick turnover to a strongly fading signal, now became a drawn-out affair.

Radiation from the dying star's shock-heated gas kept appearing in our line of sight, explaining why it stayed so bright. This kept happening all the way up to the point that any characteristic jet signature was lost in the overall emission.

This way, GRB 221009A not only confirms expectations from simulation, but also provides a clue to similarly bright events seen in the past, where people had to keep revising the energy estimate upwards while waiting for a jet edge to show.

We calculated that the likelihood of seeing a burst this bright is about one in a thousand years, so we are lucky to have spotted one. But questions remain. What role do magnetic fields play, for example?

Theorists and numerical modelers will be exploring these matters for years, scouring the Boat data while we stay on the lookout for the next big event to arrive

Provided by The Conversation

Citation: Brightest cosmic explosion of all time: How we may have solved the mystery of its puzzling persistence (2023, June 10) retrieved 23 April 2024 from https://phys.org/news/2023-06-brightest-cosmic-explosion-mystery-puzzling.html