

“Supernova Shock Breakout from a Red Supergiant”

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Press information: Quotes and background material

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Summary:

For the first time we have seen a flash of light coming from inside a star. This event happened just before the explosion of the star in a supernova. We have witnessed the shock wave of the explosion travelling inside the star and then blowing the star apart. Astronomers have predicted this phenomenon for decades, but have never before been lucky enough to catch it in the act.

What is a supernova and what leads to it? Why are they important?

"Most massive stars end their lives in supernovae of the kind we have seen here. The outer parts of the star are blown away at around 10,000 km/sec, or 20 million mph, in a fireball a billion times brighter than our sun.." (Dr Mark Sullivan)

"The core of a star normally acts as a powerful nuclear furnace producing heat and pressure that makes the star shine and be stable for a long time. When the core has no more fuel, it collapses and a shock wave runs through the star, destroying it."
(Prof. Philipp Podsiadlowski)

"Supernovae produce heavy elements such as nickel, gold, or lead." (Dr Christian Wolf)

"In previous supernovae only an expanding fireball was seen for many weeks, with no direct clue to what used to be there before." (Dr Kevin Schawinski)

What is our discovery of "first light from a supernova" and why is it important?

"We have witnessed the violent death of a massive star in a galaxy almost a billion light years away in unprecedented detail. We caught the star while the supernova shock wave approached the surface of the star and then blew it apart." (Dr Kevin Schawinski)

"This observation was special: we saw a flash of light from the inside of the star. It was the first time light from inside a star has been observed. When we look at the Sun or any other star, we just see light from its surface." (Dr Stephen Justham)

"The flash began just hours before the star was disrupted; how the shock wave travels in a star tells us the size of the star and what the inside is like in its final moments."
(Dr Stephen Justham)

"Astronomers have been dreaming about seeing the first light from the violent death of a star for over thirty years. Our observations open up an entirely new avenue for studying the final stages in the lives of massive stars and the physics of supernovae."
(Dr Kevin Schawinski)

This collaborative effort involved many Oxford scientists with different expertise and this was essential for the success of the project.

"The idea was born over our daily morning coffee more than a year before we found the supernova. It was clear that we still had to be very, very lucky to actually find such an event. We had to combine the expertise of several observers and theorists."

(Dr Stephen Justham)

"We were especially interested in finding the first flash from inside the star, and we expected it would be seen in ultraviolet light, which can only be seen from space."

(Prof. Philipp Podsiadlowski)

"We looked at images from the GALEX UV satellite at the positions of supernovae that had been found by the Supernova Legacy Survey using telescopes in Hawaii. We found a new source at the location of one supernova, suddenly outshining its galaxy host in the UV. Crucially, it appeared a couple of weeks before the optical discovery of the supernova and marked the first stage in the death of the star." (Dr Mark Sullivan)

"The real challenge was that the light signal from the supernova was changing all the time not only because its real brightness changed; also, the satellite changes its shape and the camera focus as it is being heated and cooled in its orbit."

(Dr Christian Wolf)

Where do we go from here?

"It would be tremendous if more flashes from inside a star undergoing a supernova could be observed; but for this we would really need a dedicated UV survey telescope in space looking at the right place at the right time."

(Dr Kevin Schawinski)

"This is a whole new avenue into studying the late stages of massive stars; most of what we know today is based on computer simulations. But as always when you test theory against observations for the first few times, we may be in for surprises..."

(Dr Christian Wolf)

Narrative: What would you see if you were near the dying red supergiant?

If you could view the doomed star from the outside during its final moments, you would not see much changing. You would see an enormous star, a few hundred to a thousand times the size of the sun with a turbulent red surface. When it finally runs out of its last reserves of nuclear fuel, its core collapses under its own weight down to a compact neutron star, which contains more mass than the entire sun but is only ten kilometres across. This liberates a fantastic amount of energy that eventually blows apart the entire star. At the moment of "core collapse" a large portion of this energy is released in the form of ghostly neutrinos and gravitational waves. But if you were simply watching the star, you wouldn't realise anything had happened for several hours, very different to what is often shown in science fiction stories.

The core collapse sends a shock wave outwards through the star, carrying a truly destructive amount of energy. Although the shock wave is moving at around ten thousand kilometres per second, the radiation from it can travel even more quickly, heating the surface before the shock arrives. So during the final four hours before the star begins to visibly explode, you could see the surface being heated from a few

thousand degrees Celsius to several hundred thousand degrees. The star moves from red-hot to white-hot and beyond, mostly shining in ultraviolet light and X-rays. Just before the surface of the star is blown apart, it is producing the same total luminosity as a thousand billion suns.

But soon the shock wave catches up: as it ploughs through the outer parts of the star, it accelerates several solar masses of star-stuff from rest to a few percent of the speed of light. Now the surface of the star explodes. If you had somehow avoided being killed by the radiation from the star, this would be a very good time to leave the immediate area -- quickly. The matter from the star continues to expand and cool down. In a few days, the supernova will become bright enough in visual light to be spotted by supernova hunters. It will remain bright for several weeks or months before fading as it expands further. After a few hundred years, a shell of matter will become visible as a beautiful supernova remnant such as the Crab nebula with a young neutron star at its centre. After a few ten thousand years all that remains are some wispy filaments thinly spread over light years of space as in the Cirrus nebula.