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AFTER THE COLLAPSE

Weizmann Institute scientists observe the largest exploding star yet seen

In the first observation if its kind, scientists at the Weizmann Institute of Science and San Diego State University were able to watch what happens when a star the size of 50 suns explodes. As they continued to track the spectacular event, they found that most of the star's mass collapsed in on itself, resulting in a large black hole.

While exploding stars – supernovae – have been viewed with everything from the naked eye to high-tech research satellites, no one had directly observed what happens when a really huge star blows up. Dr. Avishay Gal-Yam of the Weizmann Institute's Faculty of Physics and Prof. Douglas Leonard of San Diego State University recently located and calculated the mass of a gigantic star on the verge of exploding, following through with observations of the blast and its aftermath. Their findings have lent support to the reigning theory that stars ranging from tens to hundreds of times the mass of our sun all end up as black holes.

A star's end is predetermined from birth by its size and by the "power plant" that keeps it shining during its lifetime. Stars, among them our sun, are fueled by hydrogen nuclei fusing together into helium in the intense heat and pressure of their inner cores. A helium nucleus is a bit lighter than the sum of the masses of the four hydrogen nuclei that went into making it and, from Einstein's theory of relativity (E=MC2), we know that the missing mass is released as energy.

When stars like our sun finish off their hydrogen fuel, they burn out relatively quietly in a puff of expansion. But a star that's eight or more times larger than the sun makes a much more dramatic exit. Nuclear fusion continues after the hydrogen is exhausted, producing heavier elements in the star's different layers. When this process progresses to the point that the core of the star has turned to iron, another phenomenon takes over: In the enormous heat and pressure in the star's center, the iron nuclei break apart into their component protons and neutrons. At some point, this causes the core and the layer above it to collapse inward, firing the rest of the star's material rapidly out into space in a supernova flash.

A supernova releases more energy in a few days than our sun will release over its entire lifetime, and the explosion is so bright that one occurring hundreds of light years away can be seen from Earth even in the daytime. While a supernova's outer layers are lighting up the universe with dazzling fireworks, the star's core collapses further and further inward. The gravity created in this collapse becomes so strong that the protons and electrons are squeezed together to form neutrons, and the star's core is reduced from a sphere 10,000 kilometers around to one with a circumference of a mere 10 kilometers. Just a crate-full of this star's material weighs as much as our entire Earth. But when the exploding star is 20 times the mass of our sun or more, say the scientists, its gravitational pull becomes so powerful that even light waves are held in place. Such a star – a black hole – is invisible for all intents and purposes.

Until now, none of the supernovae stars that scientists had managed to measure had exceeded a mass of 20 suns. Gal-Yam and Leonard were looking at a specific region in space using the Keck Telescope on Mauna Kea in Hawaii and the Hubble Space Telescope. Identifying the about-to-explode star, they calculated its mass to be equal to 50-100 suns. Continued observation revealed that only a small part of the star's mass was flung off in the explosion. Most of the material, says Gal-Yam, was drawn into the collapsing core as its gravitational pull mounted. Indeed, in subsequent telescope images of that section of the sky, the star seems to have disappeared. In other words, the star has now become a black hole – so dense that light can't escape.

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