1987
ASTRONOMY

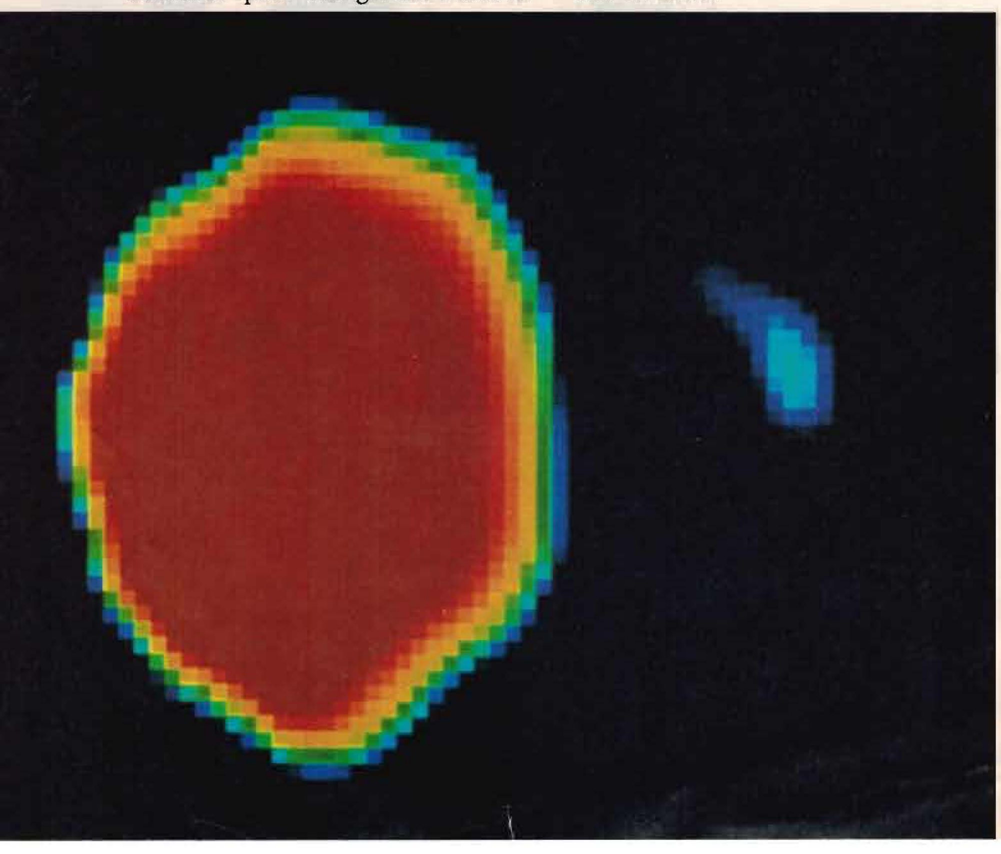
THE SHORT LIFE AND VIOLENT DEATH OF SANDULEAK −69

The point of light known as Supernova 1987A is now fading into oblivion in the southern sky; it has already faded from the public eye. For astronomers around the world, though, the excitement has just begun. Since the invention of the telescope, a dozen generations of their predecessors have lived and died without ever having had the chance to watch the explosion of a nearby star. This generation is the first to get lucky, and they are making the most of it.

Luckiest of all is Ian Shelton, resident astronomer-hermit at the Las Campanas Observatory in Chile, who stumbled onto the supernova in the early morning hours of February 24. On a photograph he had just made of the Large Magellanic Cloud, a small galaxy only 170,000 light-years from our own Milky Way, Shelton noticed an unfamiliar blotch. It was less bright than the stars in the Big Dipper but brighter by far than anything else in the misty Magellanic Cloud—and it hadn't been there the night before.

Word spread fast, and before the day was out astronomers were aiming an arsenal of space- and ground-based instruments at the brightening spot. Radio and ultraviolet telescopes, as well as optical ones like Shelton's, picked it up right away. Since then intense observations have continued at all wavelengths. By autumn Russian and Japanese space instruments had detected high-energy X-rays coming from the thinning cloud of stellar debris, and researchers were anxiously waiting to record the periodic X-ray beep of a pulsar—a whirling, superdense neutron star—that theory predicts may be left behind at the center of the cloud.

As it turned out, evidence for a neutron star reached Earth even before the light from the explosion. A day before Shelton's discovery, underground detectors in the United States and Japan recorded a remarkable signal: a brief burst of the subatomic particles called neutrinos, which theorists had said should be the first to leave the scene when a star explodes. With this historic particle burst, researchers may have witnessed for the first time the birth of a neutron star, an object so dense that a thimbleful of it would outweigh all the cars on Earth.



Although the neutrino burst arrived as predicted, in other ways Supernova 1987A did not toe the theoretical line. On the first two days, for example, its brightness increased almost a thousandfold, much swifter than expected, only to plateau at a level 40 times dimmer than expected. In March the supernova began to brighten once again, powered by the decay of radioactive elements in the stellar material. At its peak, toward the end of May, it was as luminous as billions of suns but still less brilliant than other stellar explosions.

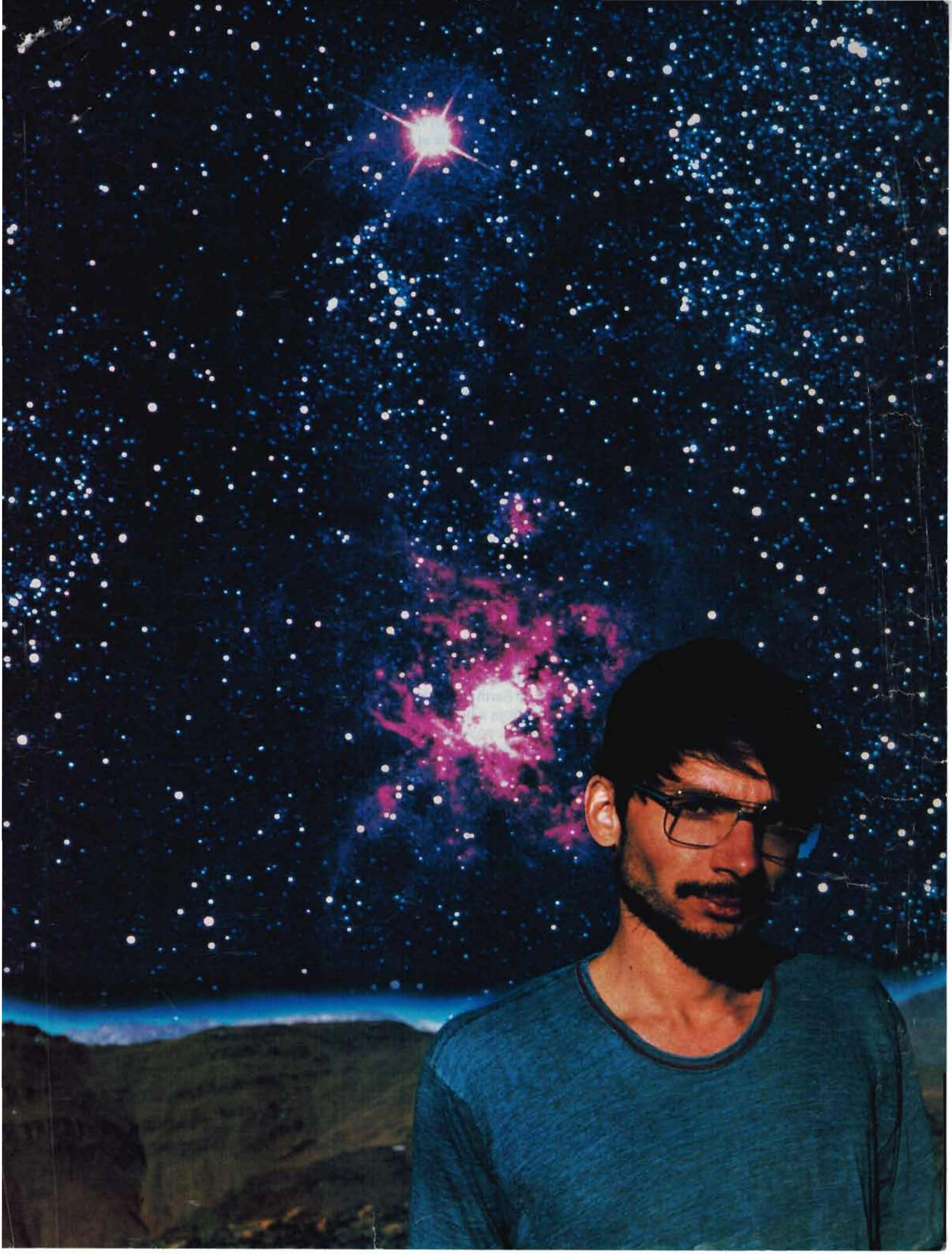
To understand this behavior astronomers had to find out which star had died, and they were initially led astray. They knew that a star that blows up rather than flickers out quietly must be at least eight times as massive as the sun. Studying preblast pictures, observers chose a blue supergiant called Sanduleak −69°202 as the most likely victim. Then Harvard astronomer Robert Kirshner complicated matters. After analyzing ultraviolet data, he assured everyone that Sanduleak −69 was still there, shining serenely.

In April, though, Kirshner contritely announced that he had been misled by two other blue stars in the immediate area. "Let's not pussyfoot around," he said. "Sanduleak −69 was it."

With the progenitor star pinned down, some pieces of the puzzle began to fit. A blue supergiant like Sanduleak −69 was smaller than the textbook supernova progenitor, which is a bloated, red supergiant. Hence it made sense that the Supernova 1987A fireworks, fueled by less stellar material, should have been faster and less spectacular than textbook predictions. Some astronomers now suspect that many exploding stars are blue supergiants, and that these relatively dim explosions have been overlooked simply because they are hard to see. It is still not clear, however, why the

PHOTOGRAPHS: LEFT, FROM THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY; RIGHT, FROM THE NATIONAL OPTICAL ASTRONOMY OBSERVATORIES; INSET BY VERA LENTZ/VISIONS

The supernova shines brightly above discoverer Ian Shelton and the Tarantula nebula; the star's small companion (photo at left) remains a mystery.



progenitor turned out to be blue rather than red; theorists are considering several explanations.

In any case, computer simulations suggest that Sanduleak −69 lived fast and died young. Born just 10 million years ago, the blue supergiant was about 20 times as massive, 40 times as large, and 100,000 times as luminous as the sun, and it aged 1,000 times faster. Over those millions of years the nuclear furnace in its core generated energy by fusing matter into ever-heavier elements. Once iron was formed, though, the game was over: the fusion of iron uses more energy than it releases.

Without fusion-generated heat, the iron core, which was about the size of the Earth, could not withstand the force of its own gravitation. In less than a second it collapsed into a sphere about a dozen miles in diameter but 1.4 times as massive as the sun. The protons and electrons in the iron merged to form neutrons, in the process unleashing a flood of 10^{58} neutrinos at or near light speed. During that split second Sanduleak −69 released more energy than all the other stars in the universe combined. The light given off by the supernova later—bright as it was—was surprisingly incidental.

Like a coiled spring, the squeezed neutron core rebounded a bit, generating a powerful shock wave that worked its way through the outer envelope of the star. Energy from the shock fused light elements into elements even heavier than iron, including nickel. The subsequent radioactive decay of nickel 56 to cobalt and iron, says Stan Woosley of the University of California at Santa Cruz, is the ultimate source of the visible light coming from the supernova. The light is actually secondary radiation from the debris cloud; the decay process itself emits gamma rays. NASA is hoping to detect these rays with balloon-borne instruments launched from Australia.

Such an observation, according to David Helfand of Columbia University, would be the first direct confirmation of the theory of stellar nucleosynthesis, which holds that all heavy elements—the stuff of planets like ours, and of life—are formed by fusion inside stars and during supernova explosions. In Sanduleak −69's final moments elements such as these would have been scattered into space. Millions of years from now these ashes may coalesce in new stars and planets.

Gamma ray and X-ray astronomers think they will be able to decipher which elements were fabricated in the blast, but they will need another stroke of luck to see the pulsar that may be hidden by the debris. According to a popular pulsar model, the rapidly spinning neutron star should emit beams of energy from its magnetic poles. Once the debris has thinned enough, these beams may be detected on Earth as regular pulses, like the signal from a lighthouse—but only if the magnetic poles are pointed more or less toward Earth. If they are, the operators of Ginga, a Japanese X-ray satellite, may see pulses as early as this winter. (Radio pulses may not be seen for decades.) Such observations would enable astronomers to measure the size, magnetic field strength, and rotation rate of the neutron star.

They can already be fairly sure the neutron star is there: they've detected the telltale neutrinos. As a rule, an individual neutrino stops for nothing; it can pass through light-years of matter and not collide with a single atom. But researchers can still hope to pick a few neutrinos out of a passing flood. Of the ten thousand trillion trillion neutrinos that the supernova shot through the Earth, a total of 19 were captured in two huge underground tanks of water, one at Kamioka, Japan, and the other near Cleveland. Because both detectors registered the neutrinos in short bursts at the same time, researchers are convinced the signal—the first of its kind—was real. Of all the remarkable observations of the supernova, the neutrino detection will be remembered best; it has spawned a new branch of astronomy.

Not that the supernova is in danger of being forgotten. A number of mysteries remain to be cleared up. One concerns the nature of a bright companion, situated just two light-weeks from the explosion, that was discovered in March by Peter Nisenson and Costas Papaliolios of Harvard. The "mystery spot" may be a clump of interstellar material lit up by the supernova, or the tip of a plasma jet squirting out of the blast. Whatever the spot is, it was not predicted by supernova models.

Those models will be tested further as observations continue. Centuries from now astronomers will still be studying the wispy, incandescent filaments of the Magellanic supernova, just as today they study the remains of the "new stars" observed centuries ago by Tycho Brahe and Johannes Kepler. The expanding remnant is already hundreds of billions of miles in diameter. Shortly before Halloween one astronomer proposed that it is not spherical, as one might expect, but flattened on two sides like a pumpkin. "The supernova has become a Rorschach test," says Woosley, "stimulating the imaginations of all who contemplate the event." —*Marcia Bartusiak*

PHOTOGRAPH FROM THE ROYAL OBSERVATORY, EDINBURGH

Supernova 1987A may one day look like these wispy remains of the Vela supernova, which exploded about 9000 B.C.