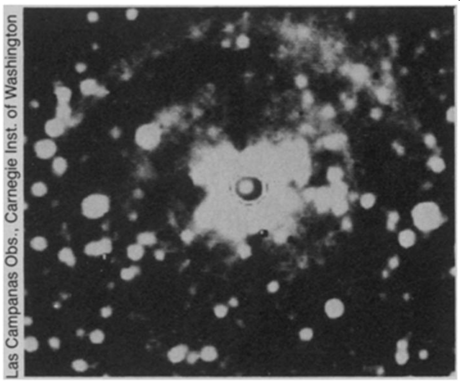
A Burst of New Data From Supernova 1987A

Astronomers are getting a chance to look at the explosion of a star all over again — a kind of cosmic rerun. Arlin Crotts of the University of Texas at Austin has detected the light echo from supernova 1987A. This light, which appears as a pair of arcs around the supernova, represents radiation that left the exploded star and arrived at earth after being reflected from interstellar dust, taking longer to reach the earth than visible light coming directly from the supernova.

"You have the entire history of the supernova played over again, only now it's laid out in a radial dimension out from the supernova," says Crotts. Crotts' discovery was one of several new findings reported at last week's American Astronomical Society meeting in Kansas City, Mo., and at a recent NASA briefing in Washington, D.C.


Las Campanas Obs., Carnegie Inst. of Washington

This photo shows two faint light-echo arcs surrounding supernova 1987A. A coronagraph mask hides the supernova itself, although a small amount of light spills out to create the cloverleaf pattern at center.

Detection of the visible-light echo, the first ever seen, had to wait until the supernova was dim enough not to wash out the faint dust-cloud reflections (SN: 12/5/87, p.361). Crotts, observing at the Carnegie Institution's Las Campanas Observatory in Chile, used a coronagraph mask to block out the supernova's bright central image and to obtain a photograph of the light echo's faint arcs.

Crotts estimates the two arcs are reflections from dusty gas clouds roughly 440 and 950 light-years out from the supernova toward earth but displaced slightly off the direct line between the two. The supernova itself lies more than 160,000 light-years from earth. Over time, the arc positions, as seen from earth, should appear to move gradually outward as reflections come from progressively more distant matter. As long as the gas cloud holds out, the light echo will remain visible.

The outer rim of each arc represents the earliest light emitted by the supernova. Thus, a cross section through an arc shows how the supernova's brightness varied over time. The characteristics of this early light, as seen at the outer fringes of the arcs, could provide clues about the supernova's behavior before the stage at which it was first detected last year.

"We've never caught a supernova early enough to observe this first breakout of the explosion through the star's surface," says Crotts. However, measuring this light will not be easy because the reflecting gas clouds appear to have a lot of structure. This distorts the reflections and makes it harder to tell where the actual edge lies.

Light-echo observations may turn out to be a useful probe for mapping the dust and gas clouds surrounding the supernova. For example, the fact that the echoes appear as arcs instead of rings suggests that the reflecting matter lies in bands instead of being uniformly distributed. Moreover, because the arcs aren't precisely centered on the supernova, the gas sheets likely are tilted.

Observations also suggest the supernova lies within one of the more turbulent regions of star formation in a nearby galaxy. "The initial indication is that we will be able to learn a lot about the nature of the gas in this star-forming region, which dominates one end of the Large Magellanic Cloud," says Crotts. Because the light echo's geometry is so simple, it also has an important role in the precise determination of distances between objects in the Large Magellanic Cloud and the earth.

Originally, supernova 1987A was thought to be unique. With distance taken into account, it appeared to be less bright than most previous supernovas. Moreover, its light curve — the variation of its brightness with time — had an unusual shape. Astronomers attributed the low luminosity and light-curve shape to the fact that 1987A was the explosion of a comparatively compact, blue, supergiant star instead of a huge, red supergiant.

Now graduate student Timothy R. Young and astronomer David Branch of the University of Oklahoma in Norman have identified another, more distant supernova, discovered in 1909, whose light-curve seems to resemble supernova 1987A. Supernova 1909A sits in the outskirts of the spiral galaxy Messier 101 (M101), about 20 million light-years away. Like the region surrounding 1987A, this part of M101 has a relatively low concentration of heavy elements.

Observing the region around 1909A could provide a preview of what may happen to 1987A, Young says. Astronomers have predicted 1987A will emit bursts of radio waves sometime in the future. "So it's important that we look now at the site of 1909A to see if it's also undergoing a radio burst," he says.

Although supernova 1909A was the only example found during Young's search of supernova records, such supernovas may not be uncommon. "They're just harder to find," he says. "Such faint supernovae in distant galaxies would go unnoticed."

Meanwhile, researchers sampling the steady stream of X-rays (SN: 1/2/88, p.5), gamma rays (SN: 3/12/88, p.168), infrared radiation and ultraviolet (SN: 12/12/87, p.380) and visible light coming from supernova 1987A are, in effect, witnessing the creation of new matter in the universe. From these measurements, they are building a picture of what happens during a supernova explosion.

"The infrared part of the spectrum gives us an excellent way to probe the inner region of a supernova," says S. Harvey Moseley of the NASA Goddard Space Flight Center in Greenbelt, Md. "It's the first glimpse at what the inside of a supernova explosion actually looks like."

Recent observations show the presence of iron, cobalt and sulfur created in the explosion, just as theorists had predicted. Measurements over several months indicate that radioactive cobalt is steadily decaying into iron, and the energy released by this nuclear reaction is largely responsible for powering the supernova at its present stage.

"The infrared observations have provided us with an early and quite complete view into the inner mantle of the supernova," Moseley says. "By future careful study and better measurements of these spectral lines, we believe we can put together a coherent picture of how the explosion occurred in the center of the supernova."

Within a year, scientists should be able to see what they strongly suspect lurks at the supernova's center: a neutron star. "We hope to see some evidence that it's there producing energy and doing some of the exotic things that neutron stars do," says Stanford E. Woosley of the University of California at Santa Cruz.

In about a decade, the main shock wave and debris from the supernova explosion will reach a slowly expanding shell of nitrogen-rich gas surrounding the supernova. When the debris hits the outer shell, "we will see lots of X-rays, radio emissions and other illuminations," says Robert P. Kirshner of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. "It should be spectacular."

— *I. Peterson*