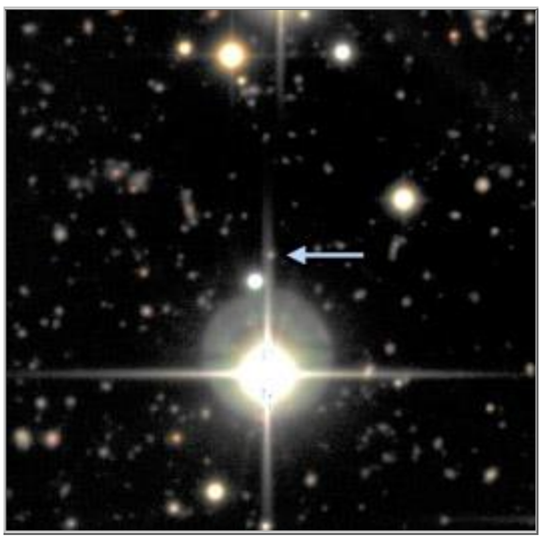
"Impossibly" large stellar explosions find explanation

Dec. 19, 2013
Courtesy of of the University of California Santa Barbara
and World Science staff

A newly identified type of stellar explosion breaks all the old rules—and records—for such explosions, a study has found. But astronomers say this ultra-powerful type of blast rarely occurs in the modern universe.

The "superluminous" outbursts have been coming to scientists' attention since the end of the last decade, but no one knew what they were at first.



SNLS-06D4eu and its host galaxy appear here where the arrow points—not as one of the bright objects in the foreground, which are stars in our own galaxy. The extreme distance makes SNLS-06D4eu show up as just a faint dot, but its true brightness is believed to be extraordinary. Most of the other background objects in the photo are distant galaxies. (Courtesy SNLS)

The new study proposes that the blasts are probably associated with the formation of a magnetar, an extraordinarily magnetized, dizzyingly fast-spinning neutron star. A neutron star is a type of highly condensed star in which the entire weight of the sun can be packed into an object the size of a city.

The new findings came after astronomers affiliated with a project called the Supernova Legacy Survey found two of the brightest and most distant "supernovae," or exploding stars, ever

recorded.

The events were measured to take place about 10 billion light-years away; a light-year is the distance light travels in a year. The measurements imply that the bursts occurred early in cosmic history.

The blasts were also a hundred times more luminous than a normal supernova—an exploding, dying star, astronomers reported. The findings are published in the Dec. 20 issue of the *Astrophysical Journal*.

The recently found supernovae are especially puzzling because the mechanism that powers most such blasts—the collapse of a giant star to a black hole or normal neutron star—couldn't explain their extreme luminosity. Discovered in 2006 and 2007, the supernovae were so unusual that astronomers at first couldn't figure out what they were or how far away.

"We had no idea... even whether they were supernovae or whether they were in our galaxy or a distant one," said lead author D. Andrew Howell of the University of California Santa Barbara, who is also a staff scientist at Las Cumbres Observatory Global Telescope Network.

"I showed the observations at a conference, and everyone was baffled. Nobody guessed they were distant supernovae because it would have made the energies mind-bogglingly large. We thought it was impossible."

One of the newly discovered supernovae, named SNLS-06D4eu, is the most distant and possibly the most luminous member of the emerging class of explosions, now called superluminous supernovae. A special subclass of these, including the two in the study, is found to lack the element hydrogen.

The study proposes that the supernovae are likely powered by the creation of a magnetar, an extraordinarily magnetized neutron star spinning hundreds of times per second. Magnetars have magnetic fields a hundred trillion times that of the Earth. While a handful of these superluminous supernovae have been seen, and magnetar formation had been suggested as a possible energy source, Howell and his colleagues describe their work as the first to match detailed observations to models of what such an explosion might look like.

Co-author Daniel Kasen from UC Berkeley and Lawrence Berkeley National Lab created models of the supernova that explained the data as the explosion of a star only a few times the size of the sun and rich in carbon and oxygen. The star likely was initially much bigger but apparently shed its outer layers long before exploding, leaving only a smallish, naked core.

"What may have made this star special was an extremely rapid rotation," Kasen said. "When it ultimately died, the collapsing core could have spun up a magnetar like a giant top. That enormous spin energy would then be unleashed in a magnetic fury."

The blasts were discovered as part of the Supernova Legacy Survey, a five-year program based on observations from several telescopes to study thousands of supernovae. It took subsequent observations of the faint host galaxy with the Very Large Telescope in Chile for astronomers to determine the distance and energy of the explosions, and years of subsequent theoretical work to figure out what could produce such astounding energy.

The supernovae are so far away that the ultraviolet light released in the explosion was stretched out fantastically by the expansion of the universe during the time the light took to get here, astronomers said. As a result, it reached Earth as the visible type of light, whose waves are highly stretched out compared to ultraviolet waves. Initial observations baffled astronomers because they hadn't seen supernovae with such extreme ultraviolet. This gave them a rare glimpse into the inner workings of these supernovae, the authors said. Superluminous supernovae are so hot that the peak of their light output is ultraviolet, an energetic form of light. Because the Earth's atmosphere blocks ultraviolet, such objects had never been fully observed.

The supernovae exploded when the universe was only four billion years old, less than a third of its present age and "before the sun even existed," Howell said. The superluminous supernovae are rare, occurring perhaps once for every 10,000 normal supernovae, he added, and seem to explode preferentially in more primitive galaxies common in the early universe.

"These are the dinosaurs of supernovae," Howell said. "They are all but extinct today, but they were more common in the early universe. Luckily we can use our telescopes to look back in time and study their fossil light. We hope to find many more."