Wanted: Amateur stargazers to help solve supernova mystery

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Ohio State University scientists have thought of a new way to solve an astronomical mystery, and their plan relies on a well-connected network of amateur stargazers and one very elusive subatomic particle.

To understand what happens inside exploding stars, or supernovae, scientists need to study particles called neutrinos, explained John Beacom, assistant professor of physics and astronomy at Ohio State. Neutrinos are formed in the nuclear reactions that make stars like our sun shine. Exploding stars overflow with the particles, and flood the universe with them.

Neutrinos should be everywhere, but they are very hard to detect – so hard to detect, in fact, that even though countless neutrinos burrow through our planet every second, scientists only capture a few of them each day.

Scientists know that most neutrinos they do detect probably come from our own sun, from nuclear reactors in terrestrial power plants, or from cosmic radiation interacting with our atmosphere. There has been no way to distinguish whether a particular neutrino came from elsewhere, until now.

That's why Beacom and his team's discovery – that each year, one or two of the neutrinos detected on Earth can probably be matched to the exploding star that made them – represents a major step forward for supernova astrophysics.

The discovery also comes at a special time, Beacom said. The method will fully exploit the capabilities of the next generation of neutrino detectors, which are now being planned, and take advantage of a growing number of amateur astronomers who are capable of discovering supernovae.

For a study appearing in a recent issue of the journal Physical Review Letters, Beacom and his coauthors developed a kind of litmus test for finding supernova neutrinos: If a detector on Earth registers two of the particles within ten seconds, odds are high that they came from a supernova in a nearby galaxy. Alternatively, if an astronomer – amateur or otherwise – spots a supernova, scientists at neutrino detectors can look back through their records to see if they captured a neutrino around that time.

Given that a few supernovae occur in nearby galaxies every year, and given the sensitivity of neutrino detectors on Earth, they've determined that at least one of those scenarios – the two-in-ten-seconds event or the identification of a supernova neutrino after the fact – should be able to happen about once a year.

The professionals need amateur astronomers to help spot new supernovae fast, so scientists can quickly match captured neutrinos with the exploding stars that made them.

"Even with all our modern telescopes, the professionals can't look at the whole sky at once," Beacom said. "But the amateurs are everywhere. With relatively small telescopes, they can see these nearby supernovae, which are very bright – often brighter than their host galaxies."

Here, "relatively small" means smaller than a telescope in an astronomical observatory, but larger than the average backyard telescope.

Coauthor Hasan Yüksel, a postdoctoral researcher at Ohio State , explained that many of today's so-called amateur astronomers aren't really so amateur. "You can think of them more as 'professional amateurs,'" he said.

These are the semi-pro players of the hobby set – skilled folks who build custom telescopes. They have day jobs, but they scan the skies at night, and share their findings with other amateurs over the Internet. Often, they have ties to professional astronomers. When a major discovery is made, they know as soon as the professionals do.

Yüksel also pointed out that since 2002, there were at least nine supernovae identified in galaxies within about 30 million light years (180 trillion miles) of our Milky Way, and more than half of those were discovered by amateurs.

Surprisingly, the Ohio State physicists got their idea in a "eureka" moment -- after a discussion with colleagues at the Department of Astronomy's morning coffee event. This daily review of new journal papers posted to an online archive (arXiv.org) has been going on since the 1990s, and often inspires faculty and students to pursue new lines of research.

Walking back to their offices after coffee, Yüksel asked Beacom and visiting scholar Shin'ichiro Ando about a special class of galaxies called starburst galaxies, in which unusually high numbers of stars are being born. Wouldn't those galaxies also have large numbers of supernovae? Wouldn't nearby starburst galaxies be good places to look and find out?

Beacom said that something clicked.

"We realized that maybe it's not totally crazy to look for neutrinos from supernovae in nearby galaxies," he said.

The three performed detailed calculations about supernova rates in nearby galaxies, and found that the explosions probably happen more often than people once thought – about three times a year. Then they looked at the rates at which neutrinos are caught in giant underground detectors on Earth.

Their discovery came down to calculating the odds: it's highly unlikely that a neutrino detector on Earth would capture two particles within any 10 second interval unless both of those neutrinos came from a supernova – in fact, the same supernova.

"We were kicking ourselves for not thinking of this before," Beacom said.

He cited Supernova 1987A, which occurred in a galaxy that is a very close companion to the Milky Way. Because detectors on Earth captured 20 neutrinos in only a few seconds during that event, astronomers knew for sure that they came from 1987A.

But since then?

"A big fat zero," he said. "What if using this technique, we could have been identifying one additional supernova neutrino per year? By now, we would have collected a sample as big as that burst in 1987." With the much larger neutrino detectors that are now being devised, and with the large number of supernovae that are being spotted these days, it could be done.

Galaxies up to 200 times farther away than the one that spawned Supernova 1987A are still considered near by astronomical standards, and amateurs would be able to spot supernovae in them. Those galaxies may give us only one or two neutrinos per year, but that's still more than scientists would be able to study otherwise.

"These are somewhat desperate measures," Ando admitted. "Why are we so desperate? Since a supernova expends 99 percent of its energy in neutrinos, those neutrinos tell the story of how the explosion works, and therefore we have to find them." Supernova neutrinos are everywhere, but the vastness of space keeps them hidden.

So, at least a thousand years after people first noticed supernovae in the skies, what's happening inside these exploding stars is still a mystery. When scientists simulate supernovae on computer, something always goes wrong. The explosion starts, and then it fizzles.

"If we can't make a supernova blow up on the computer, that means we're missing something. We need clues. We need to find those neutrinos," Ando continued.

Beacom envisions that scientists at neutrino detectors could sound an alarm whenever they detect two particles in ten seconds. Since supernovae emit neutrinos at the very start of the explosion, the particles would reach Earth hours before the supernovae would be visible in telescopes, and the announcement would amount to a supernova forecast.

Alternatively, when astronomers spot a nearby supernova, they could ask the scientists at the detectors to look back through their data from previous hours to find any particle events.

At Beacom's suggestion, scientists working at the Japanese neutrino detector Super-Kamiokande are going to search their records for events that could be linked to nearby supernovae in past years.

"While this detector is smaller than those envisioned for the future, it's been in operation for a decade or two, so it actually stands a good chance of having detected the first neutrino from an identified supernova beyond the Milky Way and its closest companions," Beacom said.

Source: Ohio State University