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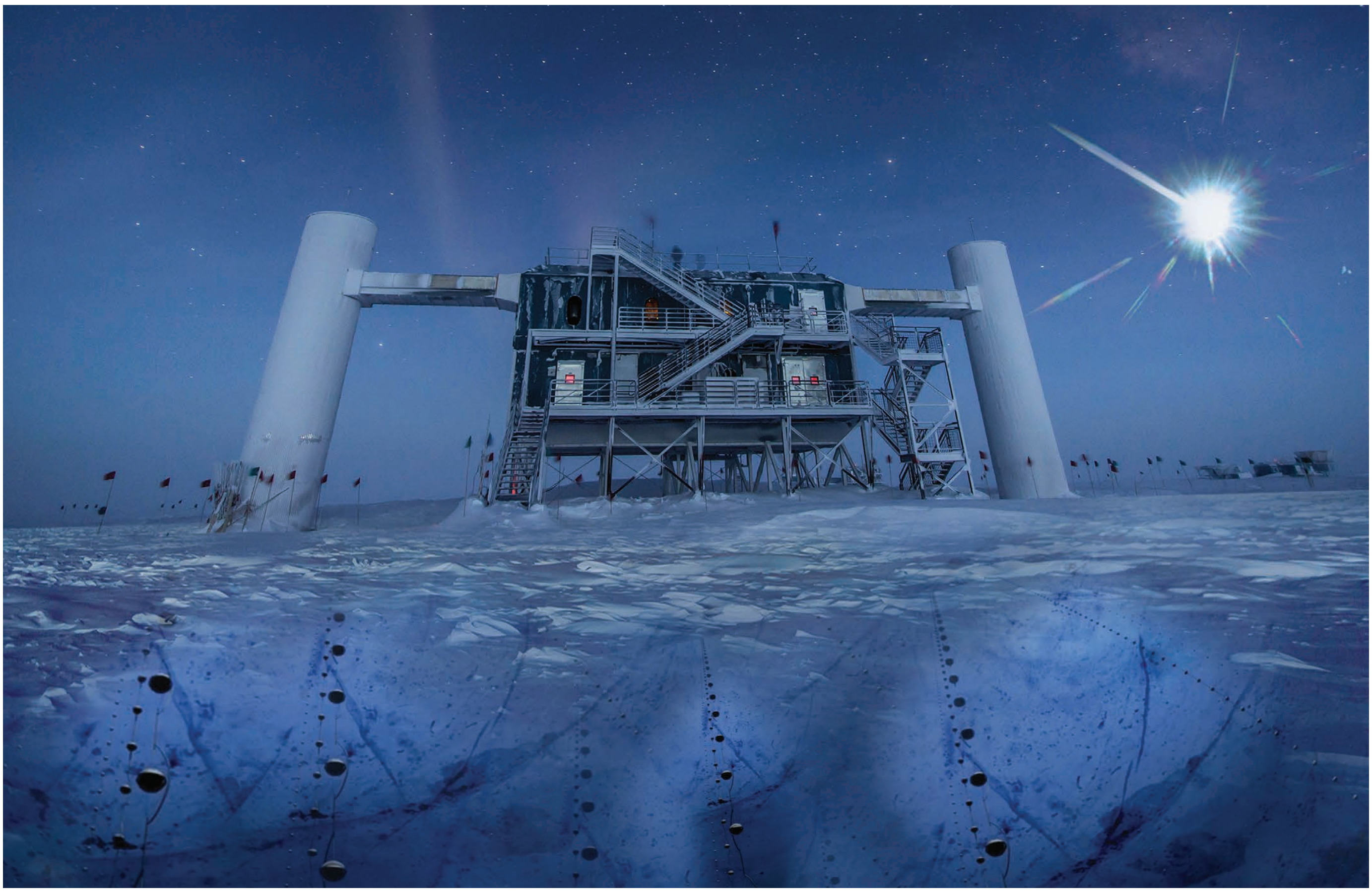

The IceCube lab is in Antarctica, on the South Pole.

ASTROPHYSICS

Particle traced from space

When a neutrino streaked through Antarctica, astrophysicists raced to find the source.

BY DAVIDE CASTELVECCHI

A single subatomic particle detected at the South Pole last September is helping to solve a major cosmic mystery: what creates electrically charged cosmic rays, the most energetic particles in nature.

Follow-up studies on the particle's trajectory by more than a dozen observatories suggest that researchers have, for the first time, identified a distant galaxy as a source of high-energy neutrinos. This discovery could, in turn, help scientists to pin down the still-mysterious sources of cosmic rays, the protons and atomic nuclei that arrive at Earth from outer space. The same mechanisms that produce cosmic rays should also make high-energy neutrinos.

Multiple teams of researchers from around the world described the neutrino's source in at least seven papers released on 12 July. "Everything points to this as the ultra-bright, energetic source — a gorgeous source," says Elisa Resconi, an astroparticle physicist at the Technical University of Munich in Germany.

Astrophysicists have proposed a number of scenarios for astrophysical phenomena that could produce both high-energy neutrinos and their electrically charged counterparts, cosmic rays. But until now, they had not managed to unambiguously trace any of these particles back to their source.

MUON ALERT

The story began on 22 September 2017, when an electrically charged particle called a muon zipped through the Antarctic ice cap at close to the speed of light. the IceCube Observatory — an array of more than 5,000 sensors buried in a cubic kilometre's worth of ice — detected ▶

flashes of light that the muon produced in its wake. The particle seemed to emerge from below the detector — an orientation that indicated it was the decay product of a neutrino that had come from below the horizon. Muons can travel only so far inside matter, whereas neutrinos often pass through the entire planet unimpeded; most of the muons that IceCube detects originate from neutrinos that have crashed with a particle inside Earth.

Within seconds, a computer cluster at the US National Science Foundation's Amundsen–Scott South Pole Station had reconstructed the precise path of the particle and recognized that the muon had come from a highly energetic neutrino; 43 seconds after the event, the station sent an automated alert to a network of astronomers through a satellite link. It tagged the neutrino as IceCube-170922A.

After receiving the alert, Derek Fox, an astrophysicist at Pennsylvania State University in University Park, quickly secured observing time on the X-ray observatory Swift, which orbits Earth. He and his team found nine sources of high-energy X-rays close to where the neutrino had come from. Among them was an object called TXS 0506+056. This is a blazar, a galaxy with a supermassive black hole at the centre and a known source of γ-rays. In a blazar, the black hole stirs up gas to temperatures of millions of degrees and shoots it out of its poles in two highly collimated jets. In this case, one of the jets points in the direction of the Solar System. Fox's team announced its findings to the astronomical community the next day.

In the following days, another team inspected data from Fermi-LAT, the Large Area Telescope aboard NASA's Fermi Gamma-ray Space Telescope. Fermi-LAT constantly sweeps the sky, and among other things monitors about 2,000 blazars. These objects go through periods of increased activity that can last weeks or months, during which they become unusually bright. "When we looked at the region that IceCube said the neutrino came from, we noticed that this blazar had been flaring more than ever before," says Regina Caputo, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, who is Fermi-LAT's analysis coordinator.

> *"Everything points to this as the ultra-bright, energetic source — a gorgeous source."*

On 28 September, the Fermi-LAT team sent out an alert to reveal this finding. It was at that point that other astronomers got excited. IceCube has detected about a dozen such high-energy neutrinos each year since it started operating in 2010, but none had been associated with a particular source in the sky. "That's what made the hair stand at the back of the neck," Fox says.

Researchers with IceCube and Fermi-LAT calculated the odds that the flare and the neutrino were related, rather than coming from the same direction in the sky by chance. They found that likelihood to be good, although not at the level of statistical significance required for claiming a discovery in physics[1,2].

A major missing piece of information was the blazar's distance from Earth, says Simona Paiano of the Astronomical Observatory of Padua in Italy. To measure it, she and her team booked 15 hours of observing time on the world's largest optical telescope, the 10.4-metre Gran Telescopio Canarias on La Palma, one of Spain's Canary Islands. They found the blazar to be around 1.15 billion parsecs (3.78 billion light years) away[3].

Together, the data pinpoint the likely source, says Kyle Cranmer, a particle physics and data-analysis expert at New York University, but "the observation isn't unambiguous", he cautions. "More follow-up is needed to conclusively establish blazars as a source of high-energy neutrinos." ■

1. IceCube Collaboration. *Science* **361**, 147–151 (2018).
2. IceCube Collaboration *et al. Science* **361**, eaat1378 (2018).
3. Paiano, S., Falomo, R., Treves, A. & Scarpa, R. *Astrophys. J. Lett.* **854**, L32 (2018).

EPIDEMIOLOGY

Chinese cities scan sewers for signs of illegal drug use

Privacy concerns and cultural differences could limit the technique's use in other nations.

BY DAVID CYRANOSKI

Dozens of cities across China are applying an unusual forensic technique to monitor illegal drug use: chemically analysing sewage for traces of drugs, or their telltale metabolites, excreted in urine.

One southern city, Zhongshan, a drug hotspot, is also monitoring waste water to evaluate the effectiveness of its drug-reduction programmes, says Li Xiqing, an environmental chemist at Peking University in Beijing who is working with police in these cities.

Li says Zhongshan police have already used the technique to help track down and arrest a drug manufacturer. He says a handful of cities are planning to use data from waste water to set targets for police arrests of drug users, some as early as next year.

Although illegal drug use has been monitored through wastewater-based epidemiology (WBE) in other countries, including Belgium, the Netherlands, Spain and Germany, most studies have collected data for epidemiological research rather than for setting policies. "The noteworthy part is that China seems to be actually acting on the technique," says Daniel Burgard, a chemist at the University of Puget Sound in Tacoma, Washington.

Last month, Chinese President Xi Jinping said that the country's war on drugs was tied to national security and the welfare of the Chinese people. Li says the central and local governments will invest at least 10 million yuan (US$1.5 million) in WBE monitoring by the end of the year. He expects the figure to at least double annually for the next few years.

Li is pushing for the method to be used internationally, including as part of the United Nations' drug control policies. "The experience and lessons from the application of WBE and its adoption by the Chinese drug police in their daily management will be very relevant for other countries," he argues.

But many issues, such as how police should be allowed to analyse the data, the need for safeguards to prevent the data from being misused, and privacy concerns, need to be ironed out. Some researchers are sceptical that the method will be adopted successfully in other countries.

DRUG USE

To show that WBE reflects drug use in the community, a number of studies have compared drug levels detected in sewage with other data sources on drug use, such as the amount