

IN DEPTH

The IceCube Laboratory at the South Pole operates a neutrino detector 1.5 kilometers beneath the ice.

ASTROPHYSICS

Ice reveals a messenger from a blazing galaxy

Neutrino astronomy is born as IceCube and other instruments find likely home of particle

By **Daniel Clery**

If astronomers are right, a ghostly particle that lit up an instrumented swathe of ice beneath the South Pole on 22 September last year was a messenger from a distant galaxy. The particle was a neutrino, electrically neutral and almost massless, which means its path could be traced back to the extragalactic event that created it. Cued by IceCube, the Antarctic detector, the orbiting Fermi Gamma-ray Space Telescope found that the neutrino likely came from a far off blazar, a hugely bright source of radiation powered by a supermassive black hole.

Astronomers have long been tantalized by the prospect of using neutrinos, which move at almost the speed of light and rarely interact with other matter, to learn about violent cosmic events. The new finding, reported on pages 146 and 147, could mark the founding event of neutrino astronomy. The detection also triggered a powerful example of another new trend, multimessenger astronomy, in which telescopes and other instruments studied the flaring blazar in all parts of the electromagnetic spectrum, from gamma rays to radio waves.

A neutrino-producing blazar could also help solve a decades-old mystery in astronomy: Where do the extremely high energy protons and other nuclei that occasionally bombard Earth come from? Known as ultrahigh-energy cosmic rays, these particles have a million times more energy than has ever been produced in an earthbound particle accelerator, but what boosts them to such colossal energies is unknown. Suspects have included neutron stars, gamma-ray bursts, hypernovae, and the radiation-spewing black holes at the center of some galaxies, but whatever the source, high energy neutrinos are a likely byproduct (*Science*, 31 July 2015, p. 465). If the IceCube team is right, blazars could be the first confirmed source of these cosmic rays.

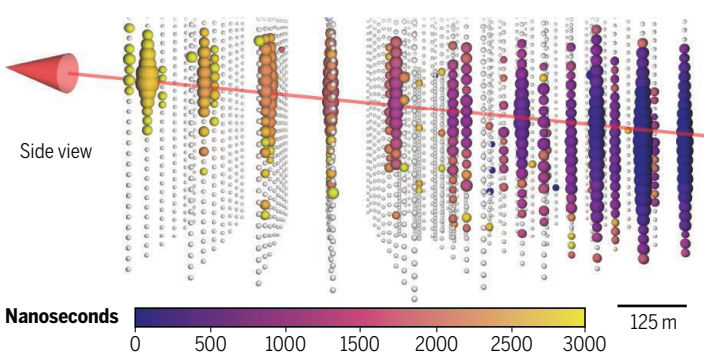
Researchers note, however, that the link between the neutrino and the blazar isn't rock-solid. "It's a very mouthwatering observation and I very much hope it will be confirmed," says Pierre Sokolsky of the University of Utah in Salt Lake City. "If their interpretation of those observations is correct it will be revolutionary, extraordinary," says Eli Waxman of the Weizmann Institute of Science in Rehovot, Israel. But, he adds, "an extraordinary result needs extraordinary support, and the support is not quite extraordinary yet."

Completed in 2010, the IceCube neutrino detector snares these elusive particles in a cubic kilometer of Antarctic ice. When a neutrino hits a nucleus in the frozen water molecules, other particles fly off in recoil; as they decelerate, they emit light called Cherenkov radiation, which some of IceCube's 5160 light detectors may pick up. Based on the location, timing, and brightness of the detected light, researchers can reconstruct the path and energy of the neutrino.

Most of the neutrinos detected by IceCube originated nearby, spawned by cosmic rays hitting Earth's upper atmosphere. IceCube researchers eliminate those using a variety of methods, leaving the very few, very high energy neutrinos, above 30 trillion electron volts (TeV). In 2013, the IceCube team first revealed a handful of such events, arguing that their high energies and other properties showed they must have come from outside of our galaxy (*Science*, 22 November 2013, p. 920). The detector continues to bag about a dozen high energy neutrinos a year; when it gets a clean track with a well-defined direction, other telescopes scramble to see if

A polar light show with cosmic origins

The detection, and computed path, of neutrino IceCube-170922A. Each circle represents one of IceCube's spherical light detectors in the Antarctic ice: size indicates the brightness detected, from earliest (in dark blue), to latest (in yellow).



CREDITS: (PHOTO) MARTIN WOLF, ICECUBE/NSF; (GRAPHIC) GRANT *ET AL.*, *SCIENCE*, VOL. 361, 147 (2018); ADAPTED BY C. BICKEL/*SCIENCE*

Downloaded from http://science.sciencemag.org/ on July 13, 2018

Published by AAAS

there is an obvious cosmic source—until now, without success.

In 2016 IceCube's operators set up an alert service, with the hope of getting more telescopes at different wavelengths involved in the hunt. Then, last September, IceCube got lucky. A detected neutrino, dubbed IceCube-170922A and calculated to have an energy of 290 TeV, offered a relatively clear track back into space. An automatic alert went out less than a minute later.

Several observatories initially didn't see anything unusual. Six days later, the Fermi team reported the satellite had found that a blazar, known as TXS 0506+056 and just 0.1° away from the neutrino track suggested by IceCube, was especially bright, having started flaring a few months earlier. Soon, more than a dozen telescopes had studied the blazar. Blazars, like quasars, are distant cosmic beacons powered by supermassive black holes, which generate intense radiation and fire jets of particles from their poles. Blazars are exceptionally bright, astronomers believe, because their jets happen to be aimed straight at Earth.

IceCube and the other observers estimate the probability that the neutrino path and the blazar coincided by chance is roughly one in 740. Physicists and astronomers, however, aren't usually convinced that two phenomena are connected until there's no more than a one in 3.5 million, or 5-sigma, probability of a coincidence.

IceCube researchers also went back through almost a decade of data to see whether an excess of high-energy neutrinos had streamed from the same location before. They found a period of 150 days in late 2014 and early 2015 when IceCube detected around 13 more neutrinos than normal from that spot. It's not yet clear whether TXS 0506+056 was flaring at that time, but "the archival event was much more interesting" than the recent detection, says IceCube Principal Investigator Francis Halzen of the University of Wisconsin in Madison.

Sokolsky and Waxman agree that IceCube's September 2017 detection should strengthen the project's longstanding bid to massively increase the size of the instrument, which would also increase how many neutrinos it can detect and improve its pointing accuracy. Since IceCube was built, the team has found the ice is clearer than previously thought, so they believe they can make IceCube 10 times bigger while only doubling the number of light detectors, matching the $280 million cost of its original construction. The team is about to start experiments to test that. "With a 10-times bigger detector, the answer [to where high energy neutrons come from] would be clear and obvious," Waxman says. ■



IMAGE: INSTITUTE OF HIGH ENERGY PHYSICS, CAS

SPACE

China announces new flotilla of space science missions

Probes will watch for colliding black holes, image Earth's magnetosphere, and monitor the sun

By **Dennis Normile**

China's ambitious human space missions get most of the headlines, but its fledgling space science program is quietly gaining strength. The Chinese Academy of Sciences (CAS) last week confirmed plans to launch four new scientific satellites beginning in 2020. Coming on the heels of four successful missions, including one devoted to x-ray astronomy and another that demonstrated quantum entanglement over a record-setting 1200 kilometers, these "phase 2" projects will examine areas including solar physics and the hunt for electromagnetic signals associated with gravitational waves.

Given that China's space science program only started about 10 years ago, the lengthening track record "is impressive, but there are still not many missions given that it's a big country with a big science community," says Xin Wu, a China-born physicist at the University of Geneva in Switzerland who collaborates on China's astrophysics missions. "There is pent-up demand" among Chinese space scientists, he says.

CAS broke with tradition for one of the new missions, the Gravitational Wave High-energy Electromagnetic Counterpart All-sky Monitor (GECAM). It fast-tracked selection and development to take advantage of a new scientific opportunity, which Xiong Shaolin, an astrophysicist at CAS's Institute of High Energy Physics in Beijing, and his colleagues identified a month after the U.S. Laser Interferometer Gravitational-Wave Observatory announced its historic detection of gravitational waves in February 2016. They proposed putting two satellites into orbit on opposite sides of Earth that together could watch the entire sky for gamma rays emanating from the events that generate gravitational waves. Funding for technical studies arrived a few months later, and the mission has jumped to the front of the launch queue, with a date of 2020. "When you have this kind of opportunity you can't handle it like a normal mission, with selection and review taking 10 or 20 years," Xiong says.

So far, gamma rays and other electromagnetic signals have only been detected from one kind of gravitational-wave source, a neutron star merger, but they yielded a trove of detail about the enigmatic event. Astrophysicists are still debating whether black hole mergers, the other confirmed source of gravitational waves, also produce electromagnetic emissions. The GECAM team is betting that they do—and that much can be learned from the signals. "I think probably we will find something," Xiong says.

GECAM's observations will complement those of another phase 2 mission, the Einstein Probe (EP), which will survey the sky

Downloaded from http://science.sciencemag.org/ on July 13, 2018

Published by AAAS

Science

Ice reveals a messenger from a blazing galaxy

Daniel Clery

Science **361** (6398), 115-116.
DOI: 10.1126/science.361.6398.115

ARTICLE TOOLS http://science.sciencemag.org/content/361/6398/115

RELATED CONTENT http://science.sciencemag.org/content/sci/early/2018/07/11/science.aat1378.full
http://science.sciencemag.org/content/sci/361/6398/eaat1378.full
http://science.sciencemag.org/content/sci/361/6398/147.full

PERMISSIONS http://www.sciencemag.org/help/reprints-and-permissions

Use of this article is subject to the Terms of Service

Science (print ISSN 0036-8075; online ISSN 1095-9203) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. 2017 © The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. No claim to original U.S. Government Works. The title *Science* is a registered trademark of AAAS.

Downloaded from http://science.sciencemag.org/ on July 13, 2018