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Space

Strange cosmic ray hotspots stalk southern skies

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- IceCube uses detectors buried in Antarctic ice (Image: NSF/B Gudbjartsson)
- Enlarge image

Cosmic rays crashing into the Earth over the South Pole appear to be coming from particular locations, rather than being distributed uniformly across the sky. Similar cosmic ray "hotspots" have been seen in the northern skies too, yet we know of no source close enough to produce this pattern.

"We don't know where they are coming from," says Stefan Westerhoff of the University of Wisconsin-Madison.

Westerhoff and colleagues used the IceCube neutrino observatory at the South Pole to create the most comprehensive map to date of the arrival direction of cosmic rays in the southern skies. IceCube detects muons produced by neutrinos striking ice, but it also detects muons

created by cosmic rays hitting Earth's atmosphere. These cosmic ray muons can be used to figure out the direction of the original cosmic ray particle.

Good mystery

Between May 2009 and May 2010, IceCube detected 32 billion cosmic-ray muons, with a median energy of about 20 teraelectronvolts (TeV). These muons revealed, with extremely high statistical significance, a southern sky with some regions of excess cosmic rays ("hotspots") and others with a deficit of cosmic rays ("cold" spots).

Over the past two years, a similar pattern has been seen over the northern skies by the Milagro observatory in Los Alamos, New Mexico, and the Tibet Air Shower array in Yangbajain. "It is interesting that the pattern can be matched between [these experiments], at least qualitatively. They have very different techniques and systematic effects," says cosmic-ray physicist Paul Sommers at Pennsylvania State University in University Park. "I regard those hotspots as a good mystery."

It's a mystery because the hotspots must be produced within about 300 billion kilometres of Earth. Further out, galactic magnetic fields should deflect the particles so much that the hotspots would be smeared out across the sky.

Cosmic funnel

One of the hotspots seen by IceCube points in the direction of the Vela supernova remnant, a possible source of cosmic rays, but it's almost 1000 light years away. Cosmic rays coming from such large distances should be constantly buffeted and deflected by galactic magnetic fields on route, and should thus have lost all directionality by the time they reach Earth. In other words, such long-distance cosmic rays should appear to come from all parts of the sky. That's not what has been observed.

Milagro has also seen hotspots that appear to come from implausibly distant sources. As an explanation, Felix Aharonian of the Dublin Institute for Advanced Studies in Ireland and colleagues have suggested that there could be a "tube" of magnetic field lines extending between the source and our solar system, funnelling the cosmic rays towards us. However, Aharonian admits the theory is highly speculative.

Others have proposed that a local phenomenon called magnetic reconnection – in which solar magnetic field lines cross and rearrange, converting magnetic energy to kinetic energy – could be accelerating local cosmic rays to energies in the TeV range and beaming them towards Earth, creating the observed hotspots. "It implies that we have a Tevatron in the solar system," says Aharonian, referring to the particle accelerator at Fermilab in Batavia, Illinois. "That's also crazy, but it is at least less crazy than other explanations."

Westerhoff's team presented their results at the American Physical Society's meeting in Anaheim, California, on Saturday.