Cosmic accelerators discovered in our galaxy by UCLA physicists, Japanese colleague

August 17 2010

Physicists from UCLA and Japan have discovered evidence of "natural nuclear accelerators" at work in our Milky Way galaxy, based on an analysis of data from the world's largest cosmic ray detector.

The research is published Aug. 20 in the journal Physical Review Letters .

Cosmic rays of the highest energies were believed by physicists to come from remote galaxies containing enormous black holes capable of consuming stars and accelerating protons at energies comparable to that of a bullet shot from a rifle. These protons — referred to individually as "cosmic rays" — travel through space and eventually enter our galaxy.

But earlier this year, physicists using the Pierre Auger Observatory in Argentina, the world's largest cosmic ray observatory, published a surprising discovery: Many of the energetic cosmic rays found in the Milky Way are not actually protons but nuclei — and the higher the energy, the greater the nuclei-to-proton ratio.

"This finding was totally unexpected because the nuclei, more fragile than protons, tend to disintegrate into protons on their long journey through space," said Alexander Kusenko, UCLA professor of physics and astronomy and co-author of the *Physical Review Letters* research. "Moreover, it is very unlikely that a cosmic accelerator of any kind would accelerate nuclei better than protons at these high energies."

The resolution to the paradox of the nuclei's origin comes from an analysis by Kusenko; Antoine Calvez, a UCLA graduate student of physics who is part of Kusenko's research group; and Shigehiro Nagataki, an associate professor of physics at Japan's Kyoto University. They found that stellar explosions in our own galaxy can accelerate both protons and nuclei.

But while the protons promptly leave the galaxy, the heavier and less mobile nuclei become trapped in the turbulent magnetic field and linger longer.

"As a result, the local density of nuclei is increased, and they bombard Earth in greater numbers, as seen by the Pierre Auger Observatory," said Kusenko, who is also a senior scientist at the University of Tokyo's Institute for Physics and Mathematics of the Universe (IPMU).

These ultra-high-energy nuclei have been trapped in the web of galactic magnetic fields for millions of years, and their arrival directions as they enter the Earth's atmosphere have been "completely randomized by numerous twists and turns in the tangled field," he said.

"When the data came out, they were so unexpected that many people started questioning the applicability of known laws of physics at high energy," Kusenko said. "The common lore has been that all ultra-high-energy cosmic rays must come from outside the galaxy. The lack of plausible sources and the arrival-direction anisotropy (the nuclei have different physical properties when measured in different directions) have been used as arguments in favor of extragalactic sources.

"However, since the cosmic rays in question turned out to be nuclei, the galactic field can randomize their arrival directions, taking care of the anisotropy puzzle. As for the plausible sources, the enormous stellar explosions responsible for gamma ray bursts can accelerate nuclei to

high energies. When we put these two together, we knew we were on the right track. Then we calculated the spectra and the asymmetries, and both agreed with the data very well."

Kusenko hopes this research will enhance the understanding of "astrophysical archeology."

"We can study the collective effects of gamma ray bursts that have taken place in the past of our own galaxy over millions of years," he said.

Stellar explosions capable of accelerating particles to ultra-high energies have been seen in other galaxies, where they produce gamma-ray bursts. The new analysis provides evidence that such powerful explosions occur in our galaxy as well, at least a few times per million years, Kusenko said.

Kusenko and his colleagues predict that the protons escaping from other galaxies should still be seen at the highest energies and should point back to their sources, providing Pierre Auger Observatory with valuable data.

The Pierre Auger Observatory records cosmic ray showers through an array of 1,600 particle detectors placed about one mile apart in a grid spread across 1,200 square miles, complemented by specially designed telescopes. The observatory is named for the French physicist Pierre Victor Auger, who in the 1920s discovered air showers.

Provided by University of California - Los Angeles