NEWS

Aug 10, 2009

Excess positrons are linked to Geminga pulsar

PAMELA

Are recently-detected excesses of cosmic electrons and positrons the first direct evidence for the existence of dark matter particles? That has been the hope of many physicists, while others have suggested a more mundane origin in a nearby pulsar. Now researchers in the US claim that the excesses can be linked to high-energy gamma rays emitted by the Geminga pulsar.

Cold dark matter is the most accepted explanation as to why the universe appears to have at least 80% more gravitating mass than is directly visible. Dark-matter particles are expected

to collide with one another and annihilate — producing high energy particles such as electrons and positrons. If these particles could be observed, they would represent the most direct evidence yet for the existence of dark matter.

Excesses of high energy electrons and positrons from space have been reported by several experiments. In particular, in 2008, researchers working on the PAMELA satellite found an excess of positrons from 10–100 GeV in the cosmic ray spectrum. The results could not be explained by standard models of cosmic ray origin and propagation in the Milky Way and instead suggested a nearby 'source' of high energy positrons. However, there has been no conclusive evidence linking the positrons to dark matter — and the annihilation rate is far higher than expected from standard theories.

Positrons from Geminga

Now, Hasan Yuksel (http://www.bartol.udel.edu/~yuksel/) and Todor Stanev (http://web.physics.udel.edu/about/directory/faculty/todor-stanev) at the University of Delaware and Matthew Kistler (http://www.physics.ohio-state.edu/~kistler/home/home.html) at Ohio State University claim that the source of these positrons is Geminga — a nearby and rapidly rotating neutron star. The results also represent the first time that astronomers can link cosmic rays to a specific source.

At the heart of their theory is seemingly unrelated set of

observations by the Milagro gamma-ray observatory in New Mexico, which has seen a halo of high energy gamma-ray sources around Geminga. Located approximately 800 light–years away from Earth and some 300,000 years old, Geminga is the nearest known gamma–ray source to Earth, excluding solar system bodies.

“We wanted to understand the origin of these gamma rays, which were not expected from such an old pulsar,” explains Yuksel. “We found that they imply pairs of electrons and positrons are being produced near the pulsar and accelerated up to very high energies.”

Tangled magnetic fields

Importantly, the extent of the gamma ray emission also implies that a 'wind' of these particles is escaping from the pulsar, confirming the presence of a powerful particle accelerator near the Earth and suggesting that the cosmic rays produced in Geminga's more active past are — after a circuitous journey through the Milky Way's tangled magnetic fields — likely the source of the excess positrons observed by PAMELA.

If so, the results are also likely to be the first 'direct' detection of cosmic rays. “When cosmic rays are detected in the atmosphere or in space, we cannot infer their origins easily as their trajectories are easily bent in the Milky Way's magnetic fields and any relevant information is usually lost,” says Kistler.

“However, if the observed excess of positrons can be associated with a known object near the Earth, then for the first time, a connection between a population of cosmic rays and the source that gave birth to them will be established.”

Other astronomers have welcomed the result. “It is at first sight not terribly surprising that Geminga could be the source of the PAMELA positron excess as it is the closest energetic pulsar,” says Stefan Funk at Stanford University in California and an associated member of the HESS gamma-ray observatory. “However, by connecting this to the recent Milagro observations, this can be used in principle to calculate the number of particles that would reach us from Geminga if these particles are electrons.”

Don't give up on dark matter

Douglas Finkbeiner at Harvard University in Massachusetts is more cautious. “I am glad people are pursuing the pulsar explanation and certainly pulsars contribute to this signal at some level,” he says. “But enough is not known about pulsars at the moment to exclude the possibility that something else dominates.”

Yuksel and his colleagues accept that dark matter cannot be ruled out as yet. However, they believe new observations from other more sensitive experiments will examine Geminga in more detail and allow scientists to better gauge the total

amount of energy contained in cosmic rays flowing from the pulsar.

The work is reported in *Physical Review Letters* (http://link.aps.org/doi/10.1103/PhysRevLett.103.051101)

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