New data shows cosmic rays are more complex than expected

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This is the "South Pillar" region of the star-forming region called the Carina Nebula. Like cracking open a watermelon and finding its seeds, the infrared telescope "busted open" this murky cloud to reveal star embryos tucked inside finger-like pillars of thick dust. Credit: NASA

During the American Physical Society's 2015 April Meeting, to be held April 11-14 in Baltimore, Maryland, Eun Joo Ahn from Fermilab will present data from the most extensive study yet on the composition of cosmic rays—an 8-year-long project carried out at the Argentina-based

Pierre Auger Observatory. Their results show that cosmic rays are more complex than previously thought: instead of being made up solely of very light particles (like protons) or very heavy ones (like iron), the data suggest that midweight particles like helium and nitrogen are significant components of cosmic rays.

High energy cosmic rays contain millions of times more energy than even particles the most powerful particle accelerators on Earth can produce. When a cosmic ray hits a molecule in the atmosphere, the energy of the collision sparks a cascading shower of particles falling to earth. Researchers can study these particle showers to learn about the high energy cosmic rays that triggered them.

Ahn and her colleagues measured the mass of cosmic ray air shower particles by examining how far into the atmosphere they penetrated. Such data can be challenging to gather because the particles become increasingly scarce as they become more energetic. For instance, at 10^{15} eV, one might expect just one particle per square meter per year. At 10^{20} eV, this drops precipitously to one particle per square kilometer per century. Observatories must therefore be very large in order to detect these scarce particles and use them to reconstruct the ray's path through the atmosphere.

The hybrid detector setup at Pierre Auger, the world's largest cosmic ray observatory, makes this type of analysis possible.

Ground detectors, 1600 tanks containing 3000-gallons of water each spaced evenly over Auger's 3000 square kilometer area, measure the radiation emitted by particles that fall to the earth. Because high-energy cosmic ray particles travel faster than the speed of light in water, they emit short bursts of detectable radiation when passing through the water tanks.

Fluorescence telescopes—the second type of detector at Auger—complement the ground detectors. Air shower particles passing through the atmosphere excite nitrogen molecules, causing them to fluoresce. Auger's telescopes can detect this faint glow, which varies depending on the particle's size.

The fluorescence telescopes can collect very precise measurements, but they are only useful when it's dark—about 13% of the time. The ground detectors provide less precise compositional data, but they run around the clock and so bring more statistical power to the data set.

"If we only have the fluorescence telescopes, we're limited by statistics. It's a bit more difficult to get an accurate reconstruction of the trajectory. If it's only the surface detectors, we don't have a very good handle on the composition," said Ahn. "If the shower is detected by both types, then we can do a very precise reconstruction" of its path through the atmosphere.

Ahn and her team used computer simulations to test how various models fit with their large data set. "There are many viable, convincing models that explain the shape of the cosmic ray spectrum," said Ahn. It's too soon to identify one particular model as a frontrunner. "Knowing the composition is key to understanding the shape of the cosmic ray spectrum" said Ahn. "It's a gateway to answering bigger questions."

More information: See the abstract at meetings.aps.org/Meeting/APR15/Session/K14.3

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