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CREAM Team Finds Surprising Features in Cosmic Ray Energy Spectra

Members of the CREAM team stand near a crane holding the CREAM instrument. Its balloon is in the background

College Park, MD - In May a University of Maryland-led team of scientists reported previously unknown features in the energy spectra of cosmic ray nuclei. Their findings contradict aspects of a prevailing model for how cosmic rays from outside our solar system may be accelerated to their very high energies by the expanding shock waves generated when massive stars explode as supernovas.

Researchers from the Cosmic Ray Energetics And Mass (CREAM) collaboration discovered a relative increase in the flow rate (flux) of cosmic-rays at high energies instead of the continuous decrease expected from conventional models. They also observed that the energy spectrum for protons (hydrogen nuclei) is different from the spectral behavior of helium and heavier nuclei. Each element's emission spectrum is unique, so scientists use spectroscopy to identify and study elements in matter of unknown composition.

Details of the cosmic-ray origin and acceleration mechanism are not yet fully understood, although they were discovered in 1912 with an electroscope carried on a manned hot air balloon.

These new spectral discrepancies could not be detected by previous experiments that had energy ranges and exposure times too limited for measuring the rare high-energy cosmic rays. However, the NASA-funded balloon-borne CREAM instrument was conceived to measure the detailed energy dependence of elemental spectra to the highest energy possible with a balloon-borne instrument. The CREAM investigation achieved 156 days of exposure to the cosmic radiation above 99.5 percent of the atmosphere in five separate flights over Antarctica. The data for this report are results from the CREAM-I (December 2004 - January 2005) and II (December 2005 - January 2006)flights of 42 days and 28 days, respectively. The data from subsequent flights are still being analyzed.

"Whether or not the proton spectrum is the same as that of heavier nuclei has long been a tantalizing question, but the spectral flattening was a surprise," said Eun-Suk Seo, Principal Investigator for the CREAM project and a professor of physics at the University of Maryland. "We were looking for a spectral cut off, evidence of the supernova acceleration limit, but instead found a relative increase in flux with energy."

Seo and her colleagues say that the observed hardening of nuclei spectra could result from a nearby source, analogous to one explanation for the electron excess. The hardening of nuclei spectra at the rigidity (momentum per charge) similar to the onset of previously reported electron enhancements indicates that a single mechanism might be responsible for both electrons and nuclei. The pervasive discrepant hardening in elemental spectra provides important constraints on cosmic-ray acceleration and propagation. It must be accounted for in any explanation of the mysterious cosmic ray "knee", the steepening, rather than flattening, of the all-particle spectrum near 10^{15} eV observed in ground based air shower measurements.

"Concave particle spectra from nonlinear diffusive shock acceleration were predicted nearly 30 years ago, but until [this study] there has been no convincing evidence from CR ions measured at the Earth," said Professor Don Ellison, physicist with North Carolina State University. "There are other possible explanations for spectral features or non-power law spectra other than [nonlinear Diffusive Shock Acceleration], such as isolated nearby sources with hard spectra poking out of the softer CR background, or non-standard propagation of CRs through the ISM. The bottom line, however, is that non-power law spectra convey information that pure power laws cannot. Whatever the explanation for the CREAM results turns out to be will be interesting and will add significantly to our understanding of the origin of Galactic cosmic rays."

The 2,500-pound CREAM instrument has been flown above some 128,000 feet altitude over Antarctica using a helium-filled balloon about as large as a football stadium. Its measurements in near space bridge the energy gap between similar lower-energy data and abundant ground-based air shower measurements at higher energies.

CREAM is an international collaboration of researchers from the University of Maryland, Penn State University; Ohio State University; Ewha Womans University in Seoul, Korea; University of Siena and INFN in Siena, Italy; University of Chicago; LPSC, France; and UNAM, Mexico. NASA supports CREAM in the United States. The flights are conducted under the auspices of the Balloon Program Office at Wallops Flight Facility by the staff of the Columbia Scientific Balloon Facility. The National Science Foundation office of Polar Programs provides Antarctic logistics support through Raytheon Polar Services Company.

For information on NASA's scientific balloon program, visit:
http://sites.wff.nasa.gov/code820/ For information about NASA and agency programs, visit:
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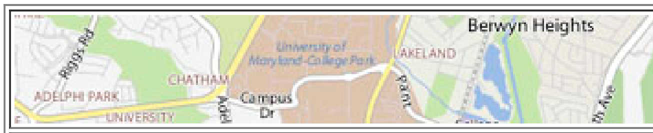

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