Understanding Killer Electrons in Space

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Settling a longstanding scientific debate, Los Alamos scientists have demonstrated conclusively how electromagnetic waves accelerate ordinary electrons in the belts of radiation outside Earth's atmosphere to a state where they become "killer electrons," particles that are hazardous to satellites, spacecraft, and astronauts.

Using data from several satellites, including NASA's Polar spacecraft, Los Alamos scientists published in the July issue of *Nature Physics* a paper showing how interactions between electromagnetic waves and electrons are responsible for accelerating radiation-belt particles in the Van Allen radiation belts to the point they become "killers."

The Van Allen radiation belts are doughnut-shaped regions encircling Earth that contain high-energy electrons and ions trapped in Earth's magnetic field.

The paper, "The Energization of Relativistic Electrons in the Outer Van Allen Radiation Belt," was written by Yue Chen, Geoffrey D. Reeves, and Reiner H.W. Friedel of the Laboratory's Space Science and Applications group. "We're not the first people to look at these space-based density gradients, but the essential achievement was coming up with the definitive test," said Reeves.

Competing models had proposed various effects involving diffusion, each roughly analogous to the ways piles of sand will spread out on a board that's shaken. The Los Alamos team's paper provides the first analysis that internal wave-particle acceleration is the only mechanism consistent with observations for the majority of radiation belt enhancement events (a surge of electrons up to 1,000 times more dense than they are in storm-free conditions).

"Debates on the source of the acceleration have lasted for at least a decade, and this paper finally settles the argument based on observations. The result should be very useful for further radiation-belt research work," Chen said.

The Los Alamos model involved measuring fluxes of electrons, counting how many per second hit a satellite-borne detector, and converting the physical measurements to magnetic coordinates. The results showed localized peaks in intensity that could only be caused by acceleration of those electrons by electromagnetic waves. "We know it's some kind of interaction between the electromagnetic waves and the particles, but not the exact mechanism. So it's a big step, but certainly not the only one in understanding radiation belts," said Reeves.

The Los Alamos teams obtained differential electron flux data from the Los Alamos energetic particle sensor (a burst-detector dosimeter) aboard a Global Positioning System satellite, the Los Alamos Synchronous Orbit Particle Analyzer (SOPA) aboard a geosynchronous orbit satellite, and the Comprehensive Energetic Particle and Pitch Angle Distribution experiment aboard NASA's Polar satellite.

The next big step in this field will be the planned 2012 launch of NASA's two Radiation Belt Storm probes, part of the agency's "Living With a Star" program to quantify the physical processes that generate the radiation belts and cause them to decay. Observations from the two spacecraft will enable the development of empirical and physics-based models for the radiation belts. The empirical models will be used by engineers to design radiation-hardened spacecraft, while the physics-based models will be used by forecasters to predict geomagnetic storms and alert both astronauts and spacecraft operators to potential hazards.

The paper is available at www.nature.com/nphys/journal/v … t/full/nphys655.html online.

Source: Los Alamos National Laboratory