Physicists Determine Source of 'Killer' Electrons in Earth's Radiation Belt

October 16 2007, by Laura Mgrdichian

Electrons trapped in the outer Van Allen radiation belt, a doughnut-shaped region of high-energy particles that surrounds Earth, kept in place by our planet's magnetic field, can have velocities approaching the speed of light. But the number of these “killer” electrons varies wildly: a few one day, many more the next. The cause has puzzled scientists – until now.

Why some electrons quickly kick into high gear has been debated for more than a decade, with two theories considered the most viable. Now, physicists from Los Alamos National Laboratory (LANL) have verified one of these theories using data collected from several satellites. The research, published in the September issue of *Nature Physics*, may lead to better space-weather models, which may help scientists predict when ultrahigh-energy electrons are abundant and, therefore, most dangerous.

“These 'killer' electrons can harm astronauts and even passengers on regular airline flights that go through Earth's polar regions,” the paper's lead author, LANL physicist Yue Chen, said to *PhysOrg.com*. “Therefore, people need to know the source of the these electrons so as to develop the ability to predict when they'll be most numerous. Our paper finally settles the argument.”

The group's work may also eventually help improve the design and operation of satellites, which are very susceptible to radiation effects and very expensive to repair or replace when damaged. Killer electrons can penetrate satellite radiation shields and cause malfunctions in the electronics on board.

The LANL group shows that the electrons' acceleration is mainly due to “gyro-resonant wave acceleration,” the end result of a complex domino effect that begins when particles from the solar wind and Earth's ionosphere (the layer of the atmosphere that is about 50-400 kilometers above the surface and contains molecules that are ionized by solar radiation) are sporadically injected into the radiation belt. This influx, bearing an unstable distribution of particles, excites many electromagnetic waves. The relative motion of waves and particles along the belt's magnetic field lines induces a Doppler shift of the wave frequency. Next, a resonant interaction occurs between the Doppler-shifted waves and electrons in the belt that are gyrating (moving in a circle around the field lines) at the same frequency as the waves – an effect known as gyro-resonance.

Most of the electrons injected into the belt follow trajectories that are nearly parallel with the magnetic field lines, and they soon lose energy. But for electrons that were initially injected at angles more perpendicular to the field lines – those with larger “pitch angles” – gyro-resonance has the opposite effect: a serious energy boost.

The losing theory, which was the accepted explanation until satellite data cast it into doubt in the mid 1990s, is “radial diffusion.” It states that fluctuations in the magnetosphere's electric and magnetic fields send electrons diffusing down into the belt from Earth's plasma sheet, a region of relatively low-energy energetic particles that extends behind Earth, away from the Sun. As the electrons descend into the stronger magnetic fields closer to Earth, they accelerate.

Chen and his colleagues used several instruments to collect the electron data that ultimately led them to verify that the gyro-resonant wave-particle interaction is the dominant acceleration mechanism. These included the Los Alamos energetic particle sensor, which sits on-board a global positioning system (GPS) satellite; the lab's GEO Synchronous Orbit Particle Analysis instruments, and a set of instruments mounted on NASA's Polar satellite, collectively known as the Comprehensive Energetic Particle and Pitch Angle Distribution experiment.

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Also see: Horne, R. B. *Nature Phys.* 3, 590–591 (2007)

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