Making waves with the hot electrons within Earth's radiation belts

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Encircling the Earth, within its magnetosphere, are two concentric, doughnut-shaped radiation belts known as the Van Allen belts. The Van Allen belts swell and recede in response to incoming energy from the sun, sometimes billowing far enough to expose orbiting satellites and other spacecraft to damaging radiation that can disrupt electronic communications and navigation signals, as well as electric grids. These radiation belt electrons travel near the speed of light and emit and absorb waves that are used by scientists to understand space weather.

An international team of scientists recently discovered the role that hot electrons may play in the waves and fluctuations detected by satellites. The research team reports its findings this week in *Physics of Plasmas*. Their results are based on data collected by the Van Allen Probes, twin robotic spacecraft launched by NASA in 2012 to help scientists better understand these belt regions.

Previous research has focused on low-frequency electromagnetic waves emitted from cold electrons as the major cause of acceleration and loss of relativistic electrons. These wave-particle interactions directly affect the width of the bands. Low-frequency waves include whistler-mode plasma waves, so named for the hissing or static sound they make that is audible through a speaker.

This general theory describes electrons from solar wind interacting with these low-frequency plasma waves. This causes the electrons to gain a tremendous amount of energy from the amplification of the whistler-mode waves via the surrounding plasmasphere.

However, according to the research team, low-frequency waves are typically associated with active magnetospheric conditions, which don't always occur. In contrast, high-frequency quasi-electrostatic (ES) fluctuations in the upper-hybrid frequency are a constant and pervasive feature in the Earth's radiation belt environment, as was recently discovered through new data from the Van Allen Probes.

"Occasional low-frequency waves with extremely large amplitudes may suddenly accelerate the electrons," said Junga Hwang, principal researcher at the Korea Astronomy and Space Science Institute in South Korea and a co-author of the paper. "But we believe that it is the high-frequency ES fluctuations that are constantly emitted and reabsorbed by the hot electrons, which allow these radiation belt electrons to remain inside the outer Van Allen band for a long time."

In their study, the researchers looked at electrons at three energy ranges: cold electrons, hot electrons and relativistic electrons. Cold electrons mainly contribute to the background electron density. Hot electrons are known as the main source for wave making. The relativistic electrons, meanwhile, result from particle acceleration processes, but they don't influence average plasma characteristics. The researchers chose "quiet-time" intervals to study the high-frequency waves when the low-frequency plasma waves were absent.

"Since hot electrons constitute only a small fraction of the total electron number density, the general thought has been that the upper-hybrid fluctuations are useful only as a tool for indirectly measuring the cold electron number density," Hwang said. "However, the data from the Van Allen Probes showed that upper-hybrid ES (electrostatic) fluctuations pervasively and ubiquitously exist in the radiation belts. From there, we proved that the presence of hot electrons and upper-hybrid fluctuations are mutually related phenomenon."

More information: J. Hwang et al, Roles of hot electrons in generating upper-hybrid waves in the earth's radiation belt, *Physics of Plasmas* (2017). DOI: 10.1063/1.4984249

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