Study explores wave-particle interaction in atmosphere

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Credit: NASA

A Dartmouth-led study sheds light on the impact of plasma waves on high-energy electrons streaking into Earth's magnetic field from space.

The findings are important because relativistic electrons can lead to ozone depletion and threaten orbital satellites, spacecraft and astronauts, and understanding the evolution of Earth's radiation belts could help lessen the effects of these particles.

The findings appear in *Geophysical Research Letters*.

Lead author Richard Denton, a research professor in Dartmouth's Department of Physics and Astronomy, uses computational research to study the magnetosphere, the region shielded by the Earth's magnetic field from solar wind; he also studies various wave phenomena, including plasma waves, which are like sound waves in air except these occur in ionized gas so the electric and magnetic fields are affected. He focuses on Alfven waves, which are similar to the oscillations of a guitar string with the magnetic field supplying the tension analogous to the string.

In their new paper, the researchers studied the resonance of relativistic electrons with electromagnetic ion cyclotron waves in the Earth's radiation belts—in other words, how these waves affect the electrons' motion. Also known as the Van Allen radiation belts, these giant concentric layers of charged particles are held in place by the Earth's magnetic field. An increase in particle density and charge brought about by solar activity can raise the level of threat to satellites.

Relativistic electrons have been thought to more easily resonate with electromagnetic ion cyclotron waves if the total density is large. But the researchers found that the lower minimum resonant energy for these electrons interacting with these waves results mainly not from high bulk density, but from low temperature of the protons that drive the instability. High density may lead to lower minimum resonant energy through causing the helium ion cyclotron mode to be dominant.

"Electromagnetic ion cyclotron waves have been thought to be a major loss mechanism for relativistic electrons in the Van Allen radiation belts ," says Denton. "Previously, high density was thought to lower the minimum energy of radiation belt particles for resonance. We show that high density is not the most important factor, though it can indirectly have an effect on the minimum resonant energy by causing a particular kind of ion cyclotron wave to grow."

More information: R. E. Denton et al. Resonance of relativistic electrons with electromagnetic ion cyclotron waves, *Geophysical Research Letters* (2015). DOI: 10.1002/2015GL064379