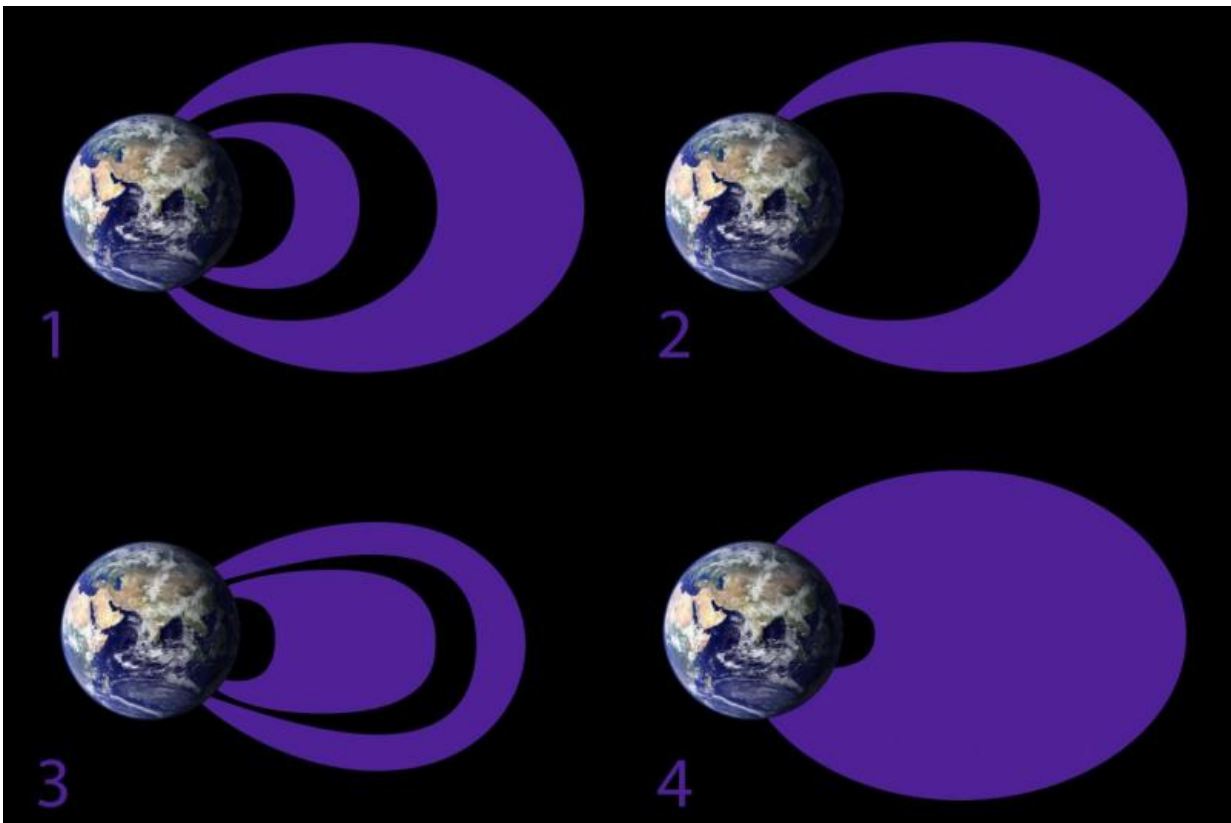


# Study finds surprising variability in shape of Van Allen Belts

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1. The traditional idea of the radiation belts includes a larger, more dynamic outer belt and a smaller, more stable inner belt with an empty slot region separating the two. However, a new study based on data from NASA's Van Allen Probes shows that all three regions--the inner belt, slot region, and outer belt -- can appear differently depending on the energy of electrons considered and general conditions in the magnetosphere. 2. At the highest electron energies measured -- above 1 MeV -- researchers saw electrons in the outer belt only. 3. The radiation belts look much different at the lowest electron energy levels

measured, about 0.1 MeV. Here, the inner belt is much larger than in the traditional picture, expanding into the region that has long been considered part of the empty slot region. The outer belt is diminished and doesn't expand as far in these lower electron energies. 4. During geomagnetic storms, the empty region between the two belts can fill in completely with lower-energy electrons. Traditionally, scientists thought this slot region filled in only during the most extreme geomagnetic storms happening about once every ten years. However, new data shows it's not uncommon for lower-energy electrons -- up to 0.8 MeV -- to fill this space during almost all geomagnetic storms. Credit: NASA Goddard/Duberstein

The shape of the two electron swarms 600 miles to more than 25,000 miles from the Earth's surface, known as the Van Allen Belts, could be quite different than has been believed for decades, according to a new study of data from NASA's Van Allen Probes that was released Friday in the *Journal of Geophysical Research*.

"The shape of the belts is actually quite different depending on what type of electron you're looking at," said Geoff Reeves of Los Alamos National Laboratory's Intelligence and Space Research Division and lead author on the study. "Electrons at different [energy levels](#) are distributed differently in these regions."

Understanding the shape and size of the belts, which shrink and swell in response to magnetic storms coming from the sun, is crucial for protecting our technology in space. The harsh radiation isn't good for satellite's health, so scientists want to know just which orbits could be jeopardized in different situations. Los Alamos has been studying space weather and its effects on national security satellites since the 1960s, when the U.S. launched the Vela satellites to support nuclear treaty verification.

Since scientists first began forming a picture of these rings of energetic particles in the 1950s, understanding of their shape has largely remained unchanged—a small, inner belt, a largely empty space known as the slot region, and then the outer belt, which is dominated by [electrons](#) and is larger and more dynamic than the others.

But this new analysis reveals that the shape varies from a single, continuous belt with no slot region, to a larger inner belt with a smaller outer belt, to no inner belt at all. Many of the differences are accounted for by considering electrons at different energy levels separately.

"It's like listening to different parts of a song," said Reeves. "The bass line sounds different from the vocals, and the vocals are different from the drums, and so on."

The authors of the study, from Los Alamos National Laboratory and the New Mexico Consortium, found that the inner belt—the smaller belt in the classic picture of the belts—is much larger than the outer belt when observing electrons with low energies, while the outer belt is larger when observing electrons at higher energies. At the very highest energies, the inner belt structure is missing completely. So, depending on what one focuses on, the radiation belts can appear to have very different structures simultaneously.

These structures are further altered by geomagnetic storms. When high-speed solar wind streams or coronal mass ejections—fast-moving magnetic material from the sun—collide with Earth's magnetic field, they send it oscillating, creating a geomagnetic storm. Geomagnetic storms can increase or decrease the number of energetic electrons in the radiation belts for days to months, though the belts return to their normal configuration after a time.

These storm-driven electron increases and decreases are currently

unpredictable, without a clear pattern showing what type or strength of storm will yield what outcomes. There's a saying in the space physics community: if you've seen one geomagnetic storm, you've seen one geomagnetic storm. But, it turns out, those observations have largely been based on electrons at only a few energy levels.

"When we look across a broad range of energies, we start to see some consistencies in storm dynamics," said Reeves. "The electron response at different energy levels differs in the details, but there is some common behavior. For example, we found that electrons fade from the slot regions quickly after a [geomagnetic storm](#), but the location of the slot region depends on the energy of the electrons."

Often, the outer electron belt expands inwards toward the inner belt during geomagnetic storms, completely filling in the slot region with lower-energy electrons and forming one huge radiation belt. At lower energies, the slot forms farther from Earth, producing an inner belt that is bigger than the outer belt. At higher energies, the slot forms closer to Earth, reversing the comparative sizes.

The twin Van Allen Probes satellites expand the range of energetic electron data we can capture. In addition to studying the extremely high-energy electrons—carrying millions of electron volts—that had been studied before, the Van Allen Probes can capture information on lower-energy electrons that contain only a few thousand electron volts. Additionally, the spacecraft measure radiation belt electrons at a greater number of distinct energies than was previously possible.

"Previous instruments would only measure five or ten energy levels at a time," said Reeves. "But the Van Allen Probes measure hundreds."

Measuring the flux of electrons at these lower energies has proved difficult in the past because of the presence of protons in the radiation

belt regions closest to Earth. These protons shoot through particle detectors, creating a noisy background from which the true electron measurements needed to be picked out. But the higher-resolution Van Allen Probes data found that these lower-energy electrons circulate much closer to Earth than previously thought.

"Despite the proton noise, the Van Allen Probes can unambiguously identify the energies of the electrons they're measuring," said Reeves.

Precise observations like this, from hundreds of energy levels, rather than just a few, will allow scientists to create a more precise and rigorous model of what, exactly, is going on in the radiation belts, both during geomagnetic storms and during periods of relative calm.

"You can always tweak a few parameters of your theory to get it to match observations at two or three energy levels," said Reeves. "But having observations at hundreds of energies constrain the theories you can match to observations."

**More information:** Geoffrey D. Reeves et al. Energy-dependent dynamics of keV to MeV electrons in the inner zone, outer zone, and slot regions, *Journal of Geophysical Research: Space Physics* (2016). [DOI: 10.1002/2015JA021569](https://doi.org/10.1002/2015JA021569) Geoffrey D. Reeves et al. Energy-dependent dynamics of keV to MeV electrons in the inner zone, outer zone, and slot regions, *Journal of Geophysical Research: Space Physics* (2016). [DOI: 10.1002/2015JA021569](https://doi.org/10.1002/2015JA021569)

Provided by Los Alamos National Laboratory

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