Geomagnetic field protects Earth from electron showers

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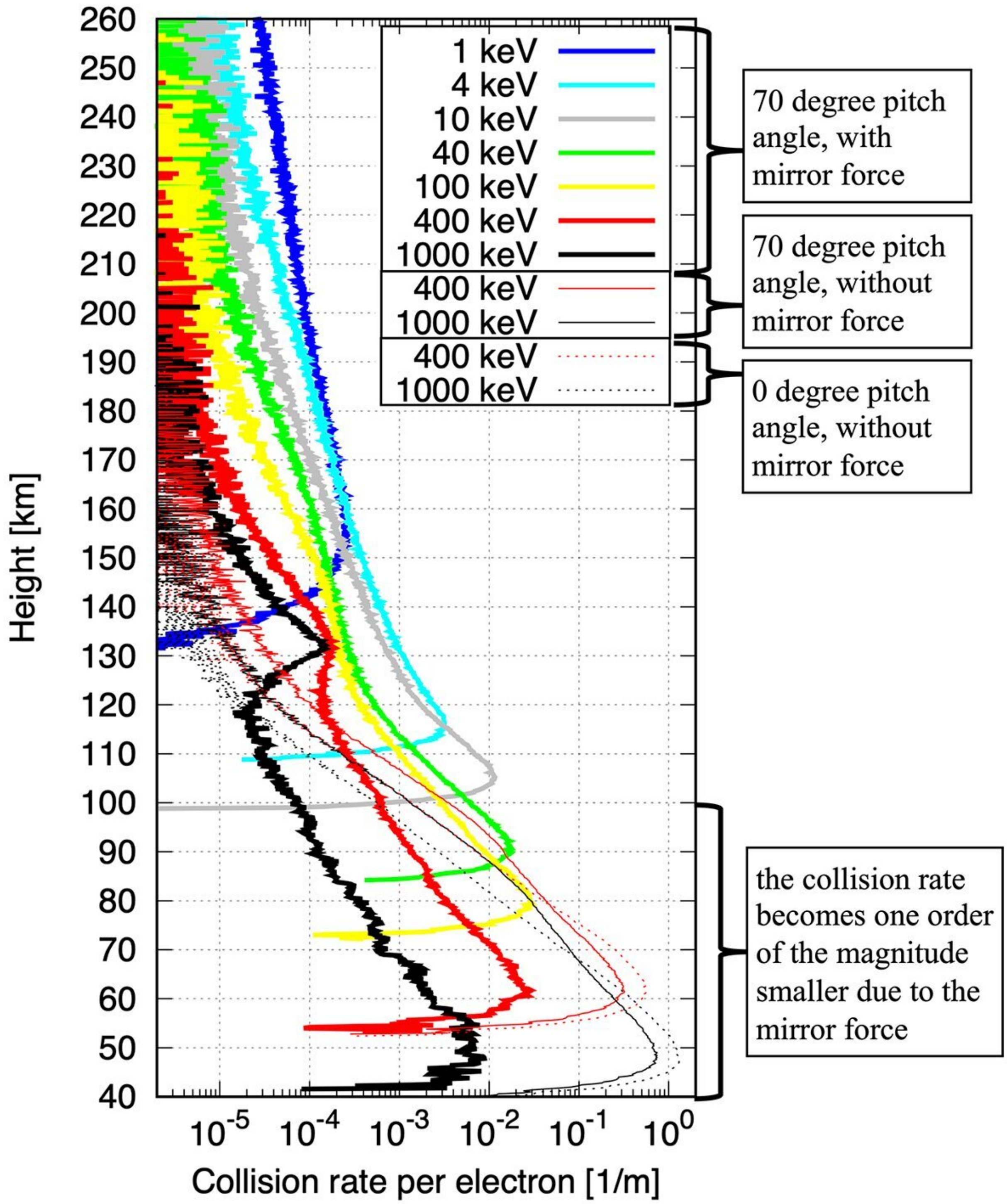

Altitude profiles of the collision rate per electron for the cases of the precipitation of 1, 4, 10, 40, 100, 400 and 1,000 keV electrons whose initial pitch angle is 70 degrees at an altitude of 400 km (thick solid lines). Credit: Yuto Katoh et al

Understanding the ionosphere high in the Earth's atmosphere is important due to its effects on communications systems, satellites and crucial chemical features including the ozone layer. New insights into the activity of high energy electrons have come from a simulation study led by geophysicist Yuto Katoh at Tohoku University, reported in the journal *Earth, Planets and Space*.

"Our results clarify the unexpected role of the geomagnetic field surrounding the Earth in protecting the atmosphere from high energy electrons," says Katoh.

The ionosphere is a wide region between roughly 60 and more than 600 kilometers above the Earth's surface. It contains electrically charged particles that are a mixture of ions and free electrons generated by the interaction of the atmosphere with radiation from the sun.

Polar regions of the ionosphere are subjected to a particularly steady and energetic stream of incoming electrons in a process called electron precipitation. These "relativistic" electrons move at close to the speed of light, where the effects of Einstein's relativity theory become ever more significant. They collide with gas molecules and contribute to many phenomena in the ionosphere, including colorful auroral displays. The processes are heavily influenced by the effects of the geomagnetic field on the charged particles involved.

The Tohoku team, with colleagues in Germany and other institutions in Japan, developed a sophisticated software code that focused particular attention on simulating the effects of a relatively unstudied "mirror force" on the electron precipitation. This is caused by the magnetic force acting on charged particles under the influence of the geomagnetic field.

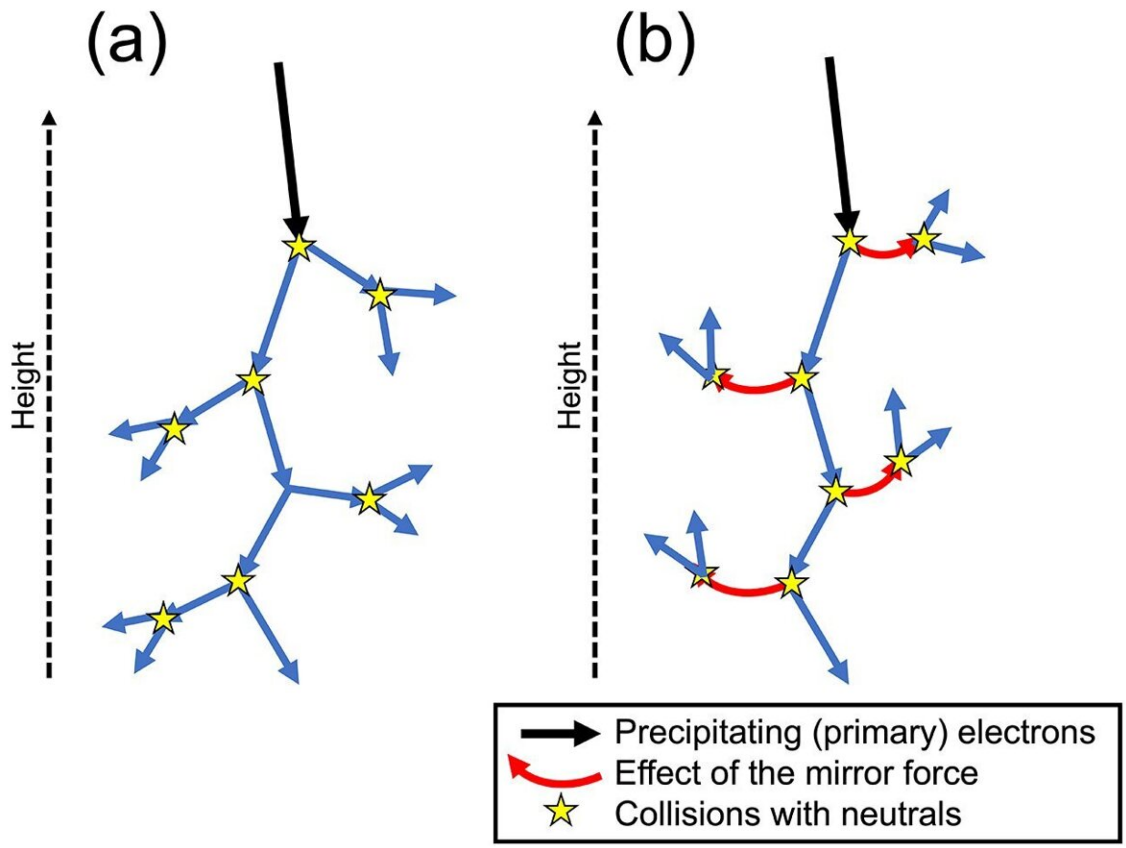

Illustration showing the relation between precipitating electrons, mirror force, and collisions with neutrals. The cases (a) without and (b) with mirror force are shown, indicating that the mirror force tends to move electrons upward through the collisions with neutrals. Credit: Yuto Katoh et al

The simulations demonstrated how the mirror force causes relativistic electrons to bounce back upwards, to an extent dependent on the angles at which the electrons arrive. The predicted effects mean that electrons collide with other charged particles higher in the ionosphere than previously suspected.

Illustrating one example of the significance of this work, Katoh comments, "Precipitating electrons that manage to pass through the mirror force can reach the middle and lower atmosphere, contributing to chemical reactions related to variations in ozone levels." Decreased ozone levels at the poles caused by atmospheric pollution reduce the protection ozone offers living organisms from ultraviolet radiation.

Katoh emphasizes the key theoretical advance of the research is in revealing the surprising significance of the geomagnetic field and the mirror force in protecting the lower atmosphere from the effects of electron precipitation activities by keeping them further away.

"We have now started a project to combine the simulation studies used in this work with real observations of the polar ionosphere to build even deeper understanding of these crucial geophysical processes," says Katoh.

More information: Yuto Katoh et al, Effect of the mirror force on the collision rate due to energetic electron precipitation: Monte Carlo simulations, *Earth, Planets and Space* (2023). DOI: 10.1186/s40623-023-01871-y

Provided by Tohoku University