A new way to create Saturn's radiation belts

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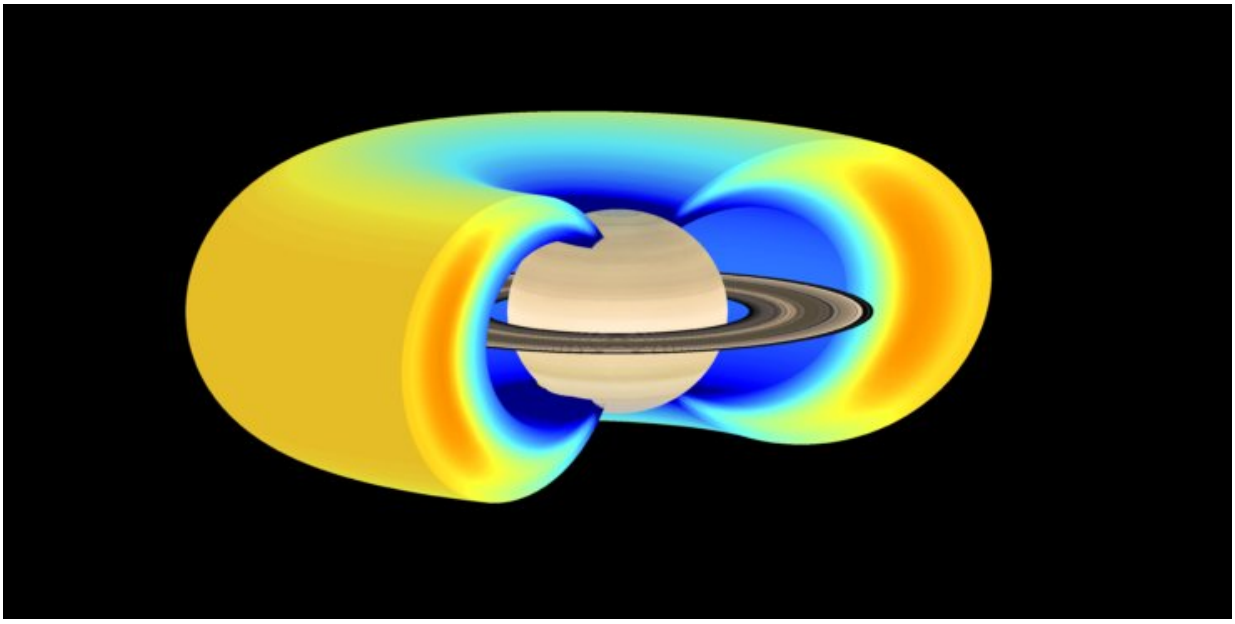

A new study describes a new way to create Saturn’s radiation belts. Credit: Emma Woodfield

A team of international scientists from BAS, University of Iowa and GFZ German Research Centre for Geosciences has discovered a new method to explain how radiation belts are formed around the planet Saturn.

Around Saturn, and other planets including the Earth, energetic charged particles are trapped in the magnetic field. Here they form doughnut-shaped zones near the planet, known as radiation belts, such as the Van

Allen belts around the Earth where electrons travel close to the speed of light.

Data collected by the NASA Cassini spacecraft, which orbited Saturn for 13 years, combined with a BAS computer model have provided new insights into the behaviour of these rapidly-moving electrons. The discovery overturns the accepted view among space scientists about the mechanisms responsible for accelerating the electrons to such extreme energies in Saturn's radiation belts. The team's results are published in the journal *Nature Communications* this week (Thursday 29 November).

It has always been assumed that around Saturn, electrons are accelerated to extremely high energies by a process called radial diffusion, where electrons are repeatedly nudged towards the planet, increasing their energy. An alternative way of accelerating electrons is their interaction with plasma waves as happens around the Earth and Jupiter with Chorus waves. Around Saturn, Chorus waves have been dismissed as ineffective; however, the authors discovered that in Saturn's unique environment, it is another form of plasma wave called the Z-mode wave that is critical.

According to lead author, Dr. Emma Woodfield from British Antarctic Survey: "This research is really exciting because the high energy electrons in the radiation belt around Saturn have always been assumed to come from radial diffusion. We've identified a different way to create a radiation belt that no one knew of before. This study provides us with a better understanding of how radiation belts work across the Solar system and will help modellers forecast space weather more accurately at the Earth, which in turn will protect both astronauts and satellites from radiation hazards."

Dr. Emma Woodfield continues:

"Saturn gave us the opportunity of abundant Z-mode waves, to really test

what these waves can do to the electrons on a large scale. Some people think that planets are just cold chunks of rock travelling through empty space, but the way each planet interacts with the particles in space is complex, unique and exquisite, and studying them can tell us about our own planet and the rare extreme events that occasionally do occur."

Prof Yuri Shprits from GFZ German Research Centre for Geosciences says: "I think it's most critical to understand the extreme radiation environments of the outer planets. These studies provide us with a unique opportunity to evaluate the potential extremes of terrestrial space weather and to understand what space weather conditions may be around planets beyond our Solar system (exoplanets)".

The team concludes that electron acceleration by Z-mode waves is more rapid at energising electrons in Saturn's radiation belt than radial diffusion and both mechanisms will work together to maintain the radiation belt at Saturn.

Formation of electron radiation belts at Saturn by Z-mode wave acceleration by E.E. Woodfield, R.B.Horne, S.A Glauert, J.D. Menietti, Y.Y. Shprits and W.S. Kurth is published in *Nature Communications* here

Van Allen radiation belts

The Van Allen radiation belts were detected by the first US satellite Explorer I, which was launched during the International Geophysical Year of 1957-58. They are composed of energetic charged particles trapped inside the Earth's magnetic field, which surrounds the Earth like a ring doughnut. Energetic electrons in the Earth's Van Allen radiation belts occupy two distinct regions.

- Solar system radiation belts – Jupiter, Saturn, Uranus and Neptune all have strong magnetic fields and radiation belts. It is

thought Mercury may have transient radiation belts.

- Radial diffusion – lots of little nudges which push electrons towards or away from the planet, motion towards the planet results in an increase in electron energy.
- Wave-particle interaction – the way in which energy is transferred to or from a plasma wave to a charged particle (e.g. electron)
- Chorus – Whistler mode chorus waves – a type of plasma wave in a magnetised plasma, these radio waves are converted to sound they sound like the dawn chorus.
- Z-mode waves – a type of plasma wave present in a magnetised plasma, so-called because of the shape seen in observations of this wave from instruments on the ground at Earth – a "Z" shape.

More information: E. E. Woodfield et al. Formation of electron radiation belts at Saturn by Z-mode wave acceleration, *Nature Communications* (2018). DOI: 10.1038/s41467-018-07549-4

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