

Cluster sees tsunamis in space

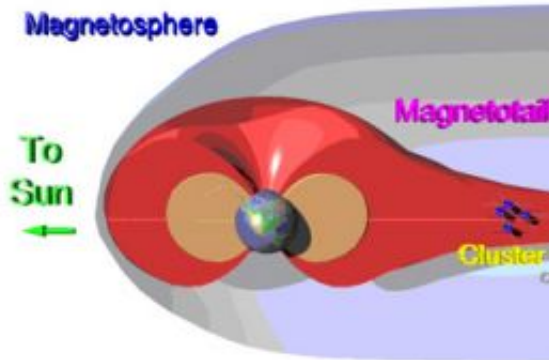
April 12 2007



The image to the left is the typical appearance of the aurora before a magnetic substorm. During a substorm, the single auroral ribbon may split into several ribbons (centre) or even break into clusters that race north and south (right).
Credits: Jan Curtis

Cluster is providing new insights into the working of a ‘space tsunami’ that plays a role in disrupting the calm and beautiful aurora, or northern lights, creating patterns of auroral dances in the sky.

Generally seen in high-latitude regions such as Scandinavia or Canada, aurorae are colourful curtains of light that appear in the sky. Caused by the interaction of high-energy particles brought by the solar wind, with Earth’s magnetic field, they appear in many different shapes.



The solar wind is a continuous flow of particles from the Sun consisting of electrically charged particles in a state known as plasma. The Earth's magnetic field is distorted by the solar wind to a droplet-shaped magnetic bubble called the magnetosphere. On the nightside, the Earth's magnetic field is stretched into a long tail, the magnetotail, much like the tail of a comet. The blue cavity represents the magnetosphere. The red area denotes the region where a large amount of charged particles reside and intense electric currents flow within the magnetosphere. The four Cluster satellites encountered a flow reversal region in the magnetotail. Credits: Tony Lui, JHU/APL, USA

Early in the evening, the aurora often forms a motionless green arc that stretches across the sky in the east-west direction. Colourful dancing auroral forms are the results of disturbances known as 'substorms' taking place in Earth's magnetosphere. These perturbations can affect our daily lives, in particular by affecting the reception of GPS signals. Thus, understanding the physical processes involved is important to our routine life and security.

These substorms typically last one to two hours and are three-dimensional physical phenomena spread over altitudes from 100 to 150 000 kilometres. Trying to understand such complex physical processes with a single scientific spacecraft is like trying to predict the behaviour of a tsunami with a single buoy in an ocean. That is why, the

simultaneous use of several satellites like the Cluster constellation is necessary to understand these events.

Currently, there are two competing theoretical models to describe these substorms or space tsunamis. The first one is called the ‘Current-Disruption’ model, while the second one is the ‘Near Earth Neutral Line Model’. Using data from the four Cluster spacecraft, a group of scientists from both sides of the Atlantic were able to confirm that the behaviour of some substorms is consistent with the Current Disruption model.

A substorm develops and builds up in different stages, and it is the detailed study of one of these stages that helps us to understand which of the two models apply. For example, in the late stage of substorm development, auroral disturbances move towards the poles, suggesting that the energy source for auroras and substorms moves away from Earth.

Previous satellite observations have found that, during this late stage, the flows of plasma (a gas of charged particles populating Earth’s magnetosphere) in the magnetotail exhibit a reversal in direction. In recent years it was generally thought that a flow reversal region is where magnetic reconnection takes place, that is where the energy of the magnetic field is converted into particle energy (dissipation effect), resulting in high-speed plasma flows that hurl towards Earth, like space tsunamis.

Detailed analysis of data obtained by the Cluster satellites while crossing such a region in the magnetotail, where flows of plasma exhibit a reversal in direction, has been reported by the team of Dr Tony Lui, a scientist of the Applied Physics Laboratory at the John Hopkins University, Maryland, USA, Co-Investigator of the Research with Adaptive Particle Imaging Detectors (RAPID) high-energy particles experiment on Cluster, and lead author of the study. Thanks to the

unique capability of Cluster to perform simultaneous multipoint measurements, the scientists were able to derive several physical parameters never before estimated for such a flow reversal region.

By comparing the directions of the electric current and the electric field in the magnetosphere it is possible to understand whether the cause of the flow reversal is a dissipation effect (where magnetic field energy converted to particle energy) or a dynamo effect (where particle energy is converted to magnetic field energy). For this case study, the Cluster scientists observed that features associated with flow reversal are actually very complex, consisting of both dissipation and dynamo effects in localised sites.

This result shows that the plasma turbulence disrupts the local electric current. "The features we observed are consistent with the current disruption model. However, it is unclear how general these findings are. More events will be examined in the future," said Dr Lui.

"The magnetic substorm phenomenon is a hot topic of research," added Philippe Escoubet, Cluster and Double Star project scientist for ESA. "This new Cluster result will certainly contribute to the on-going scientific debate and foster research cooperation with scientists involved in the newly launched NASA Time History of Events and Macroscale Interactions during Substorms (THEMIS), a mission specifically dedicated to studying substorms."

Source: European Space Agency

Citation: Cluster sees tsunamis in space (2007, April 12) retrieved 18 April 2024 from <https://phys.org/news/2007-04-cluster-tsunamis-space.html>

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