How Magnetic Field Lines around Earth Break and Reconnect and can affect your trip to Alaska

Earth’s magnetosphere is an area of space that is controlled by the Earth’s dipole magnetic field. It is filled with plasmas, which are ionized gas consisting of ions and electrons. Its shape is formed due to interaction with solar wind, which is magnetic field and plasma flowing from the sun. Like the weather in the atmosphere, the sun drives a variety of changes in the environment condition of magnetosphere and atmosphere, which we call “space weather”. The impacts of a severe space weather event can be disturbances to satellite navigation or threats on technology on Earth or near-Earth space, but also the spectacular auroras in the high latitude region. While the magnetosphere can mostly shield the magnetic field and plasma flow from accessing close the Earth and thereby protecting the Earth from harmful radiation, a part of the solar wind energy, momentum and mass commonly penetrates inside the magnetosphere due to a process called magnetic reconnection.

Magnetic reconnection occurs in a narrow layer called the diffusion region where plasma particles, otherwise captured by the magnetic field, are decoupled from the magnetic field lines that are "breaking" and then “reconnecting”. It is a process that taps the energy stored in a magnetic field and converts it—typically explosively—into heat and kinetic energy of charged particles. Magnetic reconnection results in large-scale transport of energy, momentum and mass from the solar wind to the magnetosphere and drives eruptive large-scale phenomena such as substorms and storms. In order to understand how magnetic reconnection actually works we need to study both the quick processes inside the small diffusion region and its long-time scale global consequences. The complex processes with varying time and spatial scales has been a challenge for space plasma observations.

Multi-point spacecraft measurements have significantly advanced our understanding of magnetic reconnection. The strength of the multi-point spacecraft measurement is that it can separate spatial and temporal variations. Using a constellation of four spacecraft, ESA’s Cluster mission succeeded to resolve the ion behaviours associated with magnetic reconnection. With a smaller-size onstellation and unprecedented high-time resolution instrumentation, NASA’s MMS mission enabled to detect the fast electron processes. Using radially aligned spacecraft constellation combined with ground-based observations, NASA’s THEMIS mission tackled the problem of large-scale evolution both in the magnetosphere and auroral ionosphere. Yet, the grand challenge still remains. Namely, combination of the observations with different scales of plasmas, which have inherently multi-scales natures, is necessary to understand how the magnetospheric system really works under the various conditions of solar wind driver.

Magnetic reconnection occurs not only at Earth’s magnetosphere but take place in other planets and objects in the solar system and beyond. It drives eruptive solar flares and coronal mass ejections and is therefore also an important driver of space weather. The multi-point spacecraft in Earth’s magnetosphere can be therefore also regarded as a natural plasma observatory unveiling important aspects of universal plasma processes in addition to understanding our own planet’s environment.