THE FREJA SCIENCE MISSION

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Abstract. Freja*, a joint Swedish and German scientific satellite launched on October 6, 1992, is designed to give high temporal/spatial resolution measurements of auroral plasma characteristics. A high telemetry rate (520 kbits s⁻¹) and ≈15 Mbyte distributed on board memories that give on the average 2 Mbits s⁻¹ for one minute enables Freja to resolve meso and micro scale phenomena in the 100 m range for particles and 1–10 m range for electric and magnetic fields. The on-board UV imager resolves auroral structures of kilometer size with a time resolution of one image per 6 s. Novel plasma instruments give Freja the capability to increase the spatial/temporal resolution orders of magnitudes above that achieved on satellites before. The scientific objective of Freja is to study the interaction between the hot magnetospheric plasma with the topside atmosphere/ionosphere. This interaction leads to strong energization of magnetospheric and ionospheric plasma and associated erosion, and loss, of matter from the Terrestrial exosphere. Freja orbits with an altitude of ≈600–1750 km, thus covering the lower part of the auroral acceleration region. This altitude range hosts processes that heat and energize the ionospheric plasma above the auroral zone, leading to the escape of ionospheric plasma and the formation of large density cavities.

1. Introduction

Plasma is the main state of matter in the Universe, the condensed state being limited to rare islands of ‘space debris’ (planets, asteroids, etc.) or to thinly dispersed interstellar/interplanetary gas/dust. Our largest plasma object – the Sun – represents an almost 1000 times higher mass compared to the accumulated mass of condensed matter in our solar system. In addition the Sun provides through its solar wind a plasma environment for all other bodies within the heliosphere. The result of an intrinsic magnetic field of these bodies is that a ‘magnetosphere’ is formed immersed in the plasma flow from the Sun. Our magnetosphere, though controlled by electromagnetic forces from the Sun, is populated to a large degree by plasma of terrestrial origin. In general, plasma systems organized by magnetic fields may result in a strong chemical separation of matter into cellular structures –

* Freja, the goddess of fertility in Nordic mythology, was not a gentle ‘Aphrodite of the north’. She was the empress of Folkvang, the estate of the Nordic Gods, and she stood close to Odin, the almighty. She is a female warrior like Pallas Athena in the Greek mythology. Her power encompassed life and death, love and battle, fertility and black magic. Half of the heroes killed in battle were her toll, sent to her for her amusement.
with very modest flow of matter across the 'cell walls', as noted by Alfvén (1981) in discussions concerning The Plasma Universe.

The Sun represents not only the main source of energy but also a strong source of matter interacting with the planets in our solar system. The solar wind, the loss of matter from the Sun, may correspond to about five Earth masses per billion years. This wind of solar plasma interacts with, e.g., planets and comets in a complicated way that is highly dependent on their intrinsic magnetic properties. An important common consequence of the interaction is, however, the erosion of matter from planets and comets as a result of the energy and momentum transfer from the solar wind. The Earth is more effectively protected from this interaction by a strong intrinsic magnetic field which provides a 'magnetic umbrella' shielding its topside atmosphere. Despite this the Earth is losing matter at a rate of 2–4 kg s\(^{-1}\) (Chappell et al., 1987) as a result of the heating and acceleration of plasma along the auroral oval topside ionosphere. The loss rate may appear high, but it is nevertheless insignificant on cosmogonic time scales. It will for instance take at least 10 billion years to evacuate the present terrestrial atmosphere at that rate. Other planets, such as Venus and Mars may have been less fortunate in retaining a hydrosphere and a 'habitable' atmosphere due to their lack of a strong intrinsic magnetic field. There, the solar wind interacts directly with the entire frontside ionosphere and the momentum transfer and relative atmospheric loss rate becomes correspondingly larger.

The Sun–Earth relationship is complex involving direct electromagnetic forcing from radiation as well as indirect electromagnetic forcing from the solar wind plasma interacting with the terrestrial magnetic field. Because the solar radiation input is 4 to 5 orders of magnitude higher than the solar wind energy input, one would expect solar radiation to dominate the dynamics of the topside ionosphere. However, contemporary space research has demonstrated that the solar wind forcing may become more important than solar radiation for the redistribution and loss of ionospheric plasma.

There is a strong coupling between the ionization of the upper atmosphere by solar UV and EUV and the electromagnetic forcing induced by solar wind plasma interacting with the Earth’s magnetic field. An increased conductivity in the upper atmosphere due to ionization means that electromagnetic energy more easily dissipates there and a complex chain of transport, dissipation, and loss can be set up as a consequence of the magnetosphere-ionosphere coupling. In fact, dissipation of solar wind electromagnetic energy to the topside atmosphere and ionosphere of the Earth requires a finite electrical conductivity, the solar wind electromagnetic energy being dumped to the ionosphere as waves/electric fields (providing Joule heating) or via charged particle precipitation. The former (Joule heating) can be described by a current circuit analogy where the field-aligned/Birkeland currents connect the ionospheric load to the solar wind dynamo. Although Birkeland currents and their connection to the solar wind dynamo were extensively studied during the seventies and eighties (e.g., Ijima and Potemra, 1976) our knowledge of the properties of the