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A modelling study of the impact of different magnetic field configurations on the trapped particle populations in planetary ring currents

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Abstract

The purpose of this presentation is to study the impact of the magnetic field configurations on the behaviour of the charged particles. The gradient of the magnetic field and the curvature of the field lines influence the movement of the charged particles and are responsible of a drift velocity perpendicular to the magnetic field lines. This velocity can be in opposite direction than the corotation velocity, depending on the charge of the particles. As its intensity depends on the energy of the particle, electrons or ions from a given energy $\boldsymbol{\varepsilon}_{\mathbf{limit}}$ can rotate in the opposite direction than the planet. The calculation of this energy will be used here in order to study the impact of the planetary parameters (mass, size, rotational period, tilt and magnetic moment) on the charged particles movement in ring current regions.

1. Introduction

Due to the gradient and the curvature of the field lines, the dipolar magnetic field influences the movement of the charged particles trajectories [1]. Gradient and curvature are responsible of the existence of drift velocities perpendicular to the magnetic field lines. Above a limit energy, the total drift velocity will be higher than the corotation velocity and the electrons and the ions rotate in opposite directions. This phenomenon has been observed in the terrestrial, jovian and kronian magnetospheres and is important in ring current and magnetodisc regions. We present first a model which allows the calculation of the limit energy (ε_{limit}) from which the perpendicular to the magnetic field ions and electrons rotate in opposite directions. The model has then been used to study the impact on the trapped particle populations, and in particular on ε_{limit}, of the magnetic field configuration. Several magnetic field configurations are presented, as the Earth and Saturn ones.

2. Model

2.1 The velocities

The purpose of the model is to determine ε_{limit}, the energy from which the 90° pitch-angle charged particles (located at their mirror point) contribute to the ring current generation. This energy gives the limit from which the electrons and the protons rotate in opposite directions, and, ε_{limit} can be defined as the energy for which the transport velocity of the particle is equal to zero. In a guiding centre approximation, the trajectory of a particle with a charge q located at a planetary distance R of a magnetised planet rotating at a period T is strongly related to the resulting drift pattern coming from the corotation velocity, the drift from the forces exercised on the particles, the drift from the magnetic field gradient and the drift from the curvature of the magnetic field lines [2, 3]. The model developed for this study calculates those velocities accounting the particles mass and charge and the magnetic field model.

2.2 The magnetic fields

Two models have been used to describe the magnetic field for this presentation. The first one is a dipole. This first model has been used to describe the particles behaviour in the terrestrial magnetosphere, but also to study the impact of the planetary parameters (mass, size, rotational period, tilt and magnetic moment). The second model used here is a Connerney model [4], [5], [6]. This model has been chosen in order to model the kronian magnetic field and to study the impact of the elongation of the field lines. We have to notice here that other models can easily be added and that's the purpose of a future work.

3. Results

The first part of the study consists of a comparison between the velocities calculated by the model. It shows that the mass of the planet and of the studied charged particles doesn't impact the behaviour of the particles in the ring current region. The second part of the study consists of the calculation of ε_{limit} for different magnetic fields. In order to understand the impact of the magnetic moment, the rotational period and the planetary radius, we start with the terrestrial non tilted dipolar magnetic field and we change the parameters one after each other to obtain the kronian dipolar magnetic field. This study shows that all the parameters have a significant impact, but that the magnetic moment has the higher one. The last part of the study consists of the comparison between the terrestrial magnetic field and the kronian one in order to determine the impact of the tilt of the dipole and of the elongation of the field lines. This shows that the tilt doesn't change the value of ε_{limit}, but is responsible of a lost of the symmetry in the repartition of ε_{limit}, when the elongation of the field line is responsible of an increasing of ε_{limit}.

6. Summary and Conclusions

The model developed here accounts for the basic parameters which are the tilt of the dipole and the stretch of the field lines. It allows us to determine the impact of the planetary parameters on the behaviour of the charged 90°pitch angle particles. It needs now some more development in order to account also for other effects observed in the planetary magnetospheres. It will be necessary to account for the shift of the centre of the dipole which exists for all the magnetised planets (Earth, Jupiter, Saturn, Uranus and Neptune), and in particular for Uranus and Neptune. It will also be necessary to account for the convection electric field, in particular for the study of the terrestrial magnetosphere, or for the wrapping of the tail for example in the kronian case. A last important effect to account for, in particular in the case of the Saturn and Jupiter magnetospheres, is the sub corotation velocity. This work is actually in progress and a comparison between different magnetospheres will be the purpose of a future paper.

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