DD2730 Project Abstract
Project 6: Simulating Charged Particle Trajectories in Earth's Magnetosphere with Python to study Van Allen belts

João Pedro Ferreira Biu

27 of November of 2024

1 Introduction

The Van Allen radiation belts are a region of charged particles trapped in the magnetosphere due to Earth's magnetic field. These energetic particles come mainly from solar winds and cosmic rays and are usually electrons and protons. This phenomenon of capturing charged particles shields our planet from solar winds. The dynamics of charged particles in Van Allen belts are studied for many reasons, such as to improve our understanding of space weather and how to predict it. Additionally, this research is critical in the design and protection of satellites, as the radiation within the belts can damage electronic components.

2 Project Goals

The goal of this project is to develop a computational simulation to model the dynamics of charged particles trapped in Van Allen belts and study their dynamics, with a focus on electrons. Using this simulation, we aim to study how the variation of parameters such as the pitch angle, particle energy, and fluctuations of the magnetic field affect the trajectories of particles and their confinement and drift motions. Additionally, other aspects of the simulations can be explored, such as the dynamics of other particles (e.g. protons and alpha particles), the stability of the numerical simulations for the full Lorentz force model, or the guiding center approximation, and the performance of different methods for solving the system of equations.

3 Methods

To implement the computational simulations we will use Python, namely the NumPy and SciPy libraries to implement the numerical schemes needed. The simulation will model Earth's magnetic field using the dipole approximation, and solve the equations of motion for particles (full Lorentz model and Guiding Center equations of motion) using numerical integration algorithms such as Runge-Kutta, Verlet, and Leapfrog. The visualization of the simulations will be done using mainly the libraries Matplotlib and Plotly, for interactive visualization.

4 Project Organization

In terms of grading, this project will be developed with the goal of obtaining the maximum grade possible - A. In order to do this, the planning will be (the dates refer to when the objective is expected to be achieved):

1. Implement the main part of the code such as the simulations required to obtain the trajectories of particles in Earth's magnetic field - 6/12/2024
2. Implement the result analysis part of the code such as methods to study the confinement, particle drift, etc. - 13/12/2024
3. Final Results - 19/12/2024
4. First draft of the report - 27/12/2024
5. Presentation - 7/01/2025
6. Final Report - 13/01/2025