CISM Center For Integrated Space Weather Modeling

Summer School Lab Activities

Lab #7: Particle Drift Paths in the Magnetosphere

These lab activities are intended to explore the properties of high-energy particles that make up the radiation belt.

Goals:

- categorize motions of charged particles in the Earth's magnetic field
- observe the time scales on which those motions occur
- observe how electric fields can affect the motion of a charged particle in a magnetic field
- observe how particles are lost from the radiation belts into the atmosphere
- observe how the dynamics of the magnetosphere affect the motion and population of high energy particles

Activity 1: 3-D motion in a dipole field

In this activity you will explore the various types of motions that a charged particle undergoes in a simple dipole magnetic field such as the one near the earth. You will be able to control the speed and the pitch angle of the particle to explore how these affect the motion.

Getting Started:

Open a terminal window and change to the lab 7 directory (cd swss-labs/lab7). For this activity we will use an interpreted programming language called V-Python . The "V" in this case is for visual because V-Python allows for easy 3-D visualizations.

- Start V-Python by typing "idle" at the Unix prompt. An "IDLE" window should appear.
- In the IDLE window, choose the "Open" from the "File" menu (IDLE: File -> Open). A file browser should open.
- There should be one file available called "Part_Motion.py". Choose this file and hit "OK". A second window should open with computer code in it.
- In this new window choose the "Run Module" option from the "Run" menu. (Run -> Run Module). Two windows should appear: one with a dipole field surrounding a sphere and the other with some controls in it. In the image window, you can rotate the image by holding down the right mouse button and moving the mouse around.

The image window shows a sphere that represents the Earth, surrounded by field lines at L-values 3, 5, and 7. As you rotate the image you should see a small green ball which represents a positively charged test particle. The particle is located in the equatorial plane where the dipole magnetic field is purely in the Z direction. In the control panel there is an "On" switch. Click it and watch the particle run for a while.

- ***Identify three types of motions, with three very different time scales, that the particle undergoes. Give each motion a name.***
- ***Can you explain each of these motions?***

Now look at the "Control" window. There are three sliders:

- The "Energy" slider adjusts the energy of the particle from 10 to 200 MeV.
- The "Pitch Angle" slider varies the pitch angle from zero to 90 degrees
- The "L-value" changes the starting position of the particle from 2 to 7 Earth radii.

To explore how these affect the simulation results:
- stop the simulation by click "Off"
- adjust these parameters and hit the "Set" button.
- then hit the "On" button to run the simulation.

Answer the following questions:
- ***How do the frequencies of the three different motions change with the speed and the pitch angle?***
- ***Make a table for your self to record the results of your experiments.***
- ***Is there a limit to the energy of the particles trapped in at a particular L-value? What happens to that energy for increasing L-Value? Make a table of the L-value and escape energies.***

Activity 2: Mini-Golf in the Magnetosphere

The previous activity showed a particle moving in a simple dipole magnetic field. The Earth's field is not a pure dipole and so the motion of particles in it is a little more complex. It is even more complicated because electric fields are often generated by the dynamics of the magnetosphere which will also effect the charged particles. To explore these motions, we will use an online activity called Magneto-Mini Golf [http://www.spaceweathercenter.org/our_protective_shield/01/minigolf.html]. This activity was developed as part of an outreach project, the Space Weather Center [http://www.spaceweathercenter.org], designed for a general audience, but there are some sophisticated cases to study late in the activity.

There are 9 holes in the Mini Golf activity plus a bonus hole and a check out quiz at the end. Work on each hole and the questions at the end with your group. As a group:

- ***Record your scores on each hole.***
- ***Record your answer to each quiz question.***

For class discussion:

- ***Which hole did you group have the most trouble with?***
- ***Which hole did you group need the most discussion about?***
- ***Which quiz question did you group need the most discussion about?***

Activity 3: Simulations of Particle Motions in a Dynamic Magnetosphere

In this activity you will view two movies made from research simulations results. These simulations use results from magnetosphere simulations to provide time varying input for electric and magnetic fields for the particle motion simulation.

- ***Why can the magnetosphere simulation results be used to move high-energy particles around without accounting for the fields generated by the high-energy particle motions?***

The first movie shows Solar Energetic Particles (SEP's) entering the magnetosphere as a CME shock impacts the magnetosphere. This movie was compiled by Brian Kress and is based on results published in

> Kress, B.T., M.K. Hudson, and P.L. Slocum, "Impulsive solar energetic ion trapping in the magnetosphere during geomagnetic storms", *Geophys. Res. Lett.*, 32, L06108, doi:10.1029/2005GL022373, 2005

Based on viewing this movie:

- ***When do SEP's have access to the magnetosphere? Which SEP's do not have access?***
- ***Once they have entered the magnetosphere, what do they do?***

The second video is was created by Scott Elkington.

> Elkington, S., Wiltberger, M., Chan A. A., Baker, D. N., "Physical models of the geospace radiation environment", Journal of Atmospheric and Solar-Terrestrial Physics 66 (2004) 1371–1387

This move shows electrons injected into the simulation in the magneto-tail at the edge of the simulation with very low energy. Again, a CME impacts the magnetosphere compressing it.

Based on this movie:

- ***When do these particles gain access to the inner-magnetosphere?***
- ***What happens to their energy as the travel in from the tail?***
- ***Once they enter, are they trapped there?***
- ***When do they no longer have access to the inner-magnetosphere?***