Thesis Title	The Effect of The Pitch Angles of Charged Particles on their Separation From Magnetic Field Lines
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ABSTRACT

When the charged particles are moving in a magnetic field, the charged particles follow the right hand rule due to Newton-Lorentz force. The pitch angle is defined as the angle between the particle velocity and the magnetic field. In a uniform magnetic field, the charged particles released at a 90 degree pitch angle move around the magnetic field line in a circular orbit, while the charged particles released with a pitch angle less or more than 90 degrees have helical orbits around the magnetic field. Magnetic fields are found not only on the earth, but also in interplanetary space. The interplanetary magnetic field is turbulent and always comes out from the Sun. In this work, we are interested to study the transport of charged particles in a turbulent magnetic field as in the interplanetary space by using computer simulations. We use a 2D+slab model for the magnetic field. We compare two cases which are a simple 2D field+slab turbulence case and a case where both 2D and slab components are turbulent. Then we release the charged particles by varying the pitch angle for study of the separation of charged particles and magnetic field lines. We solve the Newton-Lorentz and field line equations to find trajectories of charged particles and magnetic field lines by using the Runge-Kutta method with adaptive

time stepping regulated by a fifth-order error estimate. We analyze the positions of guiding centers of the charged particle trajectories and compare them with the magnetic field lines that are released from the initial guiding centers of the charged particles at various times. We present the effect of initial pitch angle on the separation between guiding centers and magnetic field lines when we set the initial pitch angle to 0, 30, 60 and 90 degrees. From overall results, we found that the initial pitch angle has an effect on the separation of the charged particles and their corresponding magnetic field lines. For the simple case, the separations of the charged particles are related to distance from the center of the Gaussian flux tube and intensity of 2D Gaussian field. For the 2D+slab turbulent field, we can find that the separation of the charged particles is different at each initial pitch angle and the critical initial pitch angle that gives the most separation at any time is also computed. Moreover, we found that in an intermediate range the particles released at a 90 degree pitch angle have more separation than the others. In the long time limit, all initial pitch angles give similar results for the separation. This work is useful to help us understand the mechanisms of the transport of the solar energetic particles in heliosphere and developing the theory of diffusion of charged particles in turbulent magnetic fields.

Keywords: Charge particles/Magnetic field/Pitch angle/Turbulence/
Newton-Lorentz force/Guiding center