Test-particle simulation of electron pitch angle scattering due to H_2O originating from Enceladus

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1 Introduction

Cassini observations revealed that Saturn's moon Enceladus (3.95 Rs) ejects neutral H_2O from its southern pole with temporal variability [e.g., Hansen et al., 2006]. The observations of injected electrons and ions in the inner magnetosphere suggested that these particles do not survive very long time due to the neutral cloud originated from Enceladus [e.g., Paranicas et al., 2007; 2008]. The volcanic activity of Enceladus, so-called 'plumes', leads to the electromagnetic coupling between Saturn's ionosphere and plasma around Enceladus. The coupling causes auroral activities around the footprint of Enceladus [Pryor et al., 2011]. They discovered Enceladus footprint aurora with temporal variability and reported that observed field aligned fluxes of electrons and ions are sufficient to brighten the footprint aurora observed by EUV onboard Cassini. They also interpreted that the variability of auroral brightness reflects the variations of plume activities. In contrast, electron precipitations into the atmosphere through pitch-angle scattering also cause auroral emissions. The dominant physical process controlling the activity of the footprint aurora is still controversial.

Thus, the previous study suggested that the neutral cloud is one of the important loss processes of plasma in the inner magnetosphere. However, a quantitative study of collisions between electron and neutral has not been examined. In the present study, we focus on the process of electron pitch angle scattering due to H_2O. This study aims at revealing the quantitative evaluation of Enceladus footprint auroral emissions caused by pitch angle scattering through elastic collisions between magnetospheric electrons and neutral H_2O. In this paper, conducting a spatially one dimensional test-particle simulation code with monoenergetic electron along a dipole magnetic field at Enceladus, we show a preliminary result of equatorial pitch angle distribution of electrons and electrons within loss cone angle due to the collisions between electron and neutral H_2O.

2 Simulation model

We use one dimensional test-particle simulation with electrons at 700 eV along a dipole magnetic field at Enceladus. The number of electron used in this simulation is 100,000. We assume that the boundary condition is in the magnetic latitude range of 0 – 9 degrees. Trajectories of electrons are computed by considering under a dipole magnetic field.

$$m\,dv/dt = q(\vec{E} + v \times \vec{B}),$$

where B is the magnetic field. We assume that the electric field (E) is zero.
We assume that the initial velocity distribution of the electrons at the magnetic equator forms a velocity distribution with a loss-cone (7 degrees) [e.g., *Ashour-Abdalla and Kennel,* 1978].

$$A = T_{\perp}/T_{\parallel} - 1,$$

$$f(v_{\parallel}, v_{\perp}) = Cexp\left(-v_{\parallel}^2/2V_{th,\parallel}^2\right)g(v_{\perp}),$$

$$g(v_{\perp}) = \{1/(1-\beta)\}\left\{exp\left(-v_{\perp}^2/2V_{th,\perp}^2\right) - exp\left(-v_{\perp}^2/2\beta V_{th,\perp}^2\right)\right\},$$

where V_{th} is the thermal velocity, C (=1) is the constant, and loss cone parameter β is 0.5 in this study. We assume that the anisotropy index A and electron temperature are 1.0 (pancake distribution) and 300 eV in this study.

The interaction between an electron and a background neutral H_2O is solved by the Monte-Carlo method. Figure 1 shows the flow chart of this simulation. We use the total cross section of elastic collision for H_2O under Born-dipole approximation [Khakoo et al., 2008] for decision whether an electron collides with H_2O or not. If the electron collides with H_2O, we use the differential cross sections [Khakoo et al., 2008] for a calculation of scattering angle. The collision frequency is proportional to neutral H_2O density. As shown in Figure 2, we model the H_2O density profile, n, as following equation

$$n = n_{max}/(1 + x)^{1.5},$$

where n_{max} is the peak of H_2O density at Encelaus, x is the radial distance from Enceladus. We assume that the n_{max} is 10^8 cm^3. This profile is almost consistent with the Figure 6 in Smith et al. [2010]. We assume that the scale height of H_2O is 0.15 Rs [Johnson et al., 2006].

3 Result

Figures 3 and 4 show the time variation of electron pitch angle distribution around the magnetic equator. It is found that the pitch angle distribution changes from the pancake distribution at the initial distribution to the isotropic distribution. Figure 5 indicates the variations of the loss rate of electron into the loss cone. The electrons of 1, 10, 50 % are lost in 100 sec., 10 min., and 1 hour.

4 Summary and Future Works

Conducting one dimensional test-particle simulation code along a dipole magnetic field at Enceladus (~3.95 Rs), we have examined the time variations of equatorial pitch angle distribution and electrons within loss cone (7 deg.) through electron (700 eV) pitch angle scattering due to electron-H_2O elastic collisions. It is found that the electrons of 1, 10, 50 % are lost in 100 sec., 10 min., and 1 hour. Our future works are as follows:

1. To estimate auroral emission brightness, we will conduct the calculation of electron with other energy (e.g., 500 eV, 1keV, 5keV, and 10 keV)
2. To examine variation of pitch angle, we will conduct the calculation under isotropic distribution at the initial state.

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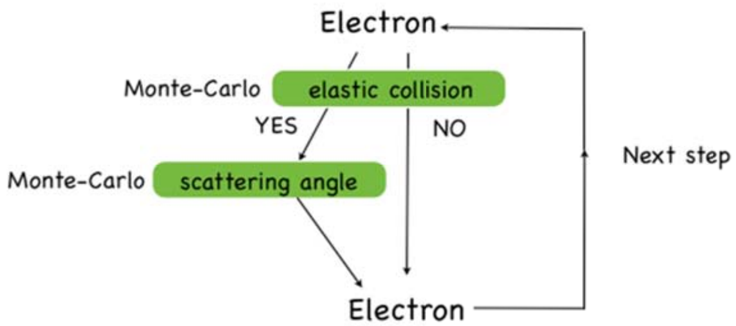

Figure 1. A flow chart of test particle simulation in this study.

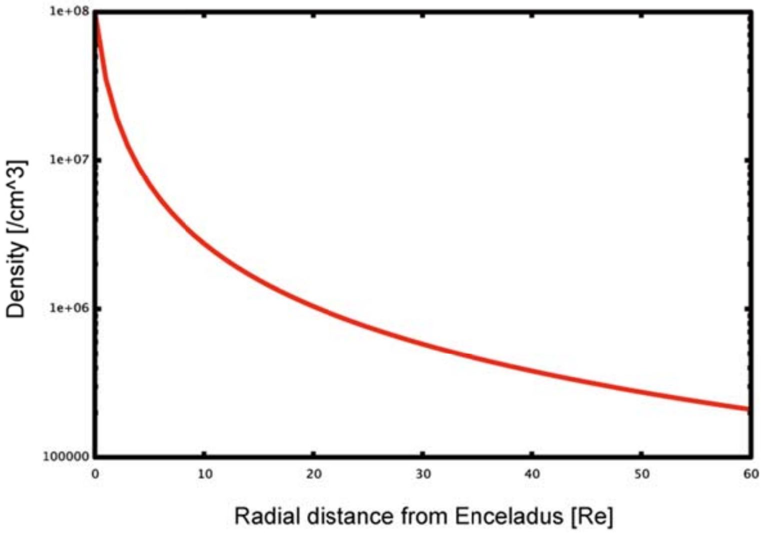

Figure 2. The neutral H_2O density profile as a function of radial distance from Enceladus

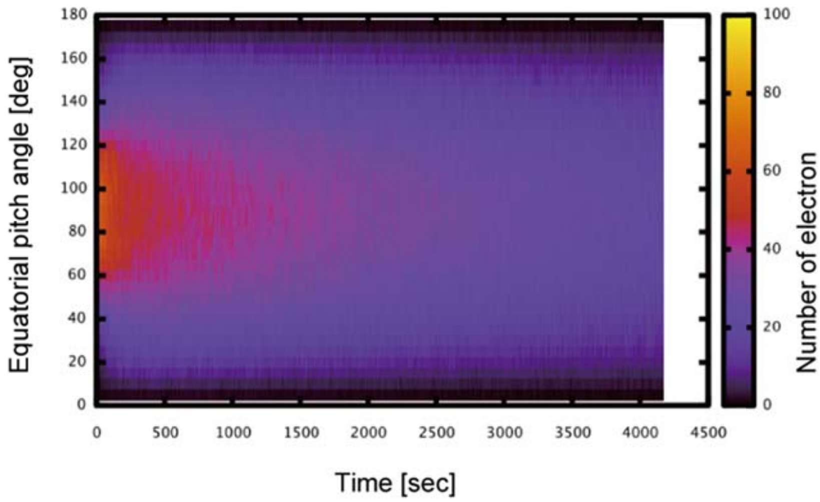

Figure 3. The equatorial pitch angle distribution of electron at 700 eV as a function of time.

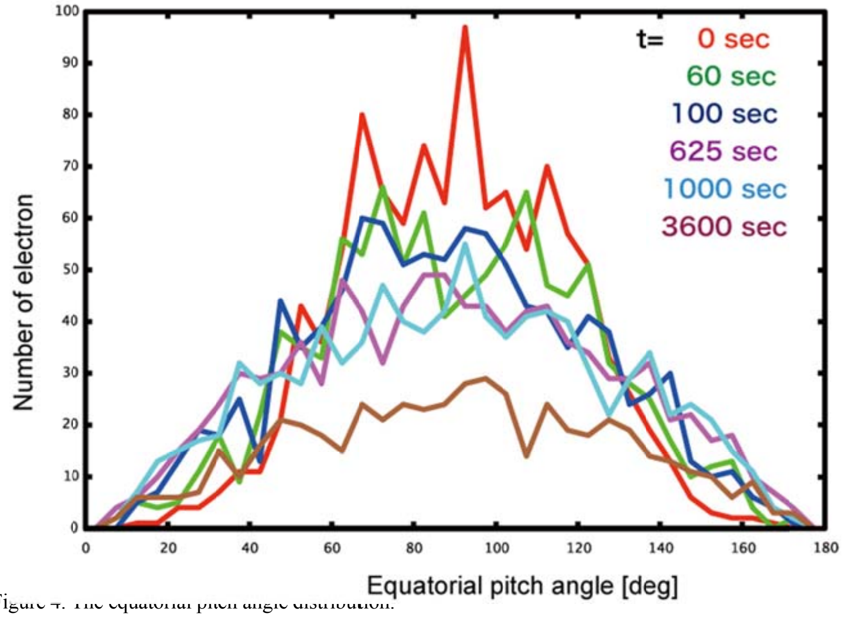

Figure 4. The equatorial pitch angle distribution.

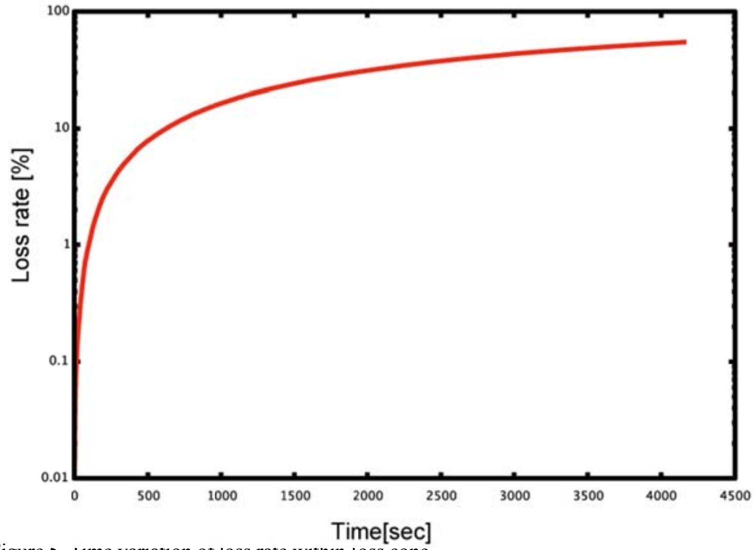

Figure 5. Time variation of loss rate within loss cone.