

Test-particle simulation of elastic scattering of energetic electrons by neutral H₂O originating from Enceladus

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1 Introduction

Cassini observations revealed that Saturn's moon Enceladus (3.95 Rs) ejects neutral H₂O, so-called 'plumes', 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]. These neutrals in the inner magnetosphere play the dominant role in a loss process of energetic electrons and ions [e.g., Paranicas et al., 2007; Sittler et al., 2008]. However, little has been reported on a quantitative study of the electron loss process due to electron-neutral collisions. Especially, a quantitative study of variation of an electron pitch angle distribution due to electron-neutral elastic collisions has not been clarified. This study aims at revealing the variation of energetic electron pitch angle distribution and the loss rate of electrons into the loss cone through pitch angle scattering due to electron elastic collisions with the neutral H₂O molecules along Saturn's magnetic field line around Enceladus when the electron flux tube passes the region of the dense H₂O molecules in the vicinity of Enceladus (~6.4 minutes).

2 Simulation model

We focus on 1 keV as a typical kinetic energy of the electrons in the present study. We conduct one dimensional test-particle simulation for monoenergetic electron along Saturn's dipole magnetic field line around Enceladus ($L=3.95$). The number of electron used in this simulation is 500,000. We assume that the boundary condition is in the magnetic latitude range of -10 – 10 degrees and the loss cone angle at the equator is 7.3 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 in this study. To examine the variation of pitch angle distribution we assume that the initial pitch angle distribution is isotropic distribution.

With regard to the elastic collision process, if the collision occurs, then we conduct a calculation of scattering angle based on the differential cross sections. The collision is solved by the Monte-Carlo method. The collisional frequency, f_{col} , between an electron and H₂O molecule can be given by

$$f_{col} = n\sigma v, \quad (2)$$

where n is the neutral H₂O density, σ is the cross section, and v is the relative velocity between an electron and neutral H₂O. We assume that the relative velocity is the electron velocity since the electron velocity is much greater than the neutral H₂O velocity. The total and differential cross sections for elastic collisions based on the experimental data are given by *Katase et al.* [1986]. We use the total cross section (5.48×10^{-17} cm²) and the differential cross sections in the scattering angle range from 0 – 180 degrees. We assume that the probability of the collision happening, P , is given by

$$P = n\sigma_{tot}v\Delta t$$

where the Δt is the time step in this simulation and σ_{tot} is the total cross section.

We assume that the neutral H₂O density is set to background parameter. As shown in Figure 1, we model the H₂O density profile, n , as following equation

$$n = n_{max}(1 + x)^\alpha,$$

where n_{max} is the peak of H₂O density at Enceladus, x is the radial distance from Enceladus, and α is the parameter. We assume that n_{max} and α are 2×10^8 (7×10^5) cm³ and 1.8 (0.7) in the southern hemisphere (northern hemisphere) of Saturn.

3 Result

Figures 2 shows the time variation of equatorial electron pitch angle distribution at 1keV through pitch angle scattering due to elastic collisions with the H₂O molecules. It is found that the normalized electron pitch angle distribution near the loss cone (<20 degrees and >160 degrees) decreases with time. In contrast, the pitch angle distribution in the range from 20 – 160 degrees does not show significant variation. Figure 3 shows the time variations of the loss rate of electron into the loss cone. The red line in Figure 3 indicates the amount of electrons into the loss cone, N_{lc} , to the total number of equatorial electrons at the initial condition, N_{0eq} . The electrons of ~19% to N_{0eq} are lost in ~380 seconds. The blue line indicates the percentage of small equatorial pitch angle electrons (<20 and >160 degrees) at the initial condition into the loss cone, N_{slc} , to N_{lc} . It is found that the percentage of the electrons decreases with time.

4 Summary

Conducting one dimensional test-particle simulation code along a dipole magnetic field at Enceladus (~3.95 Rs) when the electron flux tube passes the region of the dense H₂O molecules in the vicinity of Enceladus (~6.4 minutes), we have

examined the time variations of equatorial pitch angle distribution and electrons within loss cone (7.3 degrees) through electron (1 keV) pitch angle scattering due to electron-H₂O elastic collisions. The result showed that the electrons of 19 % are lost in ~380 sec.

References

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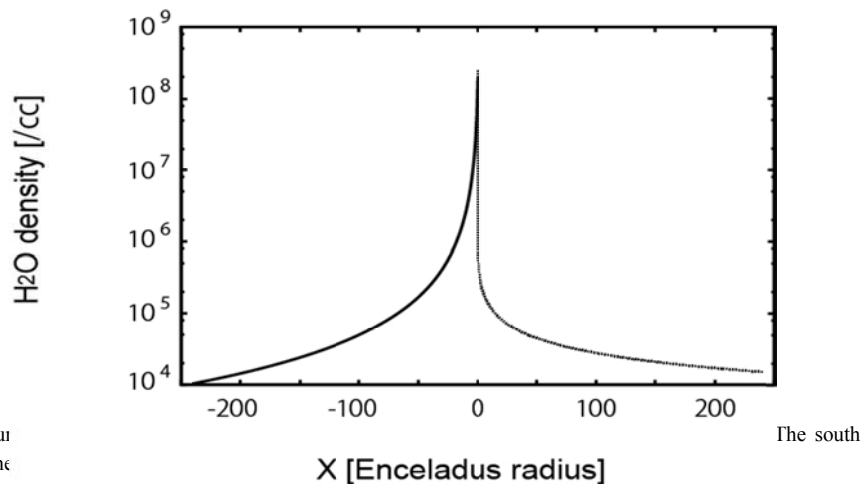


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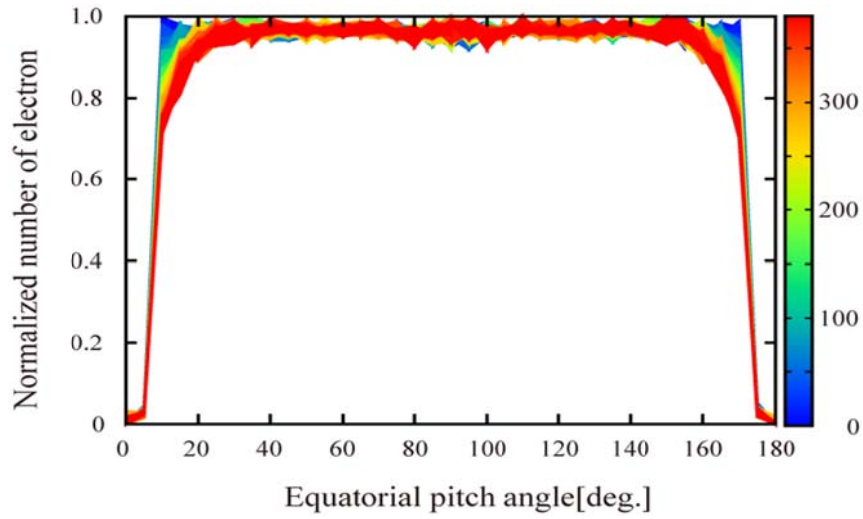


Figure 2. Time variation of the equatorial pitch angle distribution of electron at 1 keV.

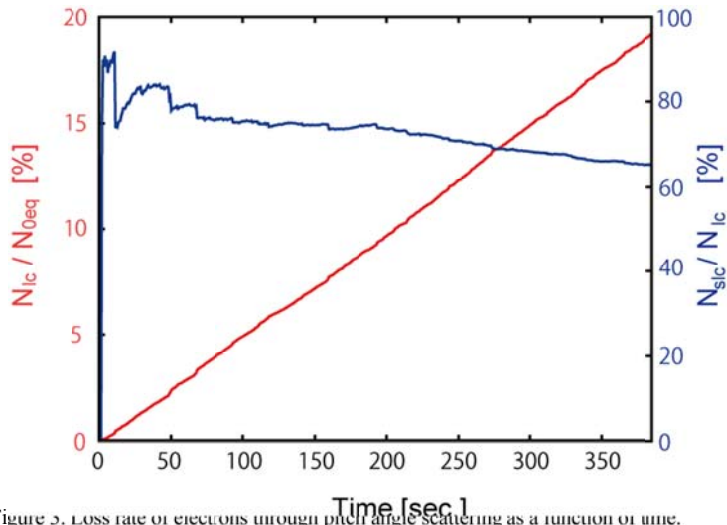


Figure 3. Loss rate of electrons through pitch angle scattering as a function of time.