Electron elastic collisions with water molecule around Enceladus torus

Hiroyasu Tadokoro[1] and Yuto Katoh[2]
[1] *Musashino University, Tokyo, Japan*
E-mail: hirotado@musashino-u.ac.jp
[2] *Tohoku University, Miyagi, Japan*

1 Introduction

Saturn's inner magnetosphere is dominated by water group neutrals (H_2O, OH, and O) originated from H_2O plume in the south pole of Enceladus (~3.95 Rs). Water group neutrals in the inner magnetosphere play the dominant role in loss of plasmas. The observations of energetic electrons and ions in Saturn's inner magnetosphere suggest that these plasmas do not survive very long time due to the neutral cloud [e.g., Paranicas et al., 2007; 2008, *Sittler et al.,* 2008]. Thus, the previous studies suggested that the neutrals contribute to loss processes of plasma in the inner magnetosphere. However, little has been reported on a quantitative study of the electron loss process due to electron-neutral collisions. Conducting one dimensional test-particle simulation, *Tadokoro et al.* [2014] examined the time variations of equatorial pitch angle distribution and electrons within loss cone through 1 keV electron pitch angle scattering due to electron-H_2O elastic collisions around Enceladus when the electron flux tube passes the region of the dense H_2O molecules in the vicinity of Enceladus (~380 sec). The result showed that the electrons of 11.4 % are lost in ~380 sec. The time corresponds to the time scale of the co-rotation of the flux tube passing through the region of the dense H_2O in the vicinity of Enceladus. Assuming the uniform azimuth H_2O density structure in the Enceladus torus, they estimated the electron loss rate of 33% during one co-rotation. Next remaining issue is the survey of energy dependent electron loss rate. We examine the loss rates of electrons with 500 eV – 50keV due to elastic collisions.

2 Simulation model

Following the method of *Tadokoro et al*. [2014], we conduct one dimensional test-particle simulation for monoenergetic electron along Saturn's dipole magnetic field line around Enceladus (*L*=3.95). A trajectory trace is terminated when a pitch angel of each article at the boundary is smaller than the loss cone angle. We assume that the electrons precipitate into the atmosphere since the collisional frequency at the boundary is smaller than the bounce frequency. Trajectories of the electrons are computed by considering under a dipole magnetic field.

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

where B is the magnetic field. We assume that the electric field (E) is zero in this study. In this study, we consider only elastic collisions and focus on the variation of electron pitch angle distribution. To examine the variation of pitch angle distribution we assume that the initial pitch angle distribution is isotropic distribution. The number of electrons used in this simulation is 500,000. We calculate by each monoenergetic electron (500 eV, 700 eV, 1 keV, 5 keV, 10 keV, 20 keV, 30 keV, 40 keV, 50 keV). We make a calculation of 10 times each monoenergetic electron.

The collision is solved by the Monte-Carlo method. The collisional frequency, f_{col}, between an electron and H_2O molecule can be given by

$$f_{col} = n\sigma v,$$

where n is the neutral H_2O density, σ is the total cross section, and v is the relative velocity between an electron and neutral H_2O. The total cross section depends on electron energy. If the elastic collision occurs, then we conduct a calculation of scattering angle based on the differential cross sections. The total and differential cross sections for elastic collisions based on the experimental data are given by *Katase et. al.* [1986].

3 Result and Summary

Figure 1 shows the calculated electron loss rate in ~380 sec as a function of electron energy in the range from 500 eV to 50 keV. The line shows the electron loss rate due to elastic collision with high H_2O density in the vicinity of Enceladus. The error bars are obtained from error by calculation of 10 times. The loss rate decreases with electron energy.

Figure 2 shows the energy input into the atmosphere. The energy input is derived from the result in Figure 1 and the observed electron flux in the magnetosphere [Cravens et al., 2011]. It can be seen that keV electrons contribute to the energy input into the atmosphere.

We need to derive auroral brightness as our future plan.

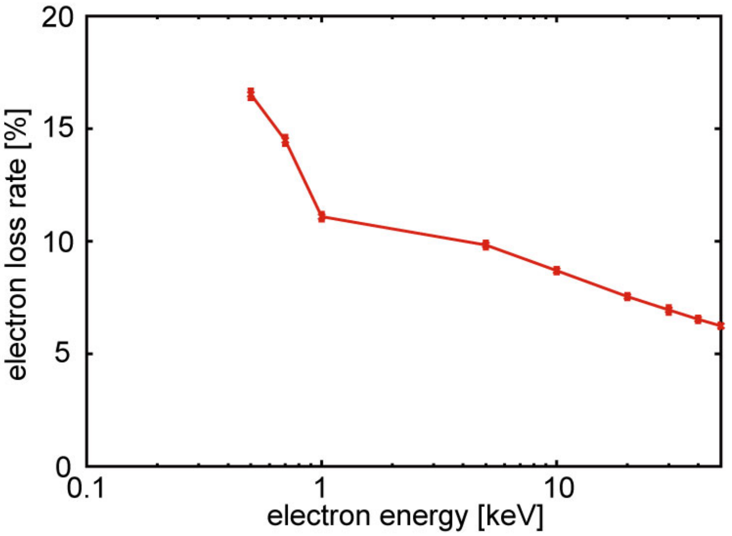

Figure 1. Electron loss rate from the magnetosphere to the atmosphere as a function of electron energy.

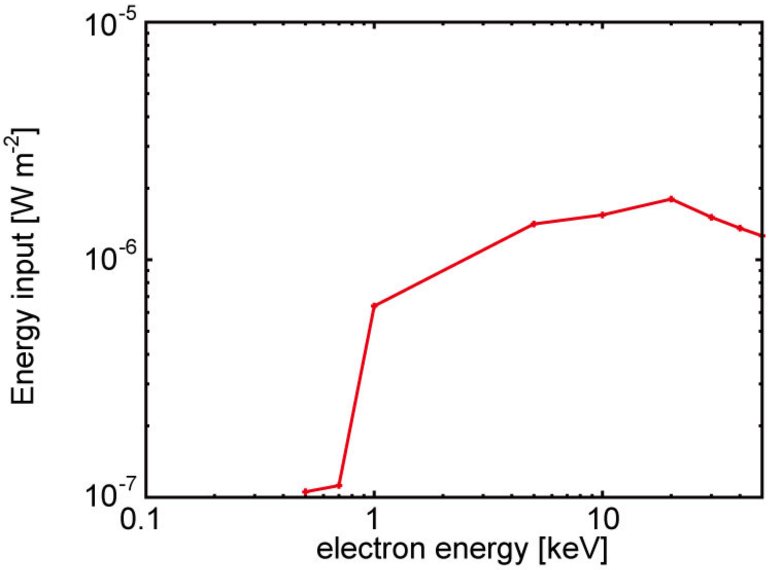

Figure 2. Energy input into the atmosphere as a function of electron energy.

References

・Cravens, T. E., N. Ozak, M. S. Richard, M. E. Campbell, I. P. Robertson, M. Perry, and A. M. Rymer (2011), Electron energetics in the Enceladus
torus, J. Geophys. Res., 116, A09205, doi:10.1029/2011JA016498.

・Katase, A., K. Ishibashi, Y. Matsumoto, T. Sakae, S. Maezono, E. Murakami, K. Watanabe, and H. Maki, Elastic scattering of electrons by water molecules over the range 100-1000 eV (1986), *J. Phys. B: At. Mol. Phys.*, 19, 2,715–2,734.

・Paranicas, C., D. G. Mitchell, E. C. Roelof, B. H. Mauk, S. M. Krimigis, P. C. Brandt, M. Kusterer, F. S. Turner, J. Vandegriff, and N. Krupp, Enegetic electrons injected into Saturn's neutral gas cloud, *Geophys. Res. Lett.,* 34, L02109, doi:10.1029/2006GL028676, 2007.

・Paranicas, C., D. G. Mitchell, S. M. Krimigis, D. C. Hamilton, E. Roussos, N. Krupp, G. H. Jones, R. E. Johnson, J. F. Cooper, and T. P. Armstrong (2008), Sources and losses of energetic protons in Saturn's magnetosphere, *Icarus*, 197, 519-525.

・Sittler Jr., E. C., N. André, M. Blanc, M. Burger, R. E. Johnson, A. Coates, A. Rymer, D. Reisenfeld, M. F. Thomsen, A. Persoon, M. Dougherrty, H. T. Smith, R. A. Baragiola, R. E. Hartle, D. Choray, M. D. Shappirio, D. Simpson, D. J. McComas, and D. T. Young (2008), Ion and neutral sources and sinks within Saturn's inner magnetosphere: Cassini results, *Planet. Space Sci.*, 56, 3–18.

・Tadokoro, H., and Y. Katoh (2014), Test-particle simulation of energetic electron-H_2O elastic collision along Saturn's magnetic field line around Enceladus, *J. Geophys. Res.*, 119, doi:10.1002/2014JA019855.