# Test particle simulation of keV electron elastic collisions with water molecules around Enceladus: reconsideration of elastic collision model

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## 1 Introduction

Saturn' inner magnetosphere is characterized by a high density of water group neutrals ($H_2O$, OH, and O) emanating from Enceladus (~3.95 Rs). Observations strongly suggests that these neutrals play a key role in the depletion of plasmas [e.g., Paranicas et al., 2007; 2008, *Sittler et al.,* 2008]. Little has been reported on a quantitative study of the electron loss process due to electron-neutral collisions. *Tadokoro and Katoh* [2014] employed one dimensional test-particle simulation regarding 1keV electrons to examine the time variations of equatorial pitch angle distribution and electrons within loss cone through pitch angle scattering due to electron-$H_2O$ elastic collisions around Enceladus. Chemical reactions in plasmas generally depend on electron energy. This study focuses on the elastic collisions between electrons with energy range from 500 eV to 50 keV and water molecules. Our computational findings suggest a need for the re-evaluation of the differential scattering cross section model.

## 2 Simulation model

We employ a one-dimensional test-particle simulation code, based on the approach of *Tadokoro and Katoh* [2014], to examine the behavior of energetic electrons along Saturn's dipole magnetic field line in the vicinity of Enceladus. Trajectories of individual 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 assume that the initial pitch angle distribution is isotropic distribution. The number of electrons used in this simulation is 500,000. A trajectory trace is terminated when a calculation time is over ~380s. The end of calculation time corresponds to the time scale of the co-rotating flux tube passing through the region of the dense $H_2O$ around Enceladus.

The elastic collision at each time step is solved by a Monte-Carlo procedure. 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, $\sigma$ is the elastic collisional cross section, and $v$ is the relative velocity between an electron and neutral $H_2O$. If a collision occurs, the scattering angle of the electron is computed using the differential scattering cross section via a Monte-Carlo method. The total and differential cross sections for elastic collisions based on the experimental data are given by *Katase et. al.* [1986]. The $H_2O$ density model used in this simulation is the same as the model based on observations used in *Tadokoro and Katoh* [2014].

## 3 Results and Discussion

We have found that the electron loss rate of 500 eV – 50 keV electrons due to elastic collisions increases with electron energy. The electron loss rate is defined as the fraction of the number of electrons into the loss cone to the number of trapped electrons around the magnetic equator at the initial condition. In order to identify the energy peak of this loss rate, further numerical calculation preformed for 100 keV electrons. However, this trend of the loss rate was maintained. This finding may indicate a need to re-evaluate the differential cross section model. Due to a lack of experimental data, the current model treats the scattering cross section for electrons more than 1 keV as equivalent to that of 1 keV electron. Reconstruction of the energy dependent scattering cross section model is our future works.

## References


・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.