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Energy balance in the core of the Saturn plasma sheet: H_2O chemistry

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Abstract

A model of the weakly ionized plasma at Saturn has been developed to investigate the properties of the system. Energy balance is a critical consideration. The present model is based on two sources of mass, H_2O, and HI. H_2O is a variable. HI is a significant volume of gas flowing through the plasma imposed by the source at Saturn [1,2,3]. The energy sources are solar radiation and heterogeneous magnetosphere electrons. The model calculations produce energy rates, species partitioning, and relaxation lifetimes. For the first time the state of the ambient plasma sheet electrons is directly connected to the energy forcing functions. Within limits of knowledge, the predicted state of the core region of the plasma sheet in neutral and ionized gas corresponds satisfactorily to observation. The dominant ions in these calculations are H_2O^+ and H_3O^+ with lifetimes of several days. The lifetime of H_2O is roughly 60 days. In calculations carried out so far the predicted source rate for H_2O is lower than the rates quoted from the Enceladus encounters.

1. Introduction

The Saturn magnetosphere is a weakly ionized plasma with neutral/ion ratios that range from 50 to more than 1000 in the plasma sheet. For comparison, Jupiter has ratios < 0.004. The primary reason for this multi-order of magnitude difference is neutral gas sources that quench the system, combined with magnetic field structure. The methodology applied in the model design is similar to that described in [4]. In this case forcing in the calculation is assignment of ambient and heterogeneous electron parameters. The code then adjusts the source rate of H_2O and applies the physical chemistry to reach an equilibrium. If the forcing parameters are not compatible with the rate processes, the calculation will fail to reach equilibrium. It is generally possible to obtain statistical equilibrium over a significant range of electron forcing parameters, but the energy budget is not necessarily balanced. In the present arrangement a separate code is used for the application of energy transfer processes to determine energy imbalance in the gas. The results are interpolated to determine the state of the energy equilibrated system.

2. Properties of the plasma

The determination of an energy equilibrated plasma in these calculations is achieved through examining the state of the ambient electron population (ec), since this population plays the core role in the system. Detailed calculations are carried out in the reactions of ec with the other species in the plasma. This includes momentum transfer, collisional radiative and ionization losses, electron-electron relaxation, electron-ion coulomb reactions, recombination, and charge transfer. The combined rate processes then determine the net gain or loss of volumetric energy contained in ec in the statistically equilibrated plasma. Figure 1 shows the volumetric energy rates determined in ec for a range of statistically equilibrated calculations. These calculations are carried out at a radial location of 4 Saturn radii (R_S)in the orbital plane.

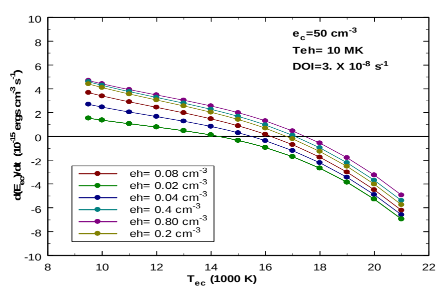

Figure 1: Volumetric energy rates in the plasma-sheet electrons, ec, as a function of ec temperature (Tec). Each point on the plot is a statistically equilibrated plasma, for ec= 50 cm^{-3}, heterogeneous electrons (eh)

at Teh= 10^7 K. The densities of eh in the calculations are identified in the colorcode.

The net volumetric energy rate for ec in Figure 1 is plotted against the ec temperature (Tec). The family of curves is established by fixing the density of the heterogeneous electrons (eh) for each case. The zero rate crossing of these curves represents the conditions required for energy equilibrium in the system. The significant slope of the curves in Figure 1 indicate that any disturbance in the system such as variance in eh properties would tend to rapidly relax to equilibrium.

Figure 2 shows the H_2O plasma species partitioning for an range of eh values with ec fixed at 100 cm^{-3}. The populations fall in the range of currently available observations [5,6].

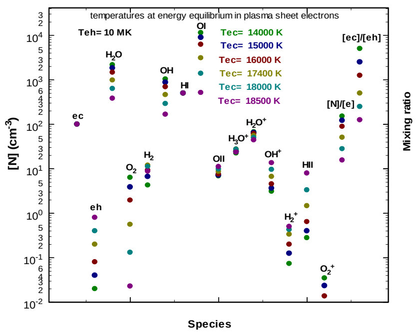

Figure 2: Species partitioning for a range of equilibrium conditions in a pure H_2O plasma.

3. Conclusions and discussion

The model calculations presented here for a pure H_2O plasma appear to fall closely enough to observational constraints to allow the conclusion that the direct involvement of cluster species or grains in the physical chemistry is not necessary to explain the state of the plasma sheet. The current calculations have been confined to the 4 R_S region, but diffusion properties are included in the rates and the model can be extended to the broader regions. The model allows accurate determination of energy forcing rates required to maintain the system. Observations of the neutrals in the magnetosphere have implied distributional and temporal properties [3] that need further investigation, including other significant sources other than Enceladus.

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References

[1]Shemansky, D. E., Hall, D. T.: The distribution of atomic hydrogen in the magnetosphere of Saturn, J. Geophys. Res., 97, 4143-4161, 1992.

[2] Shemansky, D. E., Liu, X., Melin, H.: The Saturn hydrogen plume, Planet. Space Sci., 57, 1659-1670, 2009.

[3] Melin, H., Shemansky, D. E., Liu, X.: The distribution of atomic hydrogen and oxygen in the Saturn magnetosphere, Planet. Space Sci., 57, 1743-1753, 2009.

[4] Hallett, J. T., Shemansky, D. E., Liu, X.: A rotationa level hydrogen physical chemistry model for general astrophysical application , Astrophys. J., 624, 448-461, 2005.

[5]Sittler, E. J. jr, et al.: Ion and neutral sources and sinks within Saturn's inner magnetosphere, Planet. Space Sci., 57, 1743-1753, 2009.

[6] Schippers, P., et al.: Multi-instrument analysis of electron populations in Saturn's magnetosphere , J. Geophys. Res., 113, A07208, 2008.