EPSC Abstracts
Vol. 7 EPSC2012-763 2012
European Planetary Science Congress 2012

Hydrogen in the Saturn magnetosphere

Donald E Shemansky, X. Liu, J. Yoshii. Planetary and Space Sci. Div., Space Environment Technologies, Altadena, CA, United States.

Abstract

This paper examines the impact of the sources of neutral hydrogen populating the Saturn magnetosphere. The considerations in the calculations include source rates, physical chemistry of weakly ionized plasma affecting populations, magnetospheric and solar forcing rate processes, energy balance, and observational limits. The Saturn magnetosphere is dominated by atomic hydrogen from the top of the Saturn atmosphere to beyond the magnetosphere bow shock. The hydrogen sourced by Saturn has been estimated to extend to at least 100 R_S from system center. The main source of HI is the top of the low latitude Saturn atmosphere, estimated to be ~3.X10^{30} s^{-1} . Known H_2 sources, Titan at ~10^{28} s^{-1}, Enceladus at ~3X10^{26} s^{-1} are relatively minor. H_2 has never been detected in the magnetosphere. The present work explores the properties of H_2 as a limiting factor. Solar photon processes have been recalculated; the standard for these rates has been Heubner et al. (1992). It has been found in the present calculations that there is disagreement with the Heubner rates, particularly for kinetic energy in 2H(1s) production where the current results give product energies an order of magnitude below the Heubner 8.2 eV value . Water chemistry is modeled in the core of the plasma sheet directly relating the state of the plasma sheet electrons to the magnetospheric and solar energy deposition processes, and providing detailed calculated partitioning of the weakly ionized gas, H_2O, OH, H_2, O_2, OI, HI, H^+, O^+, H_2O^+, H3O$^+$, H_2^+, OH^+, O_2^+. The calculations include detailed solar photo dissociation, ionization, and dissociative ionization of LTE and non-LTE H_2. The predicted state of non-LTE H_2 has been calculated, and detailed emission at the rotational level has been predicted for the magnetosphere in the present work. The ion/neutral ratio as a function of forcing for a pure hydrogen low density weakly ionized plasma has been calculated.

1. Introduction

The Saturn upper thermosphere is now known to show non-LTE resonance euv/fuv emission in H_2 spatially non-uniform electrodynamic excitation[1,2,3]. This high altitude process is inferred to be the primary source of the observed extensive distribution of atomic hydrogen in the magnetosphere[1]. H_2 in the magnetosphere cannot be injected from Saturn, but must appear as a product of processes in the orbiting components such as the rings and Enceladus. Solar forced rates for H_2 and the other gases in the astrophysical context have been calculated by Heubner[4], and constitute the primary source for a wide range of published model calculations. These calculations, however, are generic is the sense that there is no reference to the state of the gas as a determinant of rate, which implies that nominal ground state conditions are assumed. Recently published calculations by the present authors[5,6,7] using currently established physical properties of H_2 and D_2 now allow calculation of state dependent rates, some of which are presented here. These results show significant differences with the earlier[4] work.

H_2O physical chemistry produces the neutral components H, O, OH, H_2 and O_2 through reactions in the solid and gaseous state. The homo-nuclear components have not been detected.

2. The state and distribution of the neutral gas in the magnetosphere

Figure 1 shows a virtual image of the atomic hydrogen distribution as measured by the Cassini UVIS experiment[1,2,3]. This is the dominant neutral in the system and the primary plasma quenching component.

The new calculations for H_2 now provide an accurate prediction for the abundance of H_2 to be expected given the model reference to the other measured components. Predicted abundance and calculated state properties will be shown.

The other neutrals in the system will be discussed briefly. It is not clear that O and OH originate entirely from Endeladus. A model calculation of energetics and partitioning of the weakly ionized plasma will be given.

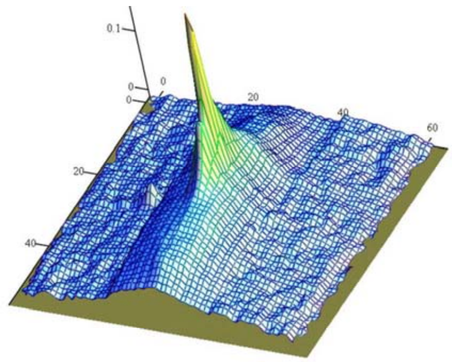

Figure 1: The extended distribution of atomic hydrogen as observed by the Cassin UVIS experiment pre SOI, showing the local time spatial dependence. The strong peak marks the planet position and the extension toward the top of the figure is the sunlit side. The peak of the ridge of emission is near the orbital plane.

3. Summary and Conclusions

Non-uniform heating at the top of the Saturn thermosphere in the equatorial region in electrodynamic excitation of non-LTE H_2 is the primary source upper thermosphere heating and atomic hydrogen injected into the Saturn magnetosphere. New state specific calculations of H_2 rate processes are significantly different than previous work.

Model calculations for the core of the plasma sheet require heterogeneous energy deposition by magnetosphere electrons in order to explain the observed state of the gas.

Acknowledgements

This work us supported by the Cassini UVIS program.

References

[1] Shemansky, D. E., Liu, X. and Melin, H. : The Saturn hydrogen plume, Planet. Sp. Sci., 57, pp. 1659-1670, 2009.

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

[3] Mauk, B. H., et al.: Fundamental Plasma Processes in Saturn's magnetosphere, in Saturn from Cassin-Huygens, Springer, pp281-332, 2009.

[4] Heubner, W. F., Keady, J. J., Lyon, S. P., Solar photo rates for planetary atmospheres and atmsophereic pollutants, Astrophys., Space Sci., 195, pp. 1-294, 1992.

[4] Heubner, W. F., Keady, J. J., Lyon, S. P., Solar photo rates for planetary atmospheres and atmsophereic pollutants, Astrophys., Space Sci., 195, pp. 1-294, 1992.

[5] Liu, X., Shemansky, D. E., Johnson, P. V., Malone, C. P., Khakoo, M. A., and Kanik, I., Electron and photon dissociation cross sections of the H_2 singlet ungerade continua, J. Phys. B, 45, doi:10.1088/0953-4075/45/1/015201, 2012.

[6] Liu, X., Shemansky, D. E., Johnson, P. V., Malone, C. P., Khakoo, M. A., and Kanik, I., Non dissociative electron and photon ionization cross sections of molecular hydrogen and deuterium, J. Phys. B, 45, doi:10.1088/0953-4075/45/9/095203, 2012.

[7] Liu, X., Shemansky, D. E., Johnson, P. V., Malone, C. P., Khakoo, M. A., and Kanik, I., Electron and photon dissociation cross sections of the D_2 singlet ungerade continua, J. Phys. B, 45, doi:10.1088/0953-4075/45/10/105203, 2012.