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Ionization sources in Titan's deep ionosphere

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Abstract

We analyze a multi-instrumental dataset from four Titan encounters by the Cassini spacecraft to investigate in detail the formation of the ionosphere. The dataset includes observations of thermospheric and ionospheric species and suprathermal electrons from: the Langmuir Probe (LP), a subsystem of the Cassini Radio and Plasma Wave Science (RPWS) experiment, the Ion and Neutral Mass Spectrometer (INMS), and the Electron Spectrometer sensor (ELS), a sub-system of the Cassini Plasma Spectrometer (CAPS). A model describing the solar and electron energy deposition is used as an organizing element of the Cassini dataset.

We first compare the calculated secondary electron production rates with the rates inferred from suprathermal electron intensity measurements. We then calculate an effective electron dissociative recombination coefficient applying three different approaches to the Cassini dataset. Our findings are three-fold [1]:

(I) The effective recombination coefficient α derived under sunlit conditions in the deep ionosphere (<1200 km) is found to be independent of solar zenith angle and flyby. Its value ranges from 6.9 $\times 10^{-7}$ cm^{3}s^{-1} at 1200 km to 5.9$\times 10^{-6}$ cm^{3}s^{-1} at 970 km at 500 K. A fit to the dataset on the dayside (solar zenith angle <85°) provides the following altitude dependence:

$$\alpha(z) = 10^{(8.82\times10^{-6}\times z_0^2 - 5.56\times10^{-3}\times z_0 - 5.405)} \quad (1)$$

where α, given at 500 K, is in cm^{3}s^{-1} and $z_0 = z - 1000$ with z, the altitude in km (970<z<1200 km). It is useful for a quick assessment of the electron density N_e given by:

$$N_e(z) = \sqrt{P_e(z) \times \alpha(z)^{-1}} \quad (2)$$

where P_e represents the total electron production rate.

(II) The presence of an additional, minor source of ionization is revealed when the solar contribution is weak enough. The contribution by this non-solar source - energetic electrons most probably of magnetospheric origin - becomes apparent for secondary electron production rates, due to solar illumination alone, close to or smaller than about 3×10^{-1} cm^{-3}s^{-1}. Such a threshold is reached near the solar terminator below the main solar-driven electron production peak (<1050 km). When this additional source of ionization is taken into account, the values obtained for the effective recombination coefficient are consistent with values derived for regions where the solar illumination dominates the ionization.

(III) Our ability to model the electron density in the deep ionosphere is very limited. Our findings highlights the need for more laboratory measurements of electron dissociative recombination coefficients for heavy ion species at high electron temperatures (especially near 500 K).

References

[1] Galand M., R. Yelle, J. Cui, J.-E. Wahlund, V. Vuitton, A. Wellbrock, and A. Coates: Ionization sources in Titan's deep ionosphere, J. Geophys. Res., Vol. 115, doi: 10.1029/2009JA015100, in press, 2010.