

## Negative ion densities in the deep ionosphere of Titan – Cassini RPWS/LP results

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### Abstract

The Cassini *s/c* Radio and Plasma Wave Science (RPWS) Langmuir Probe (LP) *in-situ* measurements of Titan's ionosphere from 47 deep flybys map the charge densities of negative ions and number densities of positive ions and electrons wrt. solar zenith angle (SZA) and an altitude range of 880-1400 km. The electron number densities are consistent with earlier observations. Negative ion charge densities exhibit a trend that exponentially increases towards lower altitudes within the covered altitude range, especially evident on the nightside of Titan (SZA > 110°). The negative ion charge densities at the lowest traversed altitudes (near 960 km) are in the range 300-2500 cm<sup>-3</sup>. Very few free electrons (ne/ni ~ 0.1-0.7) exist in the deepest regions (880-1050 km) of Titan's nightside ionosphere, instead negative and positive heavy (>100 amu) organic ions are dominant. We therefore believe a dusty/aerosol plasma exist here, similar to what is found in noctilucent clouds in Earth's mesosphere.

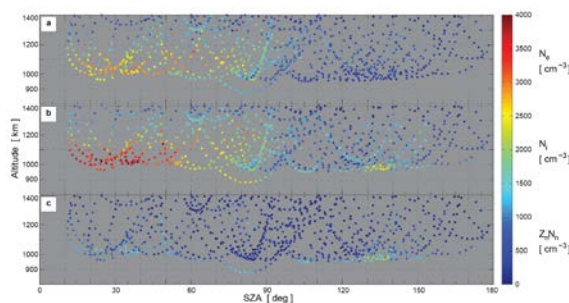
### 1. Introduction

Saturn's largest moon Titan has a dense atmosphere with complex organic chemistry [1] which may be similar to early Earth's. Titan's upper atmosphere is ionized by various energy sources (solar EUV/X-rays, cosmic rays and energetic particles) [2-4], which supply the ion chemistry leading to aerosol (tholin) formation [1, 5]. Building blocks of aerosols - positive ions of up to 350 amu/q and negative ions of up to 10000 amu/q - were discovered by the Cassini *s/c* [1, 6]. These heavy species are dominant in the lower (<1000 km) layers of the ionosphere [7, 8]. We use a large data set (47 deep flybys) of RPWS/LP *in-situ* measurements to map the charge densities of

positive and heavy negative ions wrt. altitude and solar zenith angle (SZA) in Titan's ionosphere.

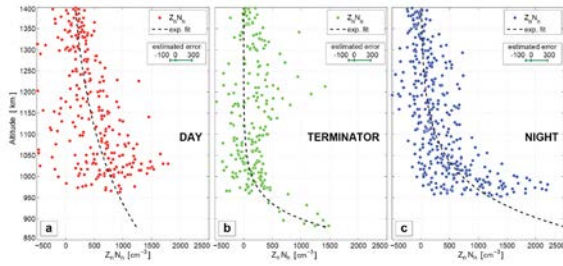
### 3. Results

Substantial charge densities of negative ions are observed below 1100 km for all covered SZAs (Figure 1). On the nightside of Titan (SZA > 110°) at these altitudes the electron population diminishes significantly and the plasma is largely dominated by ions, exhibiting properties of dusty plasma.



**Figure 1. Cassini RPWS LP electron number densities (a), positive ion number densities (b) and negative ion charge densities (c) as functions of altitude and SZA. Each point is one measurement.**

At dayside (Figure 2, a), large charge densities of negative ions (ZnNn) are detected at altitudes 1200-1400 km and the data points are spread out due to temporal ionosphere variations between the flybys. Terminator region (Figure 2, b) shows an apparent decrease in ZnNn due to solar radiation at Titan's ecliptic poles not penetrating to lower altitudes. Nightside data (Figure 2, c) shows most clear exponential trend with ZnNn also reaching highest values (up to 2500 cm<sup>-3</sup>).



**Figure 2. Altitude profiles of negative ion charge densities separated into three SZA intervals: Dayside ( $SZA < 80^\circ$ ), Terminator ( $80^\circ < SZA < 110^\circ$ ) and Nightside ( $SZA > 110^\circ$ ). Dashed lines are least-square exponential fits to the data. The error bar shows total estimated uncertainty, between -100 and +300  $\text{cm}^{-3}$ .**

## 6. Summary and Conclusions

Based on 47 flybys of Titan's ionosphere in altitude range 880-1400 km we mapped the charge distribution of positive and heavy negative ions. Charge densities of negative ions ( $ZnNn$ ) increase exponentially towards lower altitudes down to 880 km, reaching up to 2500  $\text{cm}^{-3}$ . Positive ion densities reach up to 4200  $\text{cm}^{-3}$ . Dayside  $ZnNn$  peak is seen just after 12 h LT, supporting dayside production by solar EUV. The importance of solar EUV for negative ion production is also indicated by an ecliptic polar minimum in  $ZnNn$  around 6 h LT. Titan's ionosphere below 1000 km exhibits properties of dusty plasma (negative charge carried by heavy ions rather than electrons). Estimation of dust grain charge gives at most 1-2 charges.

Presented data will be used to study production rates of pre-biotics, heavy organic molecules with masses 102 to 104 amu.

## Acknowledgements

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