EPSC Abstracts
Vol. 6, EPSC-DPS2011-1846, 2011
EPSC-DPS Joint Meeting 2011

Altitude distribution of the negative ions in Titan's atmosphere

A. Bazin (1), V. Vuitton (1),*, R. V. Yelle (2) and P. Lavvas (2)

(1) Institut de Planétologie et d'Astrophysique de Grenoble, CNRS/UJF, Grenoble, France
(2) Lunar and Planetary Laboratory, University of Arizona, Tucson AZ, USA

* Corresponding author. E-mail adress: veronique.vuitton@obs.ujf-grenoble.com

1. Introduction

Since its Saturn's orbit insertion on July 1st, 2004, the Cassini spacecraft has been measuring Titan's upper atmosphere composition in situ with two intruments: the Ion Neutral Mass Spectrometer (INMS), which analyse positive ions and neutrals densities, and the Electron Spectrometer (ELS), one of the sensors of the Cassini Plasma Spectrometer (CAPS). Analysing ELS data, unexpected heavy negative ions have been detected [2], with a mass/charge up to 10000 u/q, and with a total density that represents about a tenth of the positive ion one.

The first negative ion chemistry model [10], developed to fit the measurements done during T40, succeeded to explain the three first peaks observed on the mass spectrum from ELS: the high CN^- abundance has been attributed to the peak at 22±4 u/q, C_3N^- coupled with C_4H^- to 44±8 u/q and C_5N^- to 82±14 u/q. Above a few hundred of u/q, no ions can be accurately identified, because the chemistry is very poorly known for heavier species.

Based on this previous model including negative ions, we have developed an updated model, not adapted to a particular flyby anymore. It describes the phenomena as their averages to prepare the data necessary for a two-dimensional model, describing the processes as a function of altitude and of the Solar Zenith Angle (SZA).

The neutral densities are not fixed by the observations anymore, but are now chemistry-dependent [5, 11]. The supra-thermal electron flux is calculated with the latest data on N_2 and CH_4 [6]. The photo-detachment cross section of C_2H^-, C_4H^- and C_6H^- have been redefined according to Otto (2010) experimental studies. The dissociative electron attachment (DEA) cross sections have been updated for HCN [8], C_2H_2 and C_4H_2 [7]. Some reaction rates involving important species have been also redifined [9, 1, 4].

2. Negative ion density profiles

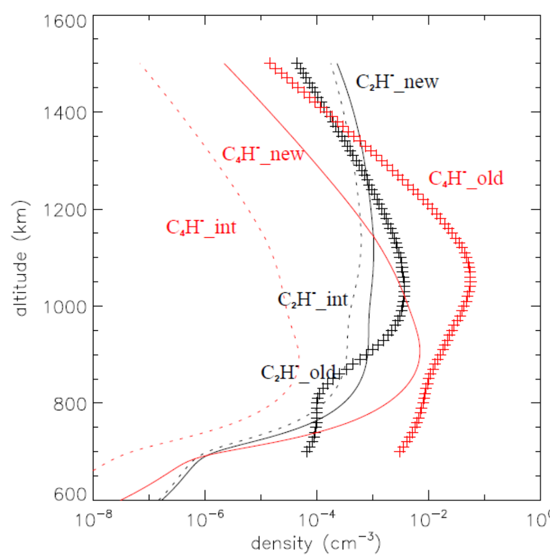

Figure 1: Comparison between the old, intermediate and new C_2H^- and C_4H^- density profiles. The old profile is taken from Vuitton et al. (2009) [10]. The intermediate profile is plotted taking into account the general modifications on the atmosphere, before the chemical updates realized species by species. This allows us to understand the influence of both of the changes separately. The new profile is realized with all the updates.

The lowest boundary for the negative ion study is extended until 600 km, that allows us to see, as an example, the peaks in the C_2H^- and C_4H^- profiles at lower altitude than previously (Fig. 1). In the previous model, the densities significantly decreased above from 1000 km to the surface, whereas they stay here important until ∼800 km. The large variations in the

C_4H^- profile are first explained by the impact of the updated HCN density through $C_4H^- + HCN \rightarrow C_4H_2 + CN^-$, then by the updated C_4H_2 DEA cross section.

3. Conclusions

The most abundant negative ions are the same as in the previous model (CN^-, C_3N^- C_5N^-, C_2H^- and C_4H^-). The comparison of the density profiles reveals that the negative ions distribution depends highly on their intrinsic parameters. In this updated model, we use all the latest data available, however the chemistry processes still need to be much more accurately known. We notably miss experimental data about the rate constants of reactions involving important species and their temperature dependence (e.g. C_4H^-/C_2H^- + HCN, CN^- + H and C_2H_2 + H^-), the dissociative electron attachment on HC_3N and HC_5N, the photo-detachment cross section for the N-bearing ions and the processes leading to the formation of heavier species.

This model takes into account the physical and chemical processes on the whole surface of Titan by averaging them. The next step is to use the data, known as a function of the solar zenith angle, to make a richer desription of Titan's atmosphere, hour by hour. This study was realized for the positive ions by Cui et al. (2009) [3]: the average must hide some differences in the behavior of the species between the dayside and the nightside, that the two-dimensional model should reveal.

Acknowledgements

This work was performed in the framework of the Marie Curie International Research Staff Exchange Scheme PIRSES-GA-2009-247509.

References

[1] S. Carles, F. Adjali, C. Monnerie, J.-C. Guillemin, and J.-L. Le Garrec, *Kinetic studies at room temperature of the cyanide anion CN^- with cyanoacetylene (HC_3N) reaction*, Icarus **211** (2011), 901–905.

[2] A.J. Coates, F.J. Crary, G.R. Lewis, D.T. Young, J.H. Waite, and E.C. Sittler, *Discovery of heavy negative ions in Titan's ionosphere*, Geophysical Research Letters **34** (2007), L22103.

[3] J. Cui, M. Galand, R. V. Yelle, V. Vuitton, J.-E. Wahlund, P. Lavvas, I. C. F. Müller-Wodarg, T. E. Cravens, W. T. Kasprzak, and J. H. Waite Jr., *Diurnal variations of Titan's ionosphere*, Journal of Geophysical Research **114** (2009), A06310.

[4] A. Faure, V. Vuitton, R. Thissen, L. Wiesenfeld, and O. Dutuit, *Fast ion–molecule reactions in planetary atmospheres: a semiempirical capture approach*, Faraday discussions **147** (2010), 337–348.

[5] S. M. Hörst, V. Vuitton, and R. V. Yelle, *Origin of oxygen species in Titan's atmosphere*, Journal of Geophysical Research **113** (2008), E10006.

[6] P. Lavvas, M. Galand, R.V. Yelle, A.N. Heays, B.R. Lewis, G.R. Lewis, and A.J. Coates, *Energy deposition and primary chemical products in Titan's upper atmosphere*, Icarus **213** (2011), 233–251.

[7] O. May, J. Fedo, B. C. Ibănescu, and M. Allan, *Absolute cross sections for dissociative electron attachment to acetylene and diacetylene*, Physical Review A **77** (2008), 040701.

[8] O. May, D. Kubala, and M. Allan, *Absolute cross sections for dissociative electron attachment to HCN and DCN*, Physical Review A **82** (2010), 010701.

[9] T. P. Snow, M. Stepanovic, N. B. Betts, B. R. Eichelberger, O. Martinez, and V. M. Bierbaum., *Formation of gas-phase glycine and cyanoacetylene via associative detachment reactions*, Astrobiology **9** (2009), 1001–1005.

[10] V. Vuitton, P. Lavvas, R.V. Yelle, M. Galand, A. Wellbrock, G.R. Lewis, A.J. Coates, and J.-E. Wahlund, *Negative ion chemistry in Titan's upper atmosphere*, Planetary and Space Science **57** (2009), 1558–1572.

[11] V. Vuitton, R.V. Yelle, and J. Cui, *Formation and distribution of benzene on Titan*, Journal of Geophysical Research **113** (2008), E05007.