EPSC Abstracts
Vol. 13, EPSC-DPS2019-1364-1, 2019
EPSC-DPS Joint Meeting 2019
© Author(s) 2019. CC Attribution 4.0 license.

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Main ions in the thermosphere of exoplanets, focussing on the transition between super-Earths and mini-Neptunes

Jérémy Bourgalais (1) and Nathalie Carrasco (1)
(1) LATMOS/IPSL, UVSQ, Université Paris-Saclay, UPMC Université Paris 06, CNRS, Guyancourt, France
(Jeremy.bourgalais@latmos.ipsl.fr)

Abstract

Thermospheres of exoplanets are submitted to the harsh UV and X-ray radiations of their host star. In the present work we focus on ion chemistry occurring in super-Earths and mini-Neptunes. We simulate in the laboratory the effect of Far-UV on gas-mixtures varying from H_2-rich to H_2-poor conditions and we analyze the ions by *in situ* mass spectrometry.

1. Introduction

Thermospheres of exoplanets are photochemically active layers, characterized by an efficient photolysis of the main components of the atmospheres. Vertical transport in thermospheres is moreover governed by molecular diffusion, also contributing to strongly modify the composition profiles of the atmospheres. On Mars, with an atmosphere based on CO_2 and N_2, the efficient photolysis of CO_2 leads to an increase of CO mixing ratio, up to several tens percent's compared to CO_2 [1]. The impact on the thermal profile of the atmosphere is determining. On Mars the progressive enrichment in CO compared to CO_2 according to altitude limits the heating of the thermosphere, as CO is a less efficient UV absorber than CO_2 [2]. Predicting and understanding the temperature and density profiles of thermospheres of exoplanets will therefore constrain atmospheric escape and photoevaporation processes, and a fortiori the evolution of atmospheres of exoplanets.

Photolysis in thermospheres involves harsh UV and X-ray stellar radiations and produces complex chemical environments coupling neutral and ion chemistry. Ion-chemistry has been shown to be largely underestimated and poorly known when the Cassini-Huygens space mission unveiled the complex ion and neutral composition of the thermosphere of the largest satellite of Saturn, Titan [3]. Its atmosphere is based on N_2 and CH_4, and nitrogen chemistry was found to be particularly important in Titan's thermosphere. We learned with the study of this body that ion-neutral chemistry was rich and efficient and could lead to unexpected abundant chemical species.

With the data of the California-Kepler Survey two populations of super-Earths and mini-Neptunes could be distinguished [4]. Super-Earths, with radii lower than 1.5 $R_\oplus$ are rocky planets with thin atmospheres mainly made of heavy molecules like N_2 and CO_2. Mini-Neptunes with masses between 2 and 3 $R_\oplus$ have on the opposite extended H_2-based atmospheres.

The aim of the present work is to characterize the main positive ions that can be expected in the thermospheres of super-Earths and mini-Neptunes. For this purpose we simulated experimentally the ion-neutral chemistry initiated by Far-UV radiations on a gas mixtures mimicking the main possible composition of thermospheres of super-Earths and mini-Neptune. The ion species are analyzed in situ by mass spectrometry.

2. Methods

Far-UV photons mimicking the stellar UV field were generated by using a gas-discharge type Far-UV source coupled windowless to our photochemical reactor [5]. We irradiated at 73.6 nm (15.6 eV by using the resonant emission lines of Ne I and Ar I, respectively, with a photon flux of ca. $1\text{-}5\times10^{14}$ $ph.s^{-1}.cm^{-2}$.

Gas mixtures were chosen to be representative of H_2-poor atmospheres and H_2-rich atmospheres. As the photolysis of CO_2 mainly produces CO, and that CO is more efficient to drive further photochemistry, we have chosen CO as a proxy of both CO_2 and CO in our experiments. In order to build a consistent experimental series, we have chosen to only modify the H_2 content in our experimental conditions. N_2 mixing ratio was therefore arbitrary chosen as equal to CO mixing ratio, and H_2 mixing ratios increased from 1% up to 96%.

The gas composition was monitored in steady state by using a high sensitivity (<1ppm) quadrupole mass spectrometer (Hiden Analytical EQP 200 QMS) allowing *in situ* measurements of the positive ions.

3. Results

H_2 mixing ratios were chosen at 1%, 33% and 96%. The main ions detected are shown on Figure 1. The first striking result is that in all conditions the main ions are the same: H_3O^+ at m/z 19 and HCO^+ and N_2H^+ at m/z 29, even in a H_2-based neutral gas mixture. In the H_2-based condition (H_2 mixing ratio of 96%), H_3^+ at m/z 3 appears as an additional important ion contributor.

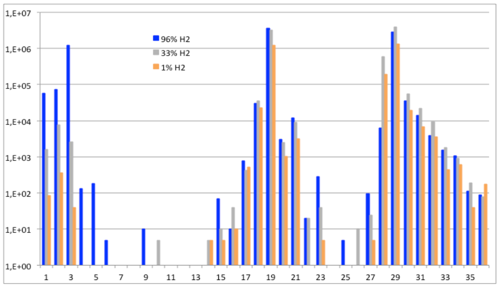

Figure 1: Ions produced after irradiation at 73 nm of $H_2/CO/N_2$ gas mixtures. H_2 mixing ratios was chosen at 1%, 33% and 96%.

Primary ions produced by photoionization at 73nm are respectively H_2^+ at m/z 2, N_2^+ and CO^+ at m/z 28. Those primary ions react with H_2, through ion-molecule efficient reactions, leading to the stable protonated ions observed. The detection of the ion H_3O^+ is a sensitive probe of the presence of H_2O in the reactive medium: as a photoproduct and/or as contaminant.

4. Summary and Conclusions

We highlight that the main ions observed in our H_2 rich (96%) and H_2 poor (1%) conditions are similar and corresponds to HCO^+ and N_2H^+. We used CO as a proxy for CO and CO_2. We can extrapolate that HCO_2^+ would similarly be observed in the presence of CO_2. Despite the drastic differences in neutral compositions of the atmospheres of super-Earths and mini-Neptunes, our work suggests that rather similar ion contributions could be expected in their thermospheres.

Acknowledgements

This research was supported by the ERC Starting Grant PRIMCHEM, grant agreement n°636829.

References

[1] Moudden Y. and Connell J.C. Icarus, 188, 18, 2007.

[2] Gonzalez-Galindo, F., Forget, F., Angelats, M., Coll, I. and Lopez-Valverde, M. A. Lecture Notes and Essays in Astrophysics, 3, 151, 2008.

[3] Waite, J. H., Young, D. T., Cravens, T. E., et al. Science, 316, 870, 2007.

[4] Fulton F., Petigura E., Howard A., et al. Astronomical Journal, 154(3), 109, 2017.

[5] Tigrine S., Carrasco N., Vettier L., Cernogora G. Journal of Physics D: Applied Physics, 49, 395202, 2016