EPSC Abstracts
Vol. 8, EPSC2013-287-1, 2013
European Planetary Science Congress 2013

N_2 states population and airglow in Titan's atmosphere

P. Lavvas (1), L. Campbell (2), R.V. Yelle (3), M. Galand (4), M.J. Brunger (2)
(1) Groupe de Spectroscopie Moléculaire et Atmosphérique, Université de Reims, Champagne-Ardenne, France
(2) ARC Centre for Antimatter-Matter Studies, School of Chemical and Physical Sciences, Flinders University, Australia
(3) Lunar and Planetary Laboratory, University of Arizona, USA
(4) Space and Atmospheric Physics Group, Department of Physics, Imperial College London, UK
(panayotis.lavvas@univ-reims.fr)

Abstract

Molecular nitrogen in Titan's atmosphere is excited to different vibrational and electronic states by direct photon absorption and electron impact. Here we present detailed calculations for the vibrational population of different electronic states and the emission rates from the de-excitation of these states.

1. Introduction

The interaction of N_2 with high energy photons and electrons excites the molecule to different vibrational and electronic levels (N_2^*). De-excitation from these states can result by spontaneous emission and by collisions of the N_2^* with other molecules. Competition among these processes will define the thermal structure of the atmosphere. Therefore a detailed calculation for the population of the different excited states is necessary in order to calculate an accurate temperature profile, as well as emission rates that can be compared with spacecraft observations such as those by the Cassini/UVIS instrument for Titan's case.

2. Model Description

The starting point of our calculations are the excitation and ionization rates based on high resolution cross sections of N_2 that we have performed in the past [1]. We expand on these calculations by calculating the population for the first 21 vibrational levels of the major singlet and triplet electronic states of N_2 and doublets of N_2^+. These include the states: $X\ ^1\Sigma_g^+$, $A\ ^3\Sigma_u^+$, $B\ ^3\Pi_g$, $W\ ^3\Delta_u$, $B'\ ^3\Sigma_u^-$, $\alpha'\ ^1\Sigma_u^-$, $\alpha\ ^1\Pi_g$, $w\ ^1\Delta_u$, $b\ ^1\Pi_u$, $c_4'\ ^1\Sigma_u^+$, $C\ ^3\Pi_u$, $E\ ^3\Sigma_g^+$ for N_2, and $X\ ^2\Sigma_g^+$, $A\ ^2\Pi_u$, $B\ ^2\Sigma_u^+$ and $C\ ^2\Sigma_u^+$ for N_2^+.

The population of each vibrational/electronic level depends on the rate this level is populated by direct excitation by photons/electrons and by cascade from higher lying states (see e.g. Fig. 1), and the rate at which it is depopulated by radiative de-excitation and de-excitation by collisions with other atmospheric species. Therefore, in order to calculate the population of the different levels we need a large number of parameters that define the transition rates among different states. These include electron impact cross sections and Frank-Condon factors for the calculation of the production rates of different vibrational levels within each electronic state, transition rates among vibrational levels within each electronic state, transition rates among vibrational levels of different electronic states, as well as de-excitation rates of different states by molecular collisions and losses in state population by pre-dissociation. We obtain these parameters from the latest compilations and studies available [2, 3, 4, 5].

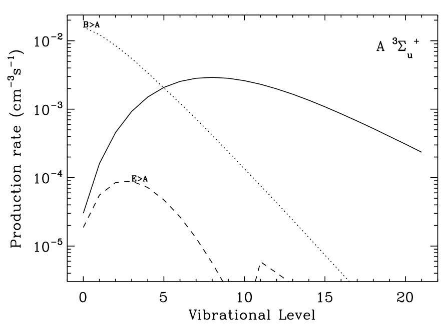

Figure 1: Production rates for the A $^3\Sigma_u^+$ state at different vibrational levels. Contributions from direct electron impact excitation (solid line) and cascade from higher electronic states (broken lines) are shown.

mosphere of Titan. *Journal of Geophysical Research (Space Physics)*, 115:9320, September 2010.

[3] Forrest R Gilmore, Russ R Laher, and Patrick J Espy. Franck-Condon Factors, r-Centroids, Electronic Transition Moments, and Einstein Coefficients for Many Nitrogen and Oxygen Band Systems. *Journal of Physical and Chemical Reference Data*, 21:1005, September 1992.

[4] D C Cartwright. Vibrational populations of the excited states of N2 under auroral conditions. *Journal of Geophysical Research*, 83:517, February 1978.

[5] B R Lewis, S T Gibson, J P Sprengers, W Ubachs, A Johansson, and C G Wahlström. Lifetime and predissociation yield of $^{14}N_2$ $b^1\Pi_u$(v=1) revisited: Effects of rotation. *The Journal of Chemical Physics*, 123(23):236101, 2005.

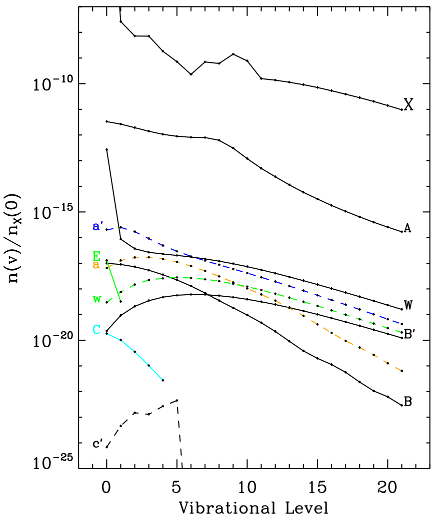

Figure 2: Vibrational populations for different N_2 states scaled to the density of the N_2 $X\ ^1\Sigma_g^+(\nu = 0)$ level.

3. Results

Our calculations for the vibrational population for different electronic states close to 1100 km in Titan's atmosphere are shown in Fig. 2. The longest lived metastable state is the N_2 $A\ ^3\Sigma_u^+$ state followed by the ground vibrational level of the $W\ ^3\Delta_u$ state. All other states/levels have small populations due to their rapid de-excitation through radiative emission and/or collisions, the relative role of each of these processes depending on the local atmospheric density. Close to 1100 km radiative transitions dominate providing an emission spectrum that covers a wide range of wavelengths (Fig. 3). We will further discuss what constraints on the atmospheric properties we can derive by comparison with the available observations.

References

[1] 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(1):233–251, May 2011.

[2] L. Campbell, H. Kato, M. J. Brunger, and M. D. Bradshaw. Electron-impact excitation heating rates in the at-

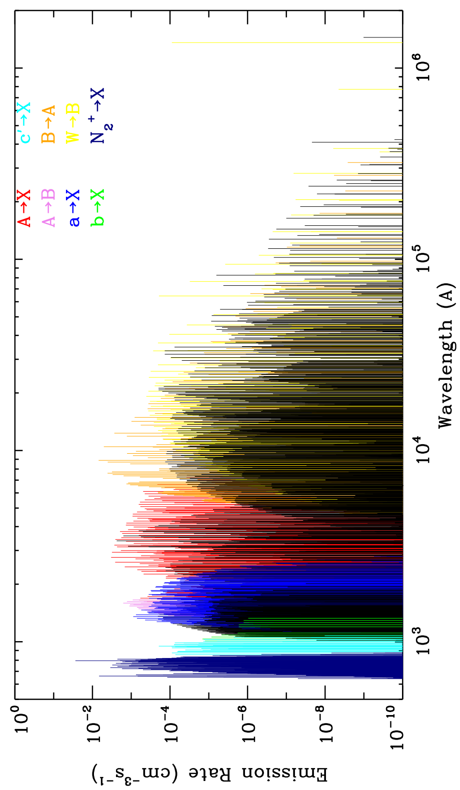

Figure 3: Emission rates for all transitions included in the model. Strongest emissions are color coded.