EPSC Abstracts
Vol. 5, EPSC2010-475, 2010
European Planetary Science Congress 2010

Jovian aurorae : sensitivity study of H_2 spectrum

H. Menager (1), M. Barthélemy (1), H. Abgrall (2), E. Roueff (2) and J. Lilensten (1)
(1) Laboratoire de Planétologie de Grenoble, France, (2) LUTH, Observatoire de Paris, France (helene.menager@obs.ujf-grenoble.fr / Fax: +33-476-51-41-46)

Abstract

The energy and angular distribution of the electrons that precipitate in Jupiter's aurora are still poorly constrained. We propose to address this problem by using EUV/FUV synthetic spectra of H_2 auroral emissions. A sensitivity study allows us to designate lines that can be used to diagnose the properties of the electron precipitation.

1. Introduction

The precipitation of energetic particles around Jupiter's magnetic poles gives rise to intense aurora. The most intense emissions are produced by H, with the intense Lyman-α line, by H_2, which has a wide spectrum in the EUV/FUV, and by H_3^+, which dominates the IR spectrum. Energetic electrons play a leading role in auroral processes whereas ion precipitation is far less important [1, 2]. The energy and angular distributions of these electrons, which originate in the magnetosphere, still have to be characterized accurately. It has been showed that the H Lyman-α line can be used to constrain the energy of electrons under 10 keV, but brings no information on the most energetic electrons [3]. This line is also a bad proxy to get information on the angular distribution of electrons since it depends only weakly on it. Other observable quantities are therefore required to get all the information on the precipitating electrons.

Several authors used H_2 emissions in FUV spectra of Jupiter's aurorae to retrieve information on the electron precipitation [4, 5, 6, 1, 7, 8]. But no strong constraints have been put on the electron energies and no one tried to constrain their angular distribution on top of the atmosphere. So accessing to both the energy and angular distributions of electrons still has to be done. In this respect, we propose here a sensitivity study of H_2 auroral emissions.

2. H_2 synthetic spectra

2.1. H_2 emission

The total intensity in the emission spectrum of H_2 reaches 100-200 kR in the diffuse auroral region and several hundred kR in the main oval [9]. This spectrum contains thousands of lines between 700 Å and 1800 Å. The lines are due to the deexcitation of electronic levels towards the fundamental $X\ ^1\Sigma_u^+$. The most intense emissions are those of the Lyman and Werner bands, which correspond to transitions from the $B\ ^1\Sigma_u^+$ and $C\ ^1\Pi_u$ states. Less intense bands starting at the $B'\ ^1\Sigma_u^+$, $D\ ^1\Pi_u$, $B''\ ^1\Sigma_u^+$ and $D'\ ^1\Pi_u$ states are also present.

We use a multi-stream kinetic transport code to compute excitation rates of H_2 states. This code solves the Boltzmann equation and accounts for both the absorption of the solar EUV/FUV flux and the collisions between auroral electrons and atmospheric particles. It has been described in [3].

The electron impact direct excitation rates of the rovibrational B, C, B', D, B'' and D' states are calculated. Excitation functions recommended by [10] are used.

Excitation rates of the B and C states due to cascades from the $EF\ ^1\Sigma_g^+$, $GK\ ^1\Sigma_g^+$ and $H\bar{H}\ ^1\Sigma_g^+$ states are also calculated, following [11]. In this aim, Franck Condon factors involved in the excitation via O and S branches of the X ground state to the Rydberg $^1\Sigma_g$ states have been computed by introducing J-dependent radial wave functions. The subsequent spontaneous Einstein emission coefficients have been introduced in the model, following the treatment reported in [12, 13]. Adequate Einstein coefficients have then been used to calculate the transitions from the $gerade$ to the $ungerade$ states.

Eventually, Einstein coefficients from the MOLAT database [12, 13] are used to calculate the emission of the B, C, B', $D \rightarrow X$ lines and continuum . Non-published coefficients are used for the B'', $D' \rightarrow X$ lines.

2.2. Radiative transfer

Radiative transfer calculations are carried out to calculate the spectrum which emerges on top of the atmosphere. Absorption by CH_4 is taken into account. Self-absorption by vibrationnaly excited H_2 is modelled as proposed by [14].

3. Sensitivity study

We study the sensitivity of the H_2 auroral spectrum towards the energy of the electrons precipitated in the aurora. We point out a few lines which vary significantly with this energy and whose relative intensities can be used to constrain it.

We also study the variations of the spectrum with the initial angular distribution of electrons and we investigate how to constrain the direction of the precipitation.

We test our criteria by using them on available spectra.

4. Conclusion

A sensitivity study of line by line synthetic spectra of H_2 in the aurorae of Jupiter allows us to point lines that can be used as diagnostics of the energy and angular distribution of electrons precipitated in the aurorae.

References

[1] D. Rego, R. Prangé, and L. Ben Jaffel, "Auroral Lyman α and H_2 bands from the giant planets 3. Lyman α spectral profile including charge exchange and radiative transfer effects and H_2 color ratios," *Journal of Geophysical research*, vol. 104, pp. 5939–5954, Mar. 1999.

[2] B. Bhattacharya, R. M. Thorne, and D. J. Williams, "On the energy source for diffuse Jovian auroral emissivity," *Geophysical Research Letters*, vol. 28, pp. 2751–2754, July 2001.

[3] H. Menager, M. Barthélemy, and J. Lilensten, "H Lyman α line in Jovian aurorae: electron transport and radiative transfer coupled modelling," *Astronomy and Astrophysics*, vol. 509, pp. A56+, Jan. 2010.

[4] Y. L. Yung, G. R. Gladstone, K. M. Chang, J. M. Ajello, and S. K. Srivastava, "H_2 fluorescencce spectrum from 1200 to 1700 by electron impact : laboratory study and apllication to jovian aurora," *Astrophysical Journal*, vol. 254, 1982.

[5] R. Prangé, D. Rego, and J.-C. Gerard, "Auroral Lyman alpha and H2 bands from the giant planets. 2: Effect of the anisotropy of the precipitating particles on the interpretation of the 'color ratio'," *Journal of Geophysical research*, vol. 100, pp. 7513–7521, Apr. 1995.

[6] W. Liu and A. Dalgarno, "The Ultraviolet Spectra of the Jovian Aurora," *Astrophysical Journal*, vol. 467, pp. 446–+, Aug. 1996.

[7] V. Dols, J. C. Gérard, J. T. Clarke, J. Gustin, and D. Grodent, "Diagnostics of the Jovian Aurora Deduced from Ultraviolet Spectroscopy: Model and HST/GHRS Observations," *Icarus*, vol. 147, pp. 251–266, Sept. 2000.

[8] J. M. Ajello, D. E. Shemansky, W. R. Pryor, A. I. Stewart, K. E. Simmons, T. Majeed, J. H. Waite, G. R. Gladstone, and D. Grodent, "Spectroscopic Evidence for High-Altitude Aurora at Jupiter from Galileo Extreme Ultraviolet Spectrometer and Hopkins Ultraviolet Telescope Observations," *Icarus*, vol. 152, pp. 151–171, July 2001.

[9] R. Prangé, D. Rego, L. Pallier, J. Connerney, P. Zarka, and J. Queinnec, "Detailed study of FUV Jovian auroral features with the post-COSTAR HST faint object camera," *Journal of Geophysical research*, vol. 103, pp. 20195–20216, Sept. 1998.

[10] X. Liu, D. E. Shemansky, S. M. Ahmed, G. K. James, and J. M. Ajello, "Electron-impact excitation and emission cross sections of the H_2 Lyman and Werner systems," *Journal of Geophysical research*, vol. 103, pp. 26739–26758, Nov. 1998.

[11] X. Liu, D. E. Shemansky, H. Abgrall, E. Roueff, S. M. Ahmed, and J. M. Ajello, "Electron impact excitation of H_2: resonance excitation of $B^1Sigma_u^+(J_j = 2, v_j = 0)$ and effective excitation function of $EF^1\Sigma_g^+$," *Journal of Physics B Atomic Molecular Physics*, vol. 36, pp. 173–196, Jan. 2003.

[12] H. Abgrall, E. Roueff, F. Launay, and J.-Y. Roncin, "The $b\prime^1\Sigma_u^+ \rightarrow x^1\Sigma_g^+$ and $d^1\Pi_u^+ \rightarrow x^1\Sigma_g^+$ band systems of molecular hydrogen," *Canadian Journal of Physics*, vol. 72, pp. 856–+, 1994.

[13] H. Abgrall, E. Roueff, X. Liu, and D. E. Shemansky, "The Emission Continuum of Electron-excited Molecular Hydrogen," *Astrophysical Journal*, vol. 481, pp. 557–+, May 1997.

[14] C. Jonin, X. Liu, J. M. Ajello, G. K. James, and H. Abgrall, "High-Resolution Electron-Impact Emission Spectrum of H_2. I. Cross Sections and Emission Yields 900-1200 Å," *The Astrophysical Journal Supplement Series*, vol. 129, pp. 247–266, July 2000.