

Photoproduction of H_3^+ from gaseous methanol inside dense molecular clouds

S. Pilling¹, D. P. P. Andrade², A. C. F. Santos², and
H. M. Boechat-Roberty²

¹LNLS, Laboratório Nacional de Luz Síncrotron, São Paulo, Brazil.
email: sergiopilling@yahoo.com.br

²UFRJ, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil.
email: diana_andrade@ufrj.br, toni@if.ufrj.br, heloisia@ov.ufrj.br

Abstract. We present experimental results obtained from photoionization and photodissociation processes of abundant interstellar methanol (CH_3OH) as an alternative route for the production of H_3^+ in dense clouds. The measurements were taken at the Brazilian Synchrotron Light Laboratory (LNLS) employing soft X-ray and time-of-flight mass spectrometry. Mass spectra were obtained using the photoelectron-photoion coincidence techniques. Absolute averaged cross sections for the production of H_3^+ due to molecular dissociation of methanol by soft X-rays (C1s edge) were determined. The H_3^+ 's photoproduction rate and column density were been estimated adopting a typical soft X-ray luminosity inside dense molecular and the observed column density of methanol. Assuming a steady state scenario, the highest column density value for the photoproduced H_3^+ was about 10^{11} cm^2 , which gives the ratio photoproduced/observed of about 0.05%, as in the case of dense molecular cloud AFGL 2591. Despite the small value, this represent a new and alternative source of H_3^+ into dense molecular clouds and it is not been considered as yet in interstellar chemistry models.

Keywords. Methods: laboratory, molecular data, ISM: molecules, astrochemistry

1. Introduction

The H_3^+ ion plays an important role in diverse fields from chemistry to astronomy, for example in the chains of reaction that lead to the production of many of complex molecular species observed in the interstellar medium (Herbst & Klemperer 1973, Dalgarno & Black 1976, McCall *et al.* 1998 and references therein). A detailed review about this simplest stable interstellar polyatomic molecule could be found in Oka (2006).

In interstellar regions its main formation pathway occurs via ionization of molecular hydrogen by ubiquitous cosmic rays or local X-rays, followed by the efficient ion-neutral reaction, $\text{H}_2^+ + \text{H}_2 \rightarrow \text{H}_3^+ + \text{H}$. Its dominant destruction pathway occurs via proton-hop reaction with the abundant interstellar carbon monoxide, $\text{H}_3^+ + \text{CO} \rightarrow \text{HCO}^+ + \text{H}_2$. However, as pointed out by Maloney *et al.* (1996) and Koyama *et al.* (1996), dense clouds, mainly the ones with embedded protostars, the soft X-ray field may represents the dominant excitation/ionization source, penetrating great depths into molecular clouds.

2. Experimental methodology and results

In an attempt to simulate the effect of stellar soft X-ray flux on gaseous molecules inside dense clouds we have used synchrotron radiation as a light source. The measurements were taken at the toroidal grating monochromator (TGM) beamline at Brazilian Synchrotron Light Laboratory (LNLS), Brazil, employing soft X-rays photons over the C1s resonance energy range (200-310 eV). The incoming radiation perpendicularly intersects

the gas sample inside a high vacuum chamber. Conventional time-of-flight mass spectra were obtained using photoelectron and photoion coincidence (PEPICO) techniques. The complete description of the experimental setup can be found elsewhere (Boechat-Roberty *et al.* 2005, Pilling *et al.* 2006, 2007b).

Methanol is one of the most abundant molecules in the interstellar medium and in dense molecular clouds. Therefore, even despite the reduced production of H_3^+ from X-rays photodissociation process, it is reasonable to expect that at least a fraction of the detected H_3^+ in molecular clouds may be produced from this simple methyl compound molecule.

The averaged cross sections for H_3^+ production by soft X-rays photons at C1s resonance, were determined taking into an account the relative intensities of the H_3^+ 's dissociative channels on PEPICOs spectra and the respective simple ionization and double ionization cross section of the parent molecule (see details in Pilling *et al.* 2007a).

The H_3^+ 's photoproduction rate and column density were estimated by adopting a typical soft X-ray luminosity inside dense molecular cloud (Stäuber *et al.* 2005) and the observed column density of its most abundant parent ion, methanol. The values for H_3^+ 's photoproduction cross section due to the dissociation of methanol by photons over the C1s edge were about $1.4 \times 10^{-18} \text{ cm}^2$.

3. Conclusion

Assuming a steady state scenario and a typical X-ray luminosity of $L_x \gtrsim 10^{31} \text{ erg s}^{-1}$ as the case for AFGL 2591 (Stäuber *et al.* 2005), the highest column density value for the photoproduced H_3^+ was about 10^{11} cm^2 , which gives the ratio photoproduced/observed of about 0.05%. Despite the small value, this represents a new and alternative source of H_3^+ inside dense molecular clouds that has not been considered as yet in interstellar chemistry models. Better estimative for H_3^+ photoproduction rate depends of more accurate soft X-ray radiation field determinations.

Moreover, the energetic ionic products released by dissociation of CH_3X molecules, including the H_3^+ ion, become an alternative and efficient route to complex molecular synthesis, since some ion-molecule reactions do not have an activation barrier and are also very exothermic. We hope that these cross sections give rise to more precise values for some molecular abundances in interstellar clouds and even in planetary atmosphere models.

References

- Boechat-Roberty, H. M., Pilling, S., & Santos, A. C. F. 2005, *A&A*, 438, 915.
 Dalgarno, A. & Black, J. H. 1976, *Rep. Prog. Phys.*, 39, 573.
 Herbst, E., & Klemperer, W. 1973, *ApJ*, 185, 505.
 Koyama, K., Hamaguchi, K., Ueno, S., Kobayashi, N., & Feigelson, E. D. 1996, *PASJ (Letters)*, 48, L87.
 Oka, T. 2006, *PNAS*, 103, 12235.
 Maloney, P. R., Hollenbach, D. J., & Tielens, A. G. G. M. 1996, *ApJ*, 466, 561.
 McCall, B. J., Geballe, T. R., Hinkle, K. H., & Oka, T. 1998, *Science*, 279, 1910.
 Stäuber, P., Doty, S. D., van Dishoeck, E. F., & Benz, A. O. 2005, *A&A*, 440, 949.
 Pilling, S., Andrade, D. P. P., Neves, R., Ferreira-Rodrigues, A. M., Santos, A.C.F., & Boechat-Roberty, H. M. 2007a, *MNRAS*, 375, 1488.
 Pilling, S., Neves, R., Santos, A. C. F., & Boechat-Roberty, H. M. 2007b, *A&A*, 464, 393.
 Pilling, S., Santos, A. C. F., & Boechat-Roberty, H. M. 2006, *A&A*, 449, 1289.