High resolution infrared spectroscopy of ions of astrophysical interest: $H^{35}Cl^+$ and $H^{37}Cl^+$, investigated in a cold plasma

J. L. Doménech[1], I. Tanarro[1], Brian Drouin[2], V. J. Herrero[1], J. Cernicharo[3]

[1]*Inst. de Estructura de la Materia, CSIC, Serrano 123, 28006 Madrid (Spain)* i.tanarro@csic.es
[2]*Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109-8099 (USA)*
[3]*Inst. de Ciencia de Materiales de Madrid, CSIC, Sor Juana Inés de la Cruz 3, 28049 Cantoblanco (Spain)*

In this work we have accurately measured the frequencies of an extensive set of vibration-rotation lines of the v = 1←0 band of $H^{35}Cl^+$ and $H^{37}Cl^+$ in the mid-IR at high spectral resolution, using a difference frequency spectrometer and a hollow cathode discharge reactor. We have also performed an extended and improved isotope independent fit with mm-wave, optical and infrared data. The chloroniumyl cation, HCl^+, was identified for the first time in space in 2012 with the Herschel Space Observatory. Now that the Herschel mission is over, IR observations from ground platforms at high spectral resolution can be an alternative and complementary tool to the mm and sub-mm observations, and a way to build up in the study of HCl^+ and other hydrides.

1. Introduction

The study of interstellar hydrides has received a great push in recent years, much of it due to observations like that of HCl^+ [1,2] from the Herschel Space Observatory. Since hydrides are some of the first molecules to form in space from atomic gas and molecular hydrogen, they provide invaluable information about the environment in which they are found. With the end of the Herschel mission, IR observations from the ground may be one of the few available means to further study this ion in space.

In this work we provide accurate wavenumber measurements of 183 vibration–rotation lines of $H^{35}Cl^+$ and $H^{37}Cl^+$, measured with a difference-frequency laser spectrometer in a hollow cathode discharge, and provide a new and improved global fit of vis-UV, IR and mm-wave spectroscopic data that will aid in future studies of this molecule [3].

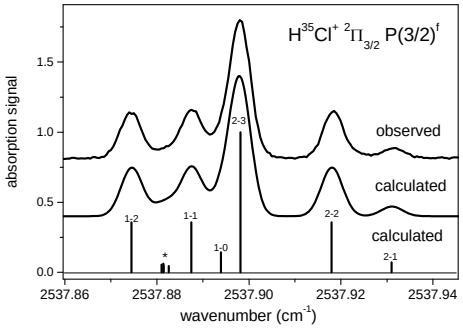
2. Experimental set-up

The experimental set-up was described earlier [4]. It is based on an infrared difference-frequency laser spectrometer and a dc modulated hollow cathode discharge reactor with multipass White cell configuration (22.4 m optical path length). The discharge current was 325 mA, with 400 V rms between electrodes. A flowing mixture of ~ 1 mbar He with traces of HCl (<0.001 mbar) was used as gas precursor. The cathode was refrigerated by water or cold N_2. Double modulation in amplitude of the discharge and the laser at two different frequencies in the kHz range, and phase-sensitive detection at the sum frequency, allowed discrimination of absorptions due to longer lived species in the plasma and IR background removal.

The IR radiation was generated by mixing the outputs of an Ar^+ laser and a tuneable ring dye laser in a $LiNbO_3$ crystal contained in a temperature-controlled oven, covering without gaps the 1900–4300 cm^{-1} region with ~ 1 mW IR power. The accuracy (3σ) in the IR frequency was 10 MHz (3.3×10^{-4} cm^{-1}). The instrumental resolution was ~3 MHz (10^{-4} cm^{-1}), so the observed line widths were limited by the Doppler effect.

3. Results

The region studied spanned the 2337–2774 cm^{-1} interval. Atmospheric CO_2 absorption hampered detections at lower frequencies. The figure shows some absorption lines of $H^{35}Cl^+$ as observed and predicted (sticks and convolution with a Gaussian function 0.0055 cm^{-1} FWHM). A kinetic temperature ~400 K was obtained for spectra recorded with water cooling and ~270 K for those recorded with nitrogen cooling of the cathode.



4. References

[1] DeLuca, M., et al. ApJL, 2012, 751, L37.
[2] Gupta, H., et al, ApJL, 2012, 751, L38.
[3] Domenech, J.L. et al. ApJL, 2016, 833, L32.
[4] Domenech, J.L. et al. ApJL, 2013, 771, L11.