Overtone spectroscopy of N_2H^+ molecular ions – application of cavity ring-down spectroscopy

Ábel Kálosi, Petr Dohnal, Dmytro Shapko, Radek Plašil, Juraj Glosík

Department of Surface and Plasma Science, Faculty of Mathematics and Physics, Charles University, Czech Republic

Introduction

Electron-ion recombination studies in afterglow plasmas – key factors [1,2]:

- Common value of temperatures
- Long-lived excited species in the afterglow
- Heating of the electron gas:
  - Superelastic collisions
  - Penning ionization

N_2H^+ in H_2/N_2 containing plasmas [3]:

Production:

$$H_3^+ + N_2 \rightarrow N_2H^+ + H_2 + 0.73\ \text{eV}$$

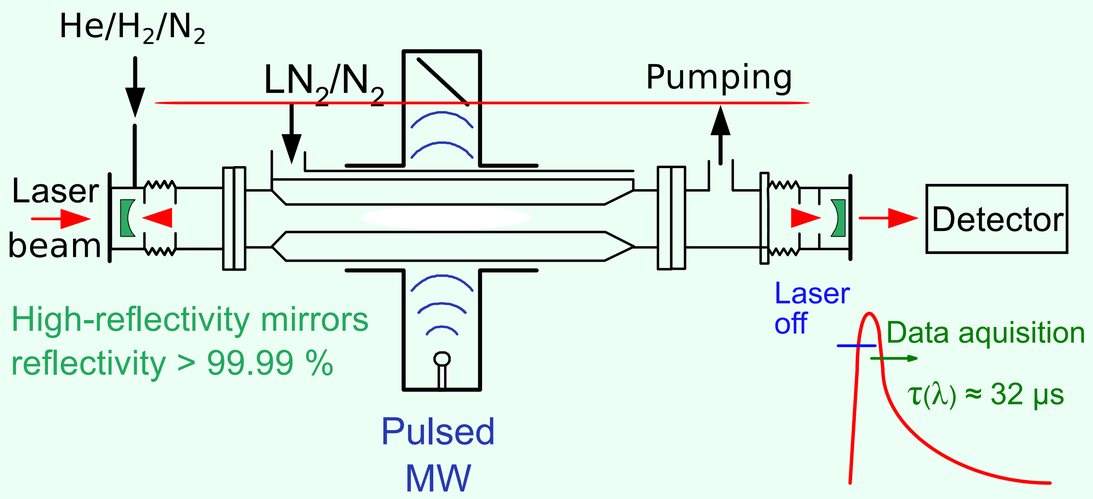
$$N_2^+ + H_2 \rightarrow N_2H^+ + H + 2.63\ \text{eV}$$

Recombination:

$$N_2H^+ + e^- \rightarrow N_2 + H + 8.47\ \text{eV}$$

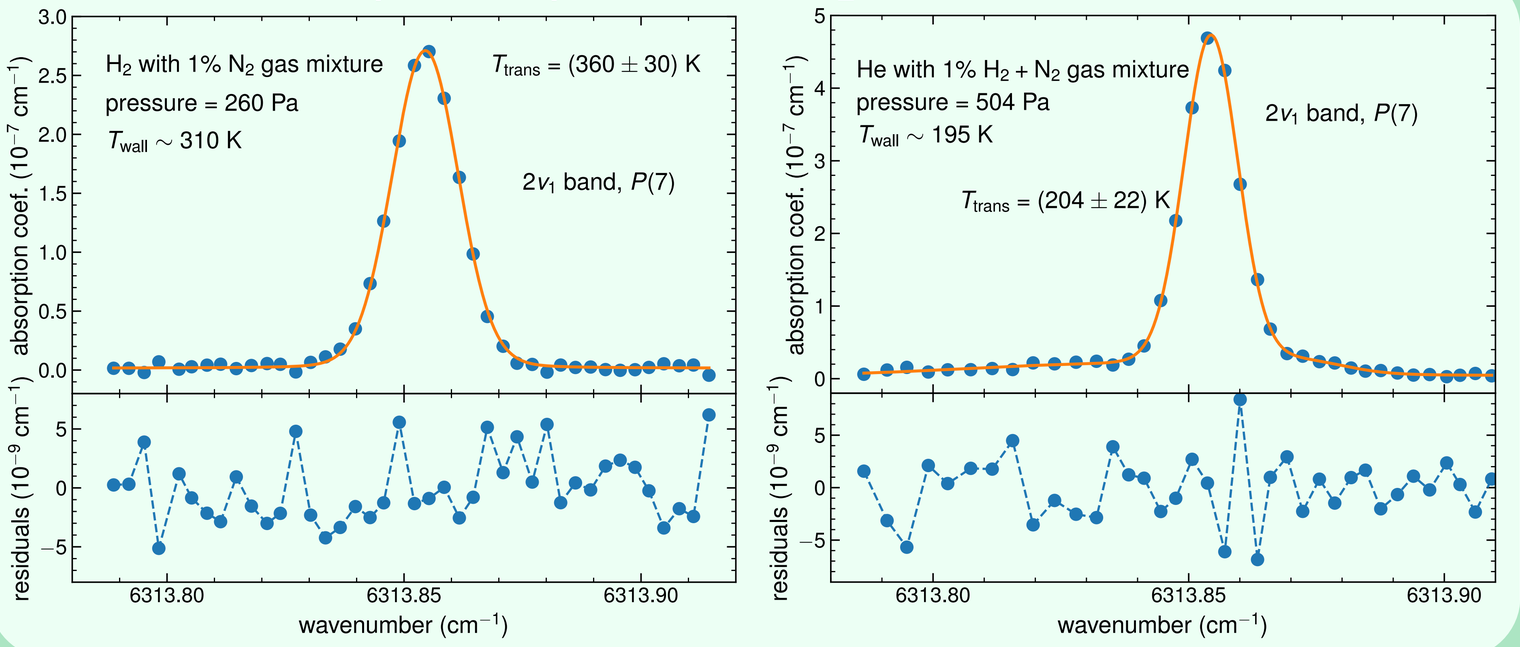
$$N_2H^+ + e^- \rightarrow NH + H + 2.4\ \text{eV}$$

CRD Absorption Spectroscopy

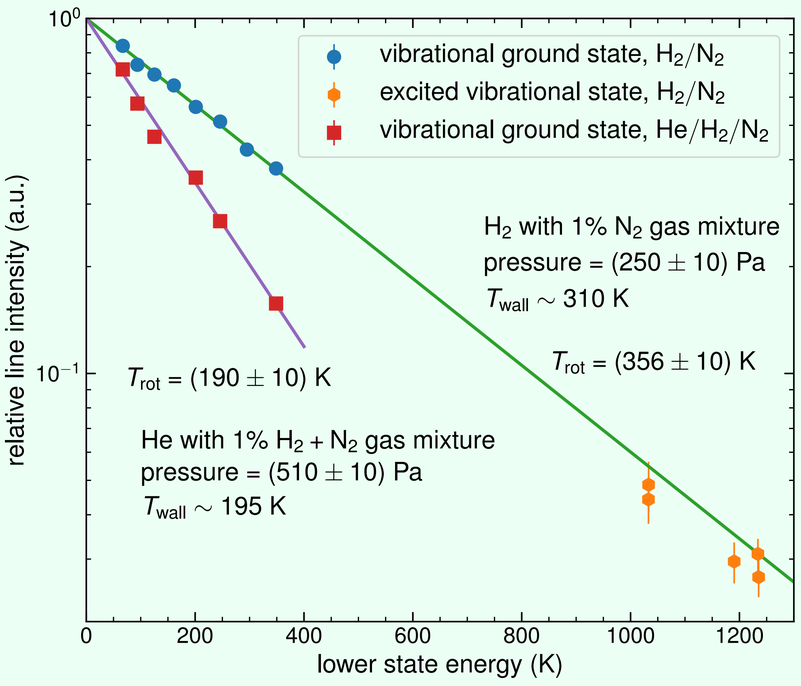


- Ions, electrons and excited neutrals produced by low-power microwave discharge
- Discharge tube cooled by liquid nitrogen or nitrogen gas: $T_{\text{wall}} = 77 - 300$ K
- Source of radiation: infrared laser diodes (DFB and external cavity) ~ 1550 nm

Absorption spectra of N_2H^+



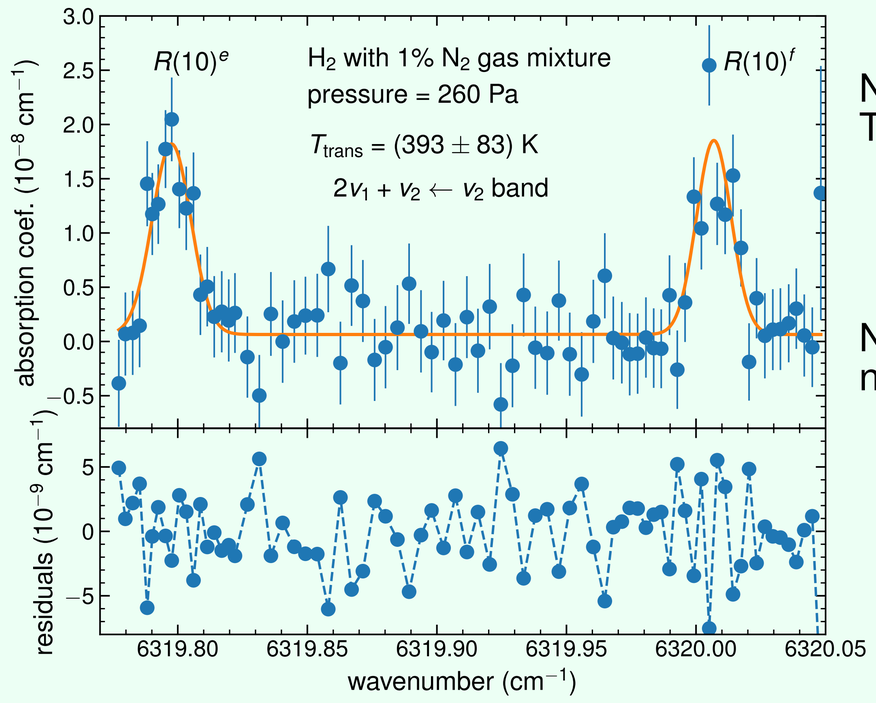
Boltzmann plot



Relative line intensity:

$$I_{\text{rel}} = \exp\left(-\frac{E(v,J)}{kT_{\text{rot}}}\right)$$

Vibrationally excited states



N_2H^+ vibrational state structure – Three normal modes:

- ν_1 N–H stretch
- ν_2 degenerate bending mode
- ν_3 N–N stretch

N_2H^+ vibrational bands near-infrared – around 1550 nm:

- $2\nu_1$ first overtone band
  $2\nu_1$ observed by Sasada and Amano [4]
- $2\nu_1 + \nu_2 \leftarrow \nu_2$ combination hot band
  newly observed transitions

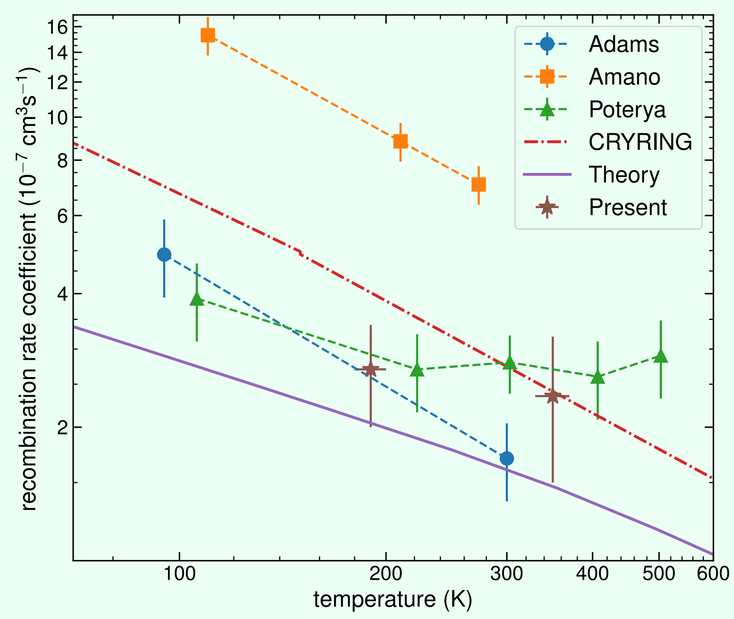
Linelist - $2\nu_1$ band

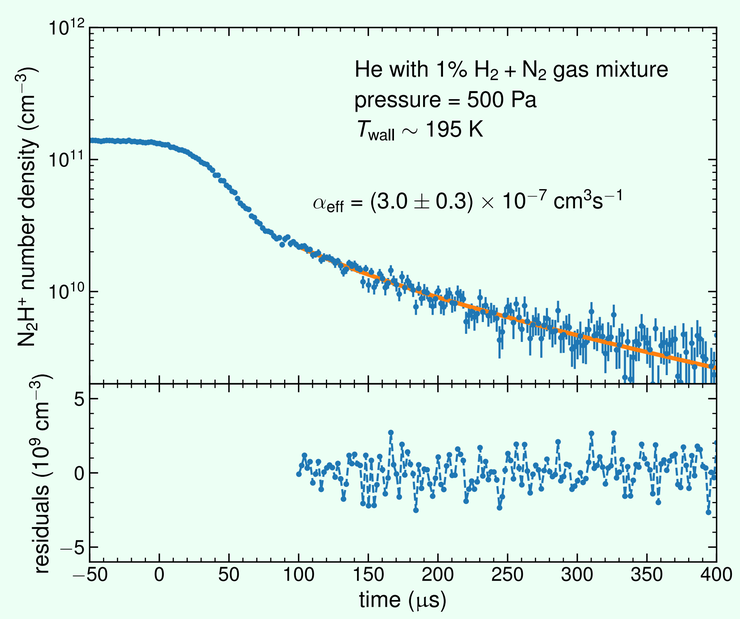
Assignement	Observed	Calculated
$P(5)$	6320.6311	6320.6310
$P(6)$	6317.2682	6317.2681
$P(7)$	6313.8544	6313.8545
$P(8)$	6310.3902	6310.3902
$P(9)$	6306.8752	6306.8753
$P(10)$	6303.3097	6303.3098
$P(11)$	6299.6940	6299.6939
$P(12)$	6296.0276	6296.0276

Ground state molecular parameters adapted from [5]
Upper state parameters determined by a linear fit to the energy expression

$$E(v,J) = G(v) + B(v)J(J+1) - D(v)[J(J+1)]^2$$

Recombination: previous and preliminary results





Acknowledgments: This work is partly supported by Czech Science Foundation projects GACR 17-08803S, GACR 15-15077S, GACR 17-18067S and by Charles University Grant Agency project GAUK 1583517.

References:

[1] M. Hejduk et al., *J. Chem. Phys.* **143**, 044303 (2015)
[2] Á. Kálosi et al., *Eur. Phys. J. Appl. Phys.* **18**, 23549 (2016)
[3] N. G. Adams et al., *J. Chem. Phys.* **98**, 4564 (1994)
[4] H. Sasada et al., *J. Chem. Phys.* **92**, 2248 (1990)
[5] S. Yu et al., *J. Mol. Spectros.* **314**, 19 (2015)