Precision Spectroscopic applications of cold molecular ions

Xin Tong[a], Zhen-Xiang Zhong[a] and Stefan Willitsch[b]

[a] *State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan 430071, China*
[b] *Department of Chemistry, University of Basel, Klingelbergstrasse 80, CH-4056 Basel, Switzerland*

Cold molecular ions prepared by sympathetic cooling with laser-cooled atomic ions in an ion trap represent attractive systems for new spectroscopic experiments. The long trapping times (up to hours) and state lifetimes (up to minutes) [1,2] in an almost perturbation-free environment enable the long interaction times required for the study of "forbidden" spectroscopic transitions which have not been accessible before in molecular ions.

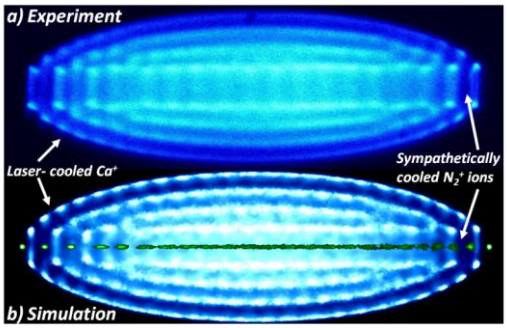

Figure 1: Bi-component Coulomb Crystal of Ca^+ and state-selected N_2^+ ions.

Here, we report the first direct observation of electric-dipole-forbidden, quadrupole- allowed infrared transitions in a molecular ion (N_2^+ in our case) [3], more than 60 years after such transitions have first been observed in a neutral molecule. The detection of these extremely weak transitions was enabled through a combination of the state-selective preparation of the molecular ions, their sympathetic cooling into the near-perturbation-free environment of a Coulomb crystal and the application of a highly sensitive charge-transfer detection scheme. The observed transitions in molecular ions can exhibit very small natural linewidths, rendering them ideal for spectroscopic precision experiments [4].

[1] X. Tong, A. Winney, and S. Willitsch, *Phys. Rev. Lett.* **105**, 143001 (2010).
[2] X. Tong, D. Wild, and S. Willitsch, *Phys. Rev. A* **83**, 023415 (2011).
[3] M. Germann, X. Tong, and S. Willitsch, *Nature Phys.* **10**, 820 (2014).
[4] Z.-X. Zhong, X. Tong, Z.-C. Yan, T.-Y. Shi, *Chin. Phys. B* **24**, 053102 (2015).