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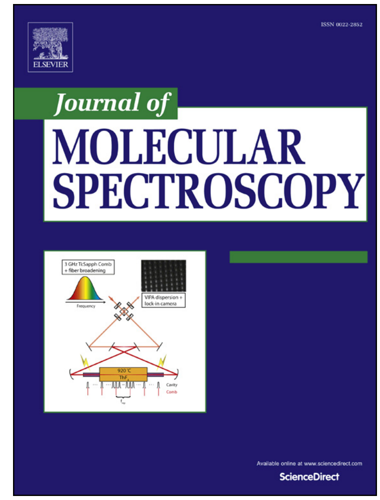

Double resonance rotational action spectroscopy of cold H_2D^+ and D_2H^+

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Double resonance rotational action spectroscopy of cold H_2D^+ and D_2H^+

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A double resonance action spectroscopic method has been applied to measure low-J rotational transitions of H_2D^+ and D_2H^+ up to frequencies of 1.5 THz. The uncertainties of two known lines of H_2D^+ and three known lines of D_2H^+ have been improved substantially, and the $2_{11} \leftarrow 2_{12}$ H_2D^+ transition measured for the first time. In addition, we derived spectroscopic parameters for both molecular cations using the Euler formalism.

Keywords: ion trap, rotational spectroscopy, THz spectroscopy, double resonance, H_2D^+, D_2H^+

INTRODUCTION

Spectroscopy in ion traps offers the advantage of cryogenic operation, long interaction times, and mass selectivity. Therefore, several action spectroscopic schemes have been set up in recent years to exploit these advantages for rotational spectroscopy, examples being laser induced reaction [1] and rotational state-selective attachment of He [2, 3]. Also recently, double resonance schemes have been developed, in which the frequency of a laser is kept fixed on a rovibrational or even electronic transition probing a rotational ground state level, resulting in a detectable constant signal. A (sub)mm wave radiation source then excites a rotational transition starting or ending at the probed level, thus decreasing or increasing the population of the probed level, respectively. A rotational line is then recorded by scanning the (sub)mm wave frequency. Such a rotational scheme, applied in a 22-pole ion trap, has been first demonstrated for H_2D^+ [4]. Later such schemes have been extended to systems such as OH^- [5], OD^- [6], CH_2D^+ [7] and CD_2H^+ [8].

In this contribution, we apply the rotational-rovibrational double resonance scheme to six transitions of H_2D^+ and D_2H^+, and provide improved molecular parameters. These ions are important astronomical probes, in particular for cold prestellar and protostellar sources, and therefore their rotational transitions are well-studied in the laboratory [1, 9–16]. There have been astronomical detections for the lowest ortho- and para-H_2D^+ transitions [17–19], as well as for the fundamental para-D_2H^+ transition [18, 20]. Recently, also the fundamental ortho-D_2H^+ transition at 1.47 THz has been detected in IRAS 16293-2422 with the SOFIA airborne telescope [21]. The frequencies for all these important transitions are confirmed and refined in this work, leading to a secured velocity determination for astronomical applications.

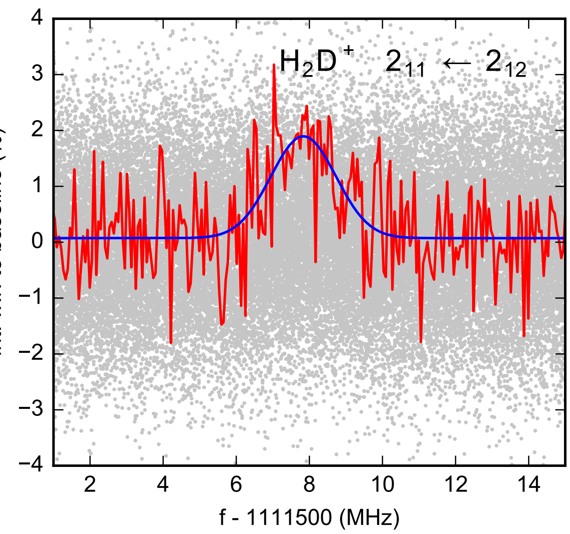

FIG. 1. Measurement of the $2_{11} \leftarrow 2_{12}$ rotational transition of H_2D^+. For the ro-vibrational excitation, the transition $1_{10} \leftarrow 2_{11}$ of the ν_1 vibrational band at 2887.3707 cm^{-1} [22, 23] has been chosen. Due to the low population of the probed 2_{12} level the signal was extremely weak, making a total acquisition time of 21 hours necessary. Gray dots represent measured data points (H_3^+ counts), the red line averaged data binned into 6 kHz intervals (magnified by a factor of 10), and the blue line represents the Gaussian fit with center frequency 1111507.837(92) MHz and temperature 27.8(6) K.

EXPERIMENTAL SETUP

As the 4 K 22-pole ion trapping machine [24] as well as the IR - mm-wave double resonance technique [5] are described in the literature, only a brief description is given here. The ionic species (H_2D^+ or D_2H^+) have been generated in a storage ion source, and several thousands of them injected and cooled in a 22-pole ion trap [25]. During the trapping time of about 700 ms, the ionic species were exposed to hydrogen gas, as well as to the cw IR and submm wave beams traversing the trap. The two beams were superposed by a focusing mm-wave elliptical mirror