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ELECTRON COLLISIONS IN HARSH ENVIRONMENTS

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Abstract.
We present our most recent **R**-matrix calculations on the electron-impact rotational excitation of astronomically important molecules. We show that electron collisions are very efficient in producing rotationally 'hot' molecules in harsh environments.

1 Introduction

Rate coefficients for the collisional excitation of molecules by electrons are crucial parameters for modelling the physical conditions of harsh environments such as diffuse interstellar clouds or photo-dissocation regions (PDRs), where electrons are abundant (Black 1998). In fact, even at modest electron fractions, $n(e)/n(H) \approx 10^{-5}$, electron collisions can dominate the molecular excitation because electron-impact collisional rates exceed that for excitation by neutral species (mainly H, He and H_2) by typically 5 orders of magnitude.

The reference methods for obtaining electron-impact excitation rates have been the Coulomb-Born approximation for molecular ions and the Born approximation for neutral species. These methods assume that the collisional excitation rates can be simply determined by the dominant long-range interaction. Within this approach, these theories predict that only single jumps in rotational quanta are allowed for polar species. Recent **R**-matrix studies have shown that this prediction is incorrect (Faure & Tennyson 2003 and references therein). Indeed, **R**-matrix calculations have shown that the inclusion of short-range interactions can lead to rotational transitions with ΔJ up to 6.

2 Results

In environments below the critical density, it has often been assumed that molecular ions rotationally excited by electron impacts will emit $j = 1 \rightarrow 0$ photons only.

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Our recent **R**-matrix calculations have shown that in all cases considered so far a significant flux from higher rotational states should also be emitted. In particular, Faure & Tennyson (2003) have shown that electron collisions might contribute to the pumping of a maser in the (4, 4)→ (3, 1) transition of H_3^+ at 217 GHz.

In the case of H_2O, Faure et al. (2003) have found that the dominant transitions are those for which $\Delta J = 0, \pm 1$, as predicted by the dipolar Born approximation. However, a pure Born treatment was found to overestimate the cross sections close to threshold energies (see figure) and to neglect important dipole-forbidden transitions. In the context of cometary water, the contribution of electron collisions might thus explain the need for large H_2O-H_2O collisional excitation rates in population models which neglect electrons.

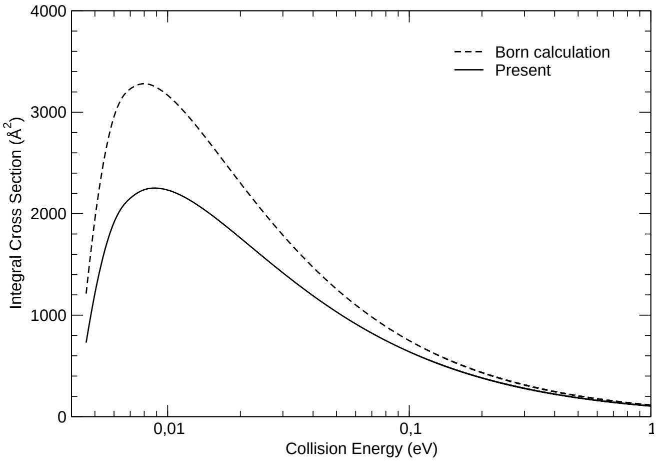

Fig. 1. Rotational excitation cross section for the $0_{00} - 1_{11}$ transition in H_2O. Our results are represented by the solid line. The dashed line gives the pure Born calculation.

3 Conclusion

We have shown that electron-impact excitation is a very efficient process to rotationally excite molecules in harsh environments. An important prediction concerns the contribution of electron collisions to the pumping of cosmic masers.

References

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