Nuclear spin symmetry conservation in H_2O water vapor cooled in a supersonic expansion

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The nuclear spin temperature (NST) deduced from the observation of hydrogenated molecules desorbed from cometary ices seems to disagree with the temperature expected for the environment in which the comets were formed [1]. The measured NST value of ~30 K is not properly understood and several hypotheses have been formulated to explain such a high value [2-4]. The relaxation process of the nuclear spin molecules in the gas phase is probably one of the key problems.

An introduction into the recent studies of nuclear spin isomers conversion (NSC) in water vapor can be found in the recent paper from Manca Tanner et al. [5]. The results reported in this study showed a rapid change in the spin-isomers state in a supersonic expansion of H_2O water vapor seeded in argon. Whereas at a low water vapor molar fraction the nuclear spin symmetry was conserved, at higher water molar fractions the *ortho* to *para* ratio (OPR) was seen to be completely relaxed, i.e., the measured OPR responded to a low rotational temperature in expansion. This fast relaxation cannot be explained by intramolecular processes in an individual water molecule and was thus interpreted as a result of water cluster formation, which is able presumably to significantly facilitate nuclear spin conversion (NSC).

We performed a new experiment based on the Jet-AILES supersonic-jet apparatus implemented on the AILES beamline at SOLEIL to investigate the water clustering effect on NSC [6]. Despite the presence of the water cluster signatures in our obtained spectra, no transition to a nuclear spin relaxation regime was observed: the OPR derived from the spectra was conserved on a level characteristic of equilibrium conditions in the stagnation reservoir, that is, the OPR was always equal to 3 irrespective of the extremely low rotational temperature achieved in the supersonic expansion. In addition, no change in OPR was observed when the argon carrier gas was replaced by oxygen. The latter is known to enhance nuclear spin relaxation because of its associated magnetic moment. On the basis of the results obtained, we are in a position to dismiss the hypothesis of a water clustering effect on nuclear spin relaxation and to question the origin of the nuclear spin relaxation reported previously [5].

References

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