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Preliminary results for the 5–20 cm wavelength opacity of ammonia pressure broadened by water vapor under jovian conditions

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Abstract

At least one laboratory measurement study indicates that water vapor can efficiently broaden the 572 GHz rotational transition of ammonia [1], and this could be true for the inversion transitions of ammonia as well. Water vapor is the fourth most abundant constituent deep in the atmospheres of the jovian planets after hydrogen, helium, and methane [2]. While the broadening effects of the first three constituents on the ammonia absorption spectrum are now well characterized, it is critical to investigate any possible pressure broadening effects of water vapor on the ammonia absorption spectrum. Experimental investigation of the pressure broadening of the inversion lines of ammonia by water vapor in the microwave region is currently being performed. Over 500 measurements of the microwave properties of ammonia broadened by water vapor in a hydrogen/helium atmosphere have been conducted at pressures up to 100 bars and temperatures in the 375–500 K range. On the basis of the data obtained in this work, an empirical estimation of the broadening of ammonia by water vapor has been obtained. These measurements will directly aid in the accurate interpretation of the observed microwave emission spectra of the jovian planets, and also improve retrievals of the atmospheric abundance of water vapor at Jupiter from the Juno microwave radiometer (MWR) measurements.

1. Introduction

Gaseous ammonia contributes to strong absorption in the jovian planets in the microwave region because of the pressure broadening (self and foreign gas) of its strong inversion transitions around 1.25 cm. Hence, knowledge of the opacity of gaseous ammonia directly impacts the accuracy of interpretation of the observed emission spectra of the jovian atmospheres. Current ammonia opacity models for jovian conditions [3, 4, 5] account for the self-broadening and foreign-gas-broadening due to hydrogen and helium. However, water vapor with its large broadening cross-section (collision diameter) can effectively broaden the inversion transitions of ammonia. Understanding the enhanced opacity of ammonia due to the presence of water vapor is crucial to the determination of the abundance of water vapor present in the jovian atmospheres.

2. Measurements

The reduction in the quality factor (Q) of a resonant mode of a resonator in the presence of a lossy gas is used to measure the absorption of the gas [4]. The measurement system used to study the enhanced opacity of ammonia due to the presence of water vapor in a hydrogen/helium environment is similar to the one presented in an accompanying paper (see, Devaraj and Steffes, 2011). Measurements are currently being made of the opacity of $NH_3 + H_2O + He + H_2$ mixture under jovian conditions at pressures up to 100 bars in the 375–500 K temperature range. Over 500 measurements of the opacity of ammonia in a water vapor/hydrogen/helium atmosphere have already been completed. Based on the initial measurements, a preliminary model of the opacity of ammonia broadened by water vapor/hydrogen/helium has been developed. Figure 1 shows an example of the measured opacity for a mixture of $NH_3 + H_2O$ and the modeled intrinsic opacity exclusively from NH_3 (see accompanying paper, Devaraj and Steffes, 2011), and exclusively from H_2O [6], along with the preliminary model that includes the interaction between NH_3 and H_2O. Figure 2 shows an example of the measured opacity for a mixture of $NH_3 + H_2O + He$ and the modeled opacities computed from currently existing models for NH_3 and H_2O along with the preliminary model. It can be seen from these figures that there is an additional enhancement of the measured opacity because of the in-

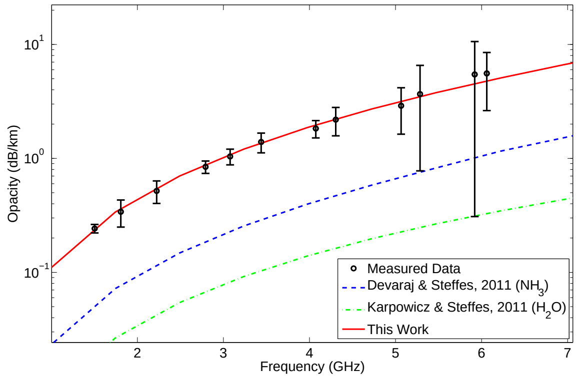

Figure 1: Opacity data measured for a mixture of NH_3 = 8.71% and H_2O=91.29% at a pressure of 1.041 bars and a temperature of 452 K along with the models

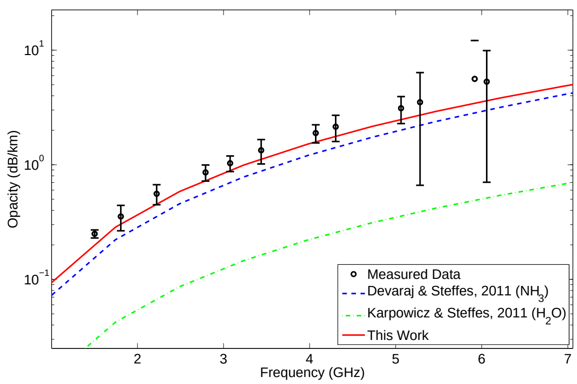

Figure 2: Opacity data measured for a mixture of NH_3 = 0.29%, H_2O = 6.76%, and He=92.96% at a pressure of 16.094 bars and a temperature of 452.5 K along with the models

teraction between NH_3 and H_2O.

3. Conclusions

Based on these results, it is clear there is a necessity to understand the enhancement of the opacity of ammonia due to the presence of water vapor. From preliminary measurements, it is estimated that the broadening effects of 1 bar of H_2O is equivalent to 10 bars of H_2 on the ammonia spectrum. An accurate ammonia opacity model for jovian atmospheres should include the effects of broadening from H_2, He, and H_2O. Current and future measurements of the properties of NH_3 in a $H_2 + He + H_2O$ atmosphere under jovian conditions can be used to create an empirical model that more accurately characterizes the microwave properties of ammonia. The results of this study will enable more accurate interpretation of the microwave radiometer (MWR) measurements from the NASA Juno mission for the successful determination of the deep abundance profiles of ammonia and water vapor at Jupiter.

Acknowledgements

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