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The 2-4 Millimeter-Wavelength Opacity of Ammonia

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A new laboratory system capable of measuring the 2-4 millimeter-wavelength properties of gases has been developed at Georgia Tech. A times-six active multiplier chain and/or a frequency tripler are used to generate the high frequency signals and various harmonic mixers are used with a spectrum analyzer for detecting the signals. A fully confocal Fabry-Perot resonator enclosed in a glass tube capable of withstanding 3 bars of pressure is used to make the measurements. Over 1000 laboratory measurements of the 2-4 millimeter-wavelength opacity of ammonia have been made under simulated Jovian atmospheric conditions using the new laboratory system (Devaraj and Steffes, B.A.A.S., 41, 2009). These laboratory measurements were made of various gas mixtures of hydrogen (~77.5-85.5%), helium (~12.5-13.5%), and ammonia (1-10%) at pressures between 0.5 bar and 3 bars and temperatures between 200K and 300K. Laboratory measurements were also made of the opacity of pure ammonia at pressures between 50 mbar and 1 bar and temperatures between 200K and 300K. These measurements have given an insight into the behavior of the inversion, rotational and 2 roto-vibrational lines of ammonia in the millimeter-wavelength region. Furthermore, the 140 GHz 2 line of ammonia which has thus far only been theoretically predicted (Shimizu, J. Chem. Phy., 51, 1969) has been directly measured in the laboratory.

Using these measurements, a new model has been developed to accurately characterize the absorption of ammonia in the 2-4 millimeter-wavelength region. The new model for the hydrogen/helium-broadened ammonia opacity uses a modified Ben-Reuven lineshape for the inversion, rotational and 2 roto-vibrational lines of ammonia and is valid for temperatures ranging from 180-300 K and pressures up to 3 bars in the 2-4 millimeter-wavelength region. These measurements and the model will help to better interpret the millimeter-wave emission spectrum of the Jovian planets and will also help predict the potential effects of the rotational lines and the 2 roto-vibrational lines on the centimeter-wave emission from the deepest levels of those atmospheres.

The new ammonia opacity model was used in a radiative transfer model of Jupiter and the disk averaged brightness temperature was obtained. The output brightness temperature shows a reduction of at least 1K at the 140 GHz roto-vibrational line of ammonia. The new ammonia opacity model and the measurements along with the radiative transfer model results will be presented.

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