A Determination of Jovian Ammonia Abundance Based on a 2 μm Spectrum

SUNIL SARANGI[1]

Infrared Astronomy Group, Physical Research Laboratory, Navrangpura Ahmedabad 380 009, India

AND

J. S. MARGOLIS[2]

Jet Propulsion Laboratory, Pasadena, California 91103

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A spectrum of Jupiter in the two micron region has been analyzed to determine the Jovian ammonia abundance. The result is a $\simeq$4 cm − amagat, assuming an airmass factor $\eta = 2.5$ and a single effective reflecting layer for this wavelength. This is compared with the abundances observed at other wavelengths.

INTRODUCTION

Ammonia has been recognized as a component of the Jovian atmosphere since 1931 (Wildt). It is apparent from studies of the Jovian spectrum in the visible and infrared wavelengths, as well as at microwave frequencies, that there is a strong wavelength dependence (really a band strength dependence) of the abundance of ammonia observed (Cruikshank and Binder, 1969). This is true also for methane and this type of behavior is taken to be good evidence for the occurrence of clouds in the Jovian atmosphere. In fact, quantitative observations of this wavelength dependence, as well as the center-to-limb variation of the abundance may be used to infer the nature of the clouds on Jupiter. We have analyzed a 2 μm spectrum of Jupiter obtained by Martin (1975) to determine the abundance of ammonia at this wavelength. It is the purpose of this note to present the result and to compare it with the ammonia abundance observed at other wavelengths.

ANALYSIS

Martin has obtained a 0.5 cm^{-1} resolution Fourier transform spectrum of Jupiter at two microns which he used to analyze the broad $S(1)$ line of the collision induced fundamental of hydrogen at 4750 cm^{-1}. However, the $(\nu_3 + \nu_4)$ perpendicular band of ammonia appears in the short wavelength wing of the hydrogen absorption. This is illustrated in Fig. 1. The strongest features are the Q-branches and clusters of ^PP and ^RR lines. This band has been measured and analyzed by Sarangi (1977a,b) using laboratory spectra of 0.05 cm^{-1} resolution. Sarangi was able to make quantum number assignments to many of the lines

[1] Present address: Cryogenic Engineering Center, Indian Institute of Technology, Kharagpur 721 302, India.

[2] To whom correspondence should be addressed.

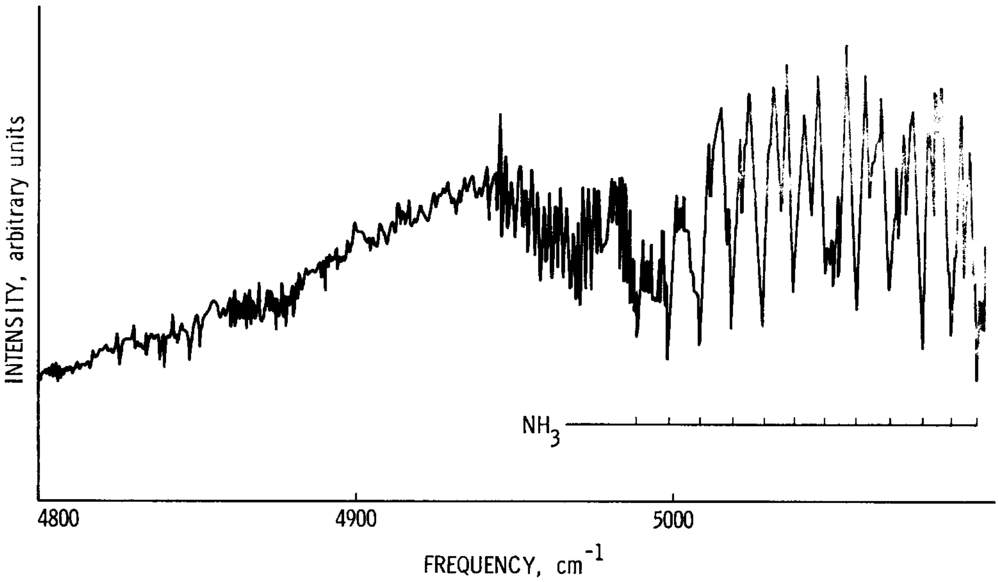

FIGURE 1

and also obtained a value of 17.2 cm^{-2} atm^{-1} at 296°K for the band strength of the perpendicular component alone. The parallel component of this band is observed to be very weak in the laboratory spectrum. With the resolution of Martin's spectrum there are no unblended features observable, and all ammonia absorption features represent blends of many individual lines. This situation results in the relative strengths of the absorption features being rather insensitive to temperature, making it difficult to derive a rotational temperature for the observations. The problem of determining abundance, though relatively simpler, is complicated due to the lack of knowledge about the effective rotational temperature and pressure, and also to the presence of clouds, hazes, and holes in the clouds (Prinn and Owen, 1976).

Ten distinct absorption features have been identified and measured in Martin's

TABLE I

LEVELS OF LINE FORMATION IN JOVIAN ATMOSPHERE FOR THE 2-MICRON AMMONIA BAND

Manifold	Frequency interval (cm^{-1})	Equivalent width (cm^{-1})	NH_3 abundance (cm amagat)	Pressure (atmos.)	Temperature (°K)
1	4993.50–4999.95	1.77	8.45	0.393	133.7
2	5001.20–5010.45	3.14	13.40	0.432	137.0
3	5012.90–5020.40	2.25	3.78	0.333	128.9
4	5023.95–5030.40	1.75	3.66	0.331	128.8
5	5034.20–5040.50	1.75	3.44	0.327	128.5
6	5044.70–5052.50	3.24	6.50	0.375	132.2
7	5053.50–5059.40	1.62	3.04	0.321	128.0
8	5063.45–5069.80	1.99	3.44	0.327	128.5
9	5073.80–5079.10	1.95	3.52	0.328	128.6
10	5082.80–5090.20	2.27	4.10	0.337	129.3

spectrum within the frequency interval between 4990 and 5090 cm^{-1}. On both sides of the interval the spectrum is badly contaminated with terrestrial carbon dioxide and water vapor bands. The terrestrial absorption was subtracted with the help of a comparison lunar spectrum. The measured equivalent widths for the ten manifolds are given in Table I. Each individual absorption feature is a blend of a manifold of lines.

Synthetic spectra were constructed using the frequencies and intensities reported by Sarangi (1977a,b), the atmospheric model of Trafton and Stone (1974), the ammonia vapor pressure data of Honig and Hook (1960), and an airmass factor $\eta = 2.5$, assuming the level of the reflecting layer to be a variable parameter. The NH_3 partial pressure was taken to be equal to the saturated vapor pressure at the corresponding temperature in the Jovian atmosphere. If the NH_3 vapor is reduced below this (Tomasko, 1974) the temperature and pressure of the effective reflecting layer will be increased. The level at which the computed equivalent width was the same as the measured value was calculated by interpolation for each manifold. The temperature, pressure and the integrated ammonia abundance above this level are given in Table I.

The results for manifolds 1 and 2 are much different from the rest and are probably incorrect due to strong contamination with terrestrial CO_2 bands. The rest of them give an average abundance of 3.9 ± 1.1 cm amagat which corresponds to a level of 0.334 atm and 129°K, according to the model of Trafton and Stone.

DISCUSSION

The uncertainty in this result is high (as much as 50%) due to the difficulty in the determination of the baseline used to measure the equivalent widths of the absorption features, the presence of terrestrial absorption, and the presence of many unidentified weak lines in the ammonia spectrum which have not been accounted for. However, this result is strikingly lower than the abundance $\eta\alpha \simeq 1600$ cm − amagat determined from the 645 nm band (Young and Margolis, 1976; Woodman *et al.*, 1977) and at other wavelengths reported by Cruikshank and Binder (1969). It should be noted here that Martin got a low value of hydrogen abundance at this wavelength. Such apparent low abundances may result from line formation higher in the atmosphere as a result of scattering by cloud particles (Prinn and Owen, 1976). These features may be explained by the two layer cloud model of Danielson and Tomasko (1969) and by more complex models involving presence of upper atmospheric dust.

It should also be noted that the model of Trafton and Stone, used here for the determination of the ammonia abundance, neglects the effect of clouds in the atmosphere. But they have pointed out that even if the effect of clouds is taken into account the resulting thermal structure will not be much different from the one used here.

The spectral resolution of Martin's spectrum, the only one available at two microns, is too low to base a more quantitative analysis. We look forward to improvements in both spectral and spatial resolution in the Jovian spectrum.

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