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HIGH SENSITIVITY SURVEY OF NH_3 IN THE SOUTHERN HEMISPHERE

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ABSTRACT

Microwave emission associated with the para form of ammonia, in the (1,1) line, was searched in the direction of 46 southern sky positions where strong H_2CO absorption or strong H_2O maser emission was observed previously. The results of those observations are presented with 17 new sources discovered.

I. INTRODUCTION

The detection of microwave emission from the inversion doublet of the lowest metastable rotation level (J,K) = (1,1) of ammonia was reported by Cheung *et al.* (1968). It was the first of a now long list of polyatomic molecules detected in our Galaxy.

In the frequency range of the spectrum from 21 to 25 GHz, ammonia presents several transitions between inversion doublets of metastable states which are of great astrophysical interest. The comparison of their intensities gives an idea about the kinetic temperature of the gas in the molecular cloud. Also the optical depth can be determined by comparing the intensities of the main and satellite hyperfine components that are relatively strong in the lowest J state.

Due to the importance of this molecule,

extensive searches for ammonia sources have been undertaken in the Northern Hemisphere, for example by Schwartz *et al.* (1977) and MacDonald *et al.* (1980).

In the Southern Hemisphere the first efforts to study interestellar ammonia was performed by Batchelor *et al.* (1977) using the Parkes antenna. The radiometer utilized was relatively noisy and they were able to discover four new sources.

Here we present the results of a sourvey for ammonia emitters in the southern sky, performed with a low noise receiver and high gain antenna. 17 new sources were discovered.

II. EQUIPMENT

Observations were carried out in November 12-17, 1980, at Itapetinga Radio Observatory using a 13.7-meter radome-enclosed radio-telescope.

The front-end used for these observations had a K-band travelling wave maser constructed at Haystack Observatory* as a preamplifier, followed by a conventional mixer with a phase locked oscillator (Kaufmann *et al.* 1977). With this configuration the complete system noise temperature (including sky) ranged from 250 to 300 K yelding a peak-to-peak antenna temperature of 0.3K in each integration of 30 minutes duration. We have adapted the rest frequency from Lovas *et al.* (1979).

* The Haystack Observatory of the Northeast Radio Observatory Corporation is partially supported by the U.S. National Science Foundation.

The observing mode used was the ON-ON, beam switching technique, positioning the source from one horn to the other one every minute. The two horns were separated approximately 20 arc minutes in azimuth. The antenna beam width at this frequency (23.7 GHz) is 3.7 arc minutes. All observations were made under good weather conditions. The atmospheric attenuation was assumed to be ~0.2 and the radome transmission was 0.77. The beam efficiency is estimated to be ~0.8, based on measurements at 22.2 GHz.

III. RESULTS

The aim of this survey was to observe as many sources as possible, all situated in the portion of the Galactic Plane observable only from the Southern Hemisphere. A detection limit of 0.2 K to be achieved with two independent 30 min observations was established.

Among hundreds of catalogued candidates, 46 sources of two different types were selected: (a) all the strong H_2O maser listed by Batchelor *et al.* (1980) and by Scalise and Braz (1980), and (b) all the Galactic positions where H_2CO absorption stronger than 0.5 K was detected by Whiteoak and Gardner (1974).

Table I (Positive Results) presents the source name in Galactic coordinates, the equatorial coordinates for 1950.0, the peak antenna temperature of the ammonia line, corrected for atmospheric attenuation and radome transmission and the corresponding velocity related to the local standard of rest, the peak absorption temperature and velocity of H_2CO as given by Whiteoak and Gardner (1974), the velocity of the H_2O maser if present within 2 arc minutes of the ammonia peak, references and number of the figures. This table also includes four well known ammonia sources and four ammonia peaks detected earlier by Batchelor *et al.* (1977) in order to calibrate the system. Spectra of all detected sources are presented in Figure 1 and 2. The spacing between the hyperfine components, assuming the rest frequencies by Lovas *et al.* (1979), is plotted relative to this main component below the radio spectrum. We also indicat the relative strenghts of the hyperfine components in LTE and for low optical depth. The peak temperature of the new sources listed in Table I may be underestimated in some cases due to filter dilution and low signal to noise (see e.g. Fig. 1b and 2c). The spectra in the figures did not receive any line fitting, but DC linear baselines were sometimes removed.

We looked for the association between ammonia molecular clouds and star formation regions represented by H_2O masers. The result is that in 10 out of 17 cases a water maser was found. Using a normal K-band front-end with 2000K system temperature we searched for probable masers situated with 4 arc min of the ammonia position and the result was such that no water source stronger than 2K was found.

All but one of the ammonia sources were found to be associated with formaldehyde clouds whose peak absorption temperature is higher than 0.5K. The only exception is G337.4-0.4, towards which there is no H_2CO data available.

No correlation between the intensity of these two lines was found.

Table II (Negative Results) presents the name and position of the sources, the velocity range searched, the intensity and velocity of the formaldehyde absorption (when detected), the velocity of the associated water maser and references, It contains water vapor and H_2CO positions as well as some peaks of HII regions.

In this table we can notice the existence of very strong H_2CO sources as well as a large number of H_2O masers with no ammonia found in their vicinity up to detection limit established in the present survey.

IV. COMMENTS ON SOME INDIVIDUAL SOURCES OF MAJOR INTEREST

G 267.9-1.1 and G 267.9-1B - These two positions lie in an extended HII region known as RCW38. The 5 GHz continuum map (Haynes *et al.* 1978) of the region shows a very bright area of emission (30 x 40 minutes of arc) surrounding G 267.9-1.1. H_2CO measurements made by Whiteoak and Gardner (1974) shows a very strong absorption of 3.6K of antenna temperature in the direction of the continuum peak moving at 2.8 Km s^{-1}. Gillespie *et al.* (1979) mapped this region at 115 GHz (carbon monoxide) and found an extended cloud of emission of 9x4.5pc, assuming the distance of the object to be 1.5 kpc. The two strong CO peaks indicated in their map correspond to the two positions searched for ammonia with negative results.

G 291.3-0.7 - Ammonia emission was detected in the direction of G 291.3-0.7 with a velocity of - 24.5 km s^{-1} (Fig. 1a) which is close to the velocity of the H_2O maser (-27.4 km s^{-1}) discovered by Kaufmann *et al.* (1977), to the recombination line (-27.4 km s^{-1}, Wilson *et al.*, 1970) and to the optical emission (-25.5 km s^{-1}, Georgelin, 1970). The intensity of the ammonia peak is 0.24 K, just above the limit set for this survey. Intense H_2CO absorption was measured by Whiteoak and Gardner (1974) at this position.

G 305.4+0.2 and G 305.2+0.21 - This is a complex HII region with several peaks at 5 GHz (Haynes *et al.* 1978). The CO map made by Gillespie *et al.* (1981) shows a large molecular cloud with peaks coinciding with the two positions observed here. Formaldehyde absorption was detected by Whiteoak and Gardner (1974) only in the direction of G 305.4+0.2 in agreement with the ammonia results now presented (see Fig. 1b). It appears that the highest density of the molecular cloud is precisely in this direction, also coinciding with a complex water maser region associated with the strongest continuum peak.

G 337.4-0.4 - Caswell *et al.* (1976) discovered H_2O at this position which coincides with an unusual OH source. The water vapor spectrum presents two features, one at -43.5 km s^{-1} (the strongest) and another at -39.5 km s^{-1}. The strong ammonia peak shown in Fig. 2e peaks precisely in between the two water vapor features. There is no H_2CO measurements in this direction. In the continuum it coincides with a peak of

1.2 K in brightness temperature (Haynes *et al.* 1979) and in the contour map of the region (Haynes *et al.* 1978) it appears only as an elongation of the minimum contour line of 1 K. Probably it is a compact region, optically thick at lower frequencies. Caswell *et al.* (1976) describe this region as a possible star, similarly to W28 (A2), which previously appeared to be unique. Future work is necessary to confirm the nature of this object.

G 345.5+0.3 - This is the strongest ammonia region detected in this survey as shown in Fig. 2i. The relative intensity of the main peak to the hyperfine components do not depart significantly from the LTE low optical depth ratio of 0.28:1:0.28. The velocity of the emitting cloud of -18.0 km s^{-1} is very close to the velocity of the strongest H_2CO absorption (-17.7 km s^{-1}) given by Whiteoak and Gardner (1974).

V. CONCLUSIONS

The results obtained in this first high sensitivity survey of ammonia in the southern skies indicate that NH_3 emission is widespread and easily detectable. In the portion of the Galaxy now observed there are extensive maps in radio continuum, extensive searches for water and hydroxyl masers and preliminary CO and infrared surveys. Other than this, there has been no information about the molecular clouds associated with the HII regions other than the formaldehyde results from Whiteoak and Gardner (1974).

The 17 objects now detected, from set of 46, constitute the best candidates for future molecular and far infrared work. Much work has to be done on the newly detected This program is currently being considered by the authors.

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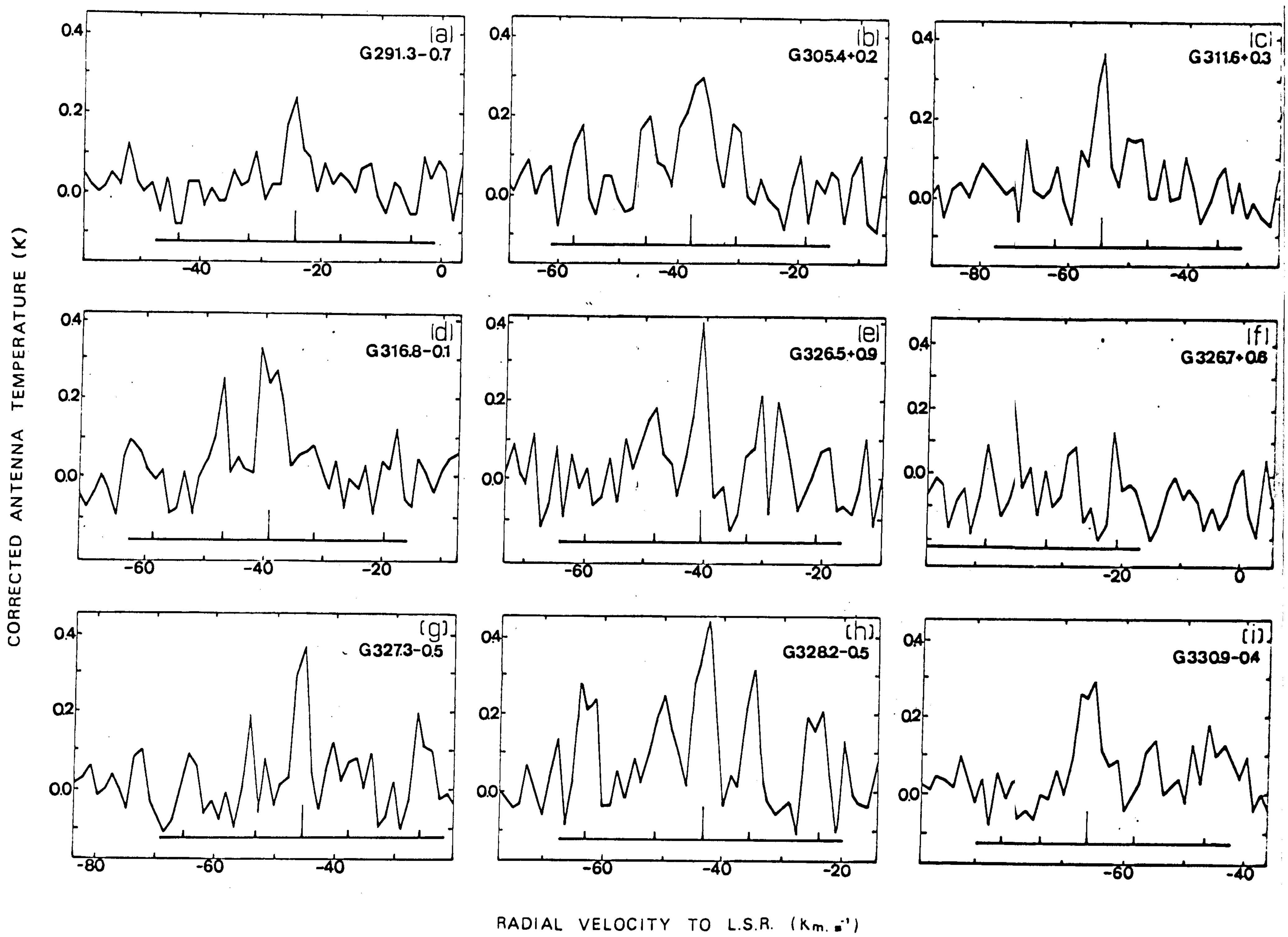
TABLE I - POSITIVE RESULTS

Source	RA (1950)	Dec (1950)	$T_A(1,1)$ (K)	V_{LSR} (Km s^{-1})	H_2CO T_A(k)	H_2CO V_{LSR}	H_2O MASER	Ref.	Fig.
G208.8-19.2	05 33 00.0	-05 12 34.0	1.4	10.4				6	
G208.9-19.4	05 32 48.0	-05 24 21.0	0.8	8.5				6	
G291.3-0.7	11 09 47.0	-61 02 36.0	0.24	-24.5	1.77	-25.8	-22.0	1,2	1a
G305.4+0.2	13 09 21.0	-62 18 54.0	0.30	-37.6	1.40	-35.1	-37.0	1,3	1b
G311.6+0.3	14 01 17.0	-61 05 36.0	0.37	-54.3	0.70	-54.0	NO	1	1c
G316.8-0.1	14 41 31.0	-59 36 54.0	0.33	-39.4	1.59	-37.1	-39.0	1,3	1d
G326.5+0.9	15 38 33.0	-53 49 00.0	0.40	-40.6	0.84	-40.1	NO	1	1e
G326.7+0.6	15 40 58.0	-53 57 18.0	0.57	-40.0	1.05	-21.7	-38.0	1,3	1f
G327.3-0.5	15 49 13.0	-54 26 30.0	0.37	-45.6	2.13	-48.7	-58.0	1,4,6	1g
G328.2-0.5	15 54 12.0	-53 52 42.0	0.45	-43.8	0.50	-42.4	NO	1	1h
G330.9-0.4	16 06 29.0	-51 58 36.0	0.29	-66.2	0.65	-62.7	-52.0	1,5	1i
G331.5-0.1	16 08 22.0	-51 19 30.0	0.46	-87.5	0.57	-89.3	-95.0	1,4	2a
G333.0-0.4	16 16 52.0	-50 33 00.0	0.44	-54.6	0.78	-54.6	NO	1	2b
G333.1-0.4	16 17 15.0	-50 29 18.0	0.39	-53.5	0.85	-52.2	-44.0	1,4	2c
G333.3-0.4	16 17 47.0	-50 19 12.0	0.53	-51.5	2.04	-53.9	NO	1,6	
G333.6-0.2	16 18 26.0	-49 58 54.0	0.47	-48.3	0.93	-45.8	-52.0	1,4	2d
G337.4-0.4	16 35 08.1	-47 22 23.0	0.59	-41.3	-	-	-44.0	5	2e
G337.9-0.5	16 37 28.0	-47 01 24.0	0.66	-39.7	0.60	-35.9	-39.0	1,4	2f
G338.1+0.0	16 35 58.0	-46 36 30.0	0.44	-38.6	0.65	-39.8	NO	1	2g
G340.8-1.0	16 50 41.0	-45 12 18.0	0.41	-29.5	0.58	-28.2	NO	1	2h
G345.5+0.3	17 00 59.0	-40 41 54.0	0.88	-18.0	0.54	-17.7	-28.0	1,3	2i
G348.7-1.0	17 16 40.0	-38 54 42.0	0.70	-14.0	0.81	-13.4	-11.0	1,3,6	
NGC6334	17 17 32.0	-35 42 00.0	1.90	- 2.0	1.01	-12.9		1	
G351.6-1.3	17 25 56.0	-36 37 54.0	0.45	-11.1				7	
G 0.7+0.0	17 44 11.0	-28 22 30.0	1.50	53.0				6	

1 - Whiteoak and Gardner (1974); 2 - Batchelor et al (1980; 3 - Kaufmann et al (1977); 4 - Caswell et al (1974); 5 - Caswell et al (1976); 6 - Barchelor et al (1977); 7 - Schwartz et al (1977) .



CORRECTED ANTENNA TEMPERATURE (K)
RADIAL VELOCITY TO L.S.R. (Km. s⁻¹)
(a) G291.3-0.7
(b) G305.4+0.2
(c) G311.6+0.3
(d) G316.8-0.1
(e) G326.5+0.9
(f) G326.7+0.6
(g) G327.3-0.5
(h) G328.2-0.5
(i) G330.9-0.4