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A SURVEY OF THE MILLIMETER-WAVE SPECTRUM OF SAGITTARIUS B2

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ABSTRACT

More than 60% of the millimeter-wave spectrum between 70 and 150 GHz of the giant Sgr B2 molecular cloud was surveyed with the AT&T Bell Laboratories 7 m telescope at a spectral resolution of 1 MHz. All observations were at the OH position $\alpha(1950) = 17^h44^m11^s$, $\delta(1950) = -28°22'30''$; the angular resolution varied from 2'.9 at 72 GHz to 1'.5 at 143 GHz. The sensitivity of the survey is generally higher than previous spectral observations of this source: the channel-to-channel rms noise in corrected antenna temperature typically lies between 0.015 and 0.06 K but is somewhat irregular. For the most part, the sensitivity below 80 GHz is lower than above. Selected frequencies were observed for as many as 5 hours in order to search for particular molecular lines. The number of spectral lines in the survey is not precisely defined, many being at the limit of detection. The 457 lines cataloged are real or very probably so, but the number of marginal features may be as large. Of the 457 lines, 31 remain unidentified. More than 300 lines are transitions of 21 molecules: SO, OCS, SO_2, HNCS, H_2CS, HNCO, NH_2CN, H_2CCO, HC_3N, NH_2CHO, CH_3CN, CH_3SH, CH_3OH, CH_2CHCN, HC_5N, CH_3CHO, CH_3CCH, $HCOOCH_3$, CH_3CH_2CN, CH_3CH_2OH, and CH_3OCH_3, for which column densities and (excepting CH_3CCH) rotational temperatures are estimated. Since the column densities were calculated from data from a single well-calibrated telescope, comparisons among them can be usefully made. The kinetic temperature of the source is estimated to be approximately 85 K, but most rotational temperatures were found to be subkinetic (between 10 and 30 K), indicating insufficient H_2 to thermalize the molecules. The high-energy transitions of CH_3OH, HNCO, and SO_2 and the detectability of vibrationally excited HC_3N and CH_3CN offer evidence for the existence of hot spots within the source.

Subject headings: interstellar: molecules — line identifications — nebulae: individual — radio sources: spectra

I. INTRODUCTION

The millimeter-wave spectrum of the very large molecular cloud toward the radio continuum source Sgr B2 near the Galactic center, one of the most massive objects in the Galaxy, is exceptionally rich in molecular lines. Almost half the 60 interstellar molecules known were first detected toward Sgr B2, and nearly all molecules discovered elsewhere were later observed in this source. As of now, several molecules and molecular isotopic species, such as those containing the amide group, e.g., NH_2CN and CH_3NH_2, or the formyl group, e.g., CH_3CHO, or both groups, i.e., NH_2CHO, have only been observed in either Sgr B2 or Sgr A.

In the search for specific new molecules, as well as in a general spectral exploration of the millimeter-wave band to low flux levels, a great portion of the spectrum of Sgr B2 between 70 and 150 GHz was surveyed with the Bell Laboratories 7 m telescope at Crawford Hill, New Jersey. Some of this work has been described in earlier papers (on the discovery of methyl mercaptan CH_3SH, Linke, Frerking, and Thaddeus 1979; isothiocyanic acid HNCS, Frerking, Linke, and Thaddeus 1979; and the ions HCS^+ and $HOCO^+$, Thaddeus, Guélin, and Linke 1981), as well as more recently (on the determination with CH_3CN of the kinetic temperature and density of the Sgr B2 cloud, Cummins *et al.* 1983). The present paper on the entire survey lists 457 lines, most of them identified, with the derived column densities for 21 molecules and rotational temperatures for these with one exception, CH_3CCH (§ V). Roughly 30 lines (7% of the total), some fairly strong, that defied identification constitute a particularly interesting product of the survey that challenges both the molecular theorist and the laboratory spectroscopist.

Since the column densities and rotational temperatures summarized in Table 1 are derived from data obtained with a single, well-calibrated telescope, comparisons can now be made within each set. Although we do not discuss in detail the physical and chemical structure of the Sgr B2 cloud, the derived column densities and rotational temperatures given here will, for the first time, make such discussion possible.

Section II, on the observations, discusses instrumentation, including beam efficiency and beamwidth as functions of frequency (Fig. 1) and frequency coverage and rms noise (Figs. 2 and 3), and describes the survey as a whole. Section III discusses the catalog used to identify the lines. Section IV

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TABLE 1

COLUMN DENSITIES, ROTATIONAL TEMPERATURES, AND AVERAGE LINE WIDTHS AND v_{LSR}'S

Molecule	N (10^{13} cm^{-2})	T_{rot} (K)	Δv (km s^{-1})	v_{LSR} (km s^{-1})
NH_2CN	2.0±0.2	15±3	21±1	61.1±0.7
HNCS	2.5±1.0	14±5	20±3	62±2
CH_2CHCN	4.7±0.6	23±7	18±2	62.1±0.7
CH_3CH_2CN ...	6.2±0.8	23±5	13±1	62.0±0.5
HC_5N	7±50% est.	21±8	17±3	60±1
NH_2CHO	7.2±0.3	12.8±0.9	20.7±0.6	61.4±0.3
CH_3CN	13.5±0.1	16.4±0.3	20.7±0.1	59.7±0.1
CH_3SH	16±2	10±3	17±2	61.0±0.8
H_2CCO	17±2	18±4	20±1	60.7±0.7
CH_3CHO	24±2	10±2	21.1±0.8	59.5±1.1
$HCOOCH_3$	34±3	23±4	8.9±0.9	61.7±0.6
HC_3N	34.8±0.2	26.4±0.3	21.36±0.08	59.64±0.05
SO	43.8±0.6	18.9±0.7	25.3±0.2	59.4±0.1
CH_3CH_2OH ...	53±4	14±2	17±1	61.3±0.5
CH_3OCH_3.....	50±10	24±6	...	...
CH_3CCH.....	60	...	...	...
H_2CS.....	60±4	25±2	22.4±0.4	59.8±0.2
HNCO	140±20	14.8±0.2	25.1±0.1	64.16±0.07
	44±5	61±10	20±1	62.4±0.6
OCS	210±10	31±3	22.2±0.4	62.1±0.2
SO_2	58±4	26±2	21.5±0.8	59.3±0.4
	310±70	290±60	17.6±0.7	59.0±0.4
CH_3OH	2750±70	49±1	22.2±0.1	60.8±0.2
	350±50	120±20	11±1	65±1

explains how the data were analyzed to determine column densities and rotational temperatures and discusses the range of rotational temperatures obtained and their relation to the kinetic temperature, as well as implications for the hydrogen density. Section V presents the results of the analysis for each of the 21 molecules and includes excitation diagrams (Fig. 4) for most of them. In § VI we attempt, not altogether successfully, to use ratios of the calculated abundances to predict abundances of as yet undetected species and discuss briefly the correlation of the average parameters for each species (Figs. 5 and 6). Last, the spectra of the entire survey (Fig. 7) are presented, which, because they are numerous, were left to the end.

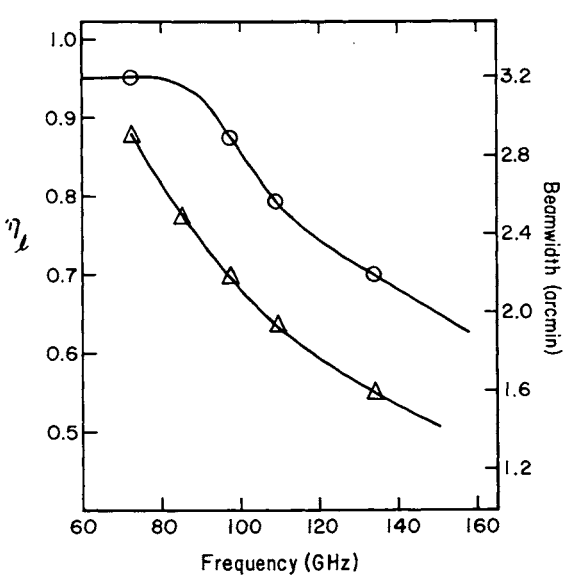

FIG. 1.—Main-beam efficiency, η_l, indicated by circles, and beamwidth, indicated by triangles, as functions of frequency for the Bell Laboratories 7 m telescope used for the survey.

II. OBSERVATIONS

The data were obtained during five observing seasons, from 1977 to 1982, with the Bell Laboratories (BTL) 7 m offset Cassegrain antenna at Crawford Hill, New Jersey (Chu *et al.* 1978). Determined from scans of Jupiter, the beamwidth of this antenna varies from 2'.9 to 1'.5 over the frequency range of the survey, 72–143 GHz (Fig. 1). With an uncertainty estimated to be less than 5%, the corresponding values of main-beam efficiency, obtained by assuming a temperature of 170 K for Jupiter and a Gaussian shape for the main beam, range from 0.95 to 0.69 (also Fig. 1). No corrections for main-beam efficiency have been applied to the spectra shown in Figure 7.

Pointing, checked weekly during the first part of each observing season, nearly always was good to 0.25 beamwidth and always to 0.4 beamwidth. All spectra were taken at the Sgr B2 OH position: $\alpha(1950) = 17^h44^m11^s$, $\delta(1950) = -28°22'30''$. Data were obtained by position switching once every minute to a reference position, displaced +49' in right ascension and 29' in declination, shown to be free of CO emission at 115.27 GHz.

Two single-sideband cryogenic receivers were used: the first, which covered the 60–90 GHz waveguide band, had a noise temperature ranging from 290 to 390 K and, typically, an image rejection of at least 20 dB (for a detailed description see Linke, Schneider, and Cho 1978); the second was a scaled

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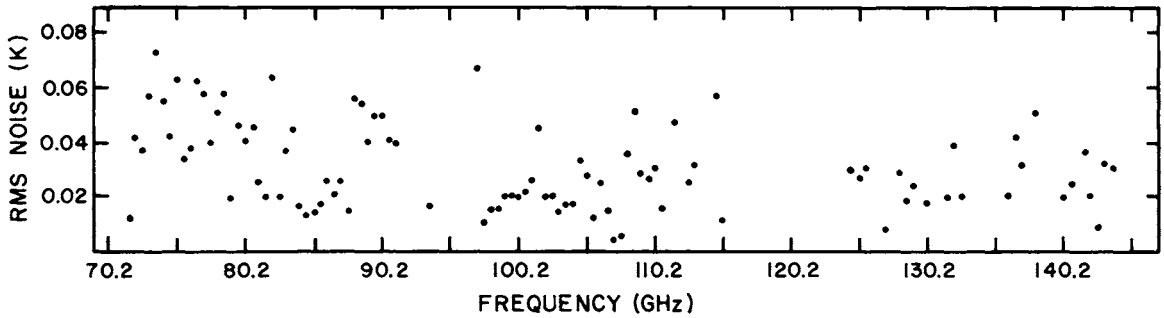

FIG. 2.—Root mean square noise level for each portion of the survey as a function of frequency

version of the first for the 90–140 GHz band, with a noise temperature ranging from 350 to 450 K. Two filter banks, each with 256 1 MHz channels available for most of the observations, provided a spectral range of 512 MHz.

The telescope was calibrated every 40 minutes by chopping between hot (290 K) and cold (77 K) loads, while the atmospheric emissivity was measured by chopping between the sky and the cold load. The data (Fig. 7) were corrected for atmospheric opacity, calculated from a single-layer atmospheric model for which the parameters were atmospheric emissivity and ambient temperature. Typical zenith opacities were 0.15–0.20 on clear days, but corrections to low elevation data as large as a factor of 2 were applied on poor days. In some cases, errors from inaccurate atmospheric correction may be as large as 15%–20%. Data taken when atmospheric conditions were insufficiently stable to permit reliable calibration were not included in the survey.

From Crawford Hill the Galactic center is observable for approximately 6 hours each day; between 1977 and 1982 observations for this survey were made during about 20 days per year, for a total of nearly 600 observing hours. Certain selected frequencies were observed for as long as 5 hours to search for particular molecular lines, although more typically the integration time was 2–3 hours. In the first season (1977–1978) data were obtained for several different frequency bands each observing day, so that 22 GHz of coverage (70–92 GHz) had a typical rms noise of 50 mK for 1 MHz channels. We later decided to sacrifice some spectral coverage for increased sensitivity, so most subsequent data, and even a portion in the initial band, were obtained with an rms noise of 20 mK or better. A number of gaps occurred in the frequency coverage, one large one at 91–97 GHz where neither receiver was sensitive, and another at 115–124 GHz around the telluric O_2 line at 118.75 GHz (for details see Figs. 2 and 3). Spectra where the rms noise is especially low occur at frequencies studied intensively for particular molecular lines.

The 457 lines from the survey included in Table 2 are real, or probably so (yet, as always, numerous marginal features are present). Of these 457 lines, the majority—about 300—come from transitions of the 21 molecules discussed here (§ V). Transitions of at least 18 additional molecules (and possibly as many as 22) were observed. At least 13 molecules (possibly as many as 18) were observed with isotopic substitutions, at least 24 varieties of isotopically substituted molecules (possi-

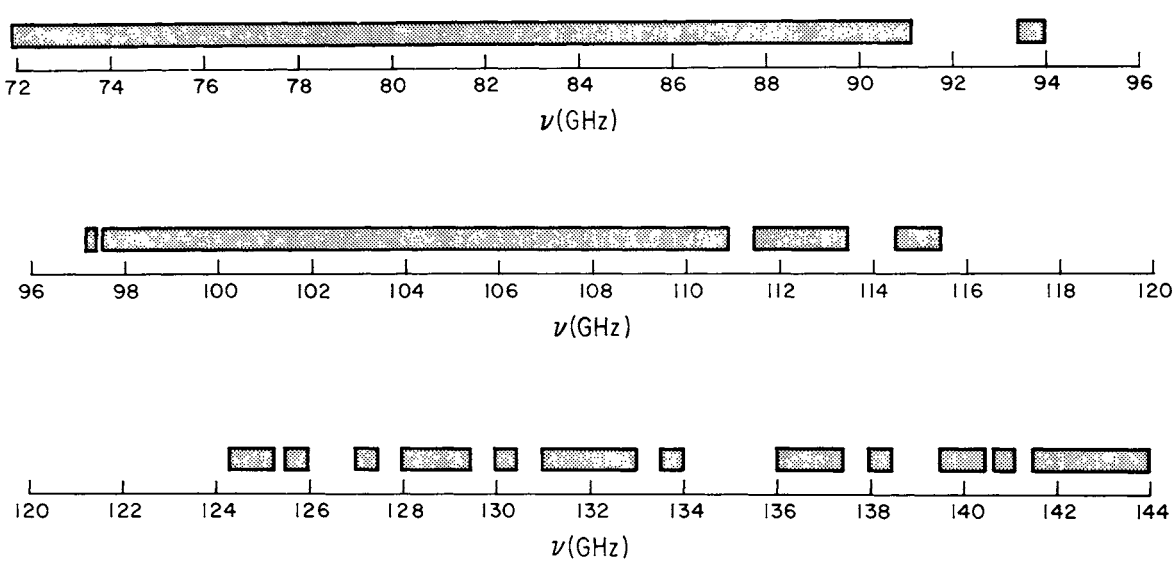

FIG. 3.—Map of frequencies covered in the survey. Data in the range 143.20 ± 0.25 GHz may not be valid; see the discussion of SO_2 (§ V).

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bly as many as 30) being observed in all. The only vibrationally excited transitions seen in this survey are of HC_3N and CH_3CN. Aside from the molecular transitions, the survey included 10 hydrogen recombination lines.

Most of the identifications in Table 2 and Figure 7 were made with a catalog (§ III); 31 lines remain tantalizingly unidentified. In certain instances a question mark follows our identification:

1. When the signal-to-noise ratio (S/N) is low but the line has approximately the right intensity for a particular molecule
2. When for a transition of a known astrophysical molecule no quantum numbers have been assigned or line strength calculated (e.g., CH_3OH)
3. When the intensity is anomalous although the frequency is correct.

A question mark also follows any unidentified line when whether it is real or merely an artifact of the noise remains unclear.

A Gaussian profile was numerically fitted to each of the 457 lines to obtain the peak antenna temperature, T_A^*, line width Δv (FWHM), and center frequency, on the assumption that the velocity relative to the local standard of rest, $v_{\rm LSR}$, is 62 km s^{-1}. Table 2 gives the results of the Gaussian fits and the $v_{\rm LSR}$ derived from the difference between the fit frequency and the rest frequency. When a line shape consisted of two obviously separate peaks (e.g., $H^{13}CO^+$), each peak was fitted with a Gaussian. Lines with somewhat blended velocity components (see, e.g., SiO) were fitted with a single Gaussian to obtain the center frequency and line width, but the intensity of this single Gaussian is not included in Table 2; instead, the intensities estimated for the separate components are tabulated and the frequencies at which the maximum intensities occur are listed in the Comments column.

III. THE CATALOG

To help identify the lines of the survey, we prepared a catalog of over 178,000 millimeter-wave transitions of most known and many plausible interstellar molecules. We included all interstellar molecules known in 1982 with transitions in the frequency range (70–150 GHz) of the present survey. When data were available for known interstellar molecules, we included the most abundant isotopically substituted forms and transitions within several sets of vibrationally excited states. Some 300 other molecules selected as plausible candidates for detection in space but not yet observed were included, such as sulfur analogs of molecules containing oxygen (e.g., CH_3SCH_3) and molecules formed from combinations of functional groups that occur in known interstellar molecules (e.g., vinyl alcohol, CH_2CHOH, and amino acetonitrile, NH_2CH_2CN). Only a few molecules with more than 12 atoms or containing elements with low cosmic abundance were included.

To limit the number of transitions, only frequencies up to 300 GHz were retained in the catalog. With a few exceptions, such as HC_5N, the rotational quantum number J was restricted to values less than 30, and weakly permitted lines and lines likely to be weak under the excitation expected in Sgr B2 and similar molecular clouds were excluded.

In preparing the catalog, we did not generally reanalyze laboratory frequencies. Most frequencies were calculated from published rotational constants, including, when available, centrifugal distortion data. For linear molecules and symmetric tops the calculation was elementary; for asymmetric rotors we used a program written at the National Bureau of Standards (Kirchhoff 1972) that included centrifugal distortion to order J^6, which we extended to J^{12} to generate more accurate spectra of molecules with light off-axis atoms (such as HNCO). The program was modified to accept rotation constants and centrifugal distortion constants in six different forms (see Gordy and Cook 1970, pp. 219, 222, and 230) and convert them into the form compatible with the Kirchhoff Hamiltonian. For several exceptional molecules, notably those with large hindered rotation (e.g., CH_3OH), the frequencies themselves were entered directly into the catalog from the measurements or calculations of others, rather than calculated from molecular constants. The references for the rest frequencies listed in Tables 2 and 3 and the method by which they were obtained (observations or calculations) are given in the footnotes to Table 2. Further references for the rest frequencies are given in Lovas, Snyder, and Johnson (1979) and Lovas (1986).

IV. ANALYSIS

a) Calculation of Column Densities and Rotational Temperatures

The quantitative analysis of the spectral data was based on the assumption that the lines are optically thin, that background continuum radiation is negligible, that the source is homogeneous, and that the source fills the beam at all frequencies. In rotational equilibrium, at a temperature $T_{\rm rot}$, as shown in the Appendix,

$$\log\left(\frac{3kW}{8\pi^3\nu S\mu_x^2}\right) = \log\left(\frac{N}{Z}\right) - \frac{\log e}{T_{\rm rot}}\frac{E_u}{k}, \qquad (1)$$

where W is the integrated intensity of a line ($W = \int T_R dv$), ν the frequency, S the line strength, μ_x the dipole moment, N the column density, Z the partition function, and E_u the energy of the upper state. The variable L will denote the left-hand side of equation (1). If L versus E_u/k is linear, the slope yields $T_{\rm rot}$, and from this and the vertical intercept, $\log(N/Z)$, one then calculates N. If the graph is not linear, it signals that the assumption of thermal equilibrium has not been met or that the identification of a line was incorrect.

The fairly linear appearance of the data (Fig. 4) seems to justify the assumption of thermal equilibrium. Each graph suggests a common rotational temperature for the transitions of a given molecule, although as exceptions, the data for HNCO, CH_3OH, and SO_2 suggest two temperatures. The low values of optical depth ($\tau < 0.05$) obtained for the transitions appear consistent with the assumption of the model, with a few exceptions: the $K_{-1} = 0$ HNCO transitions (for which $\tau = 0.5$), and all HC_3N and a few SO transitions (for which $\tau = 0.2$). For discussion of correction for optical depth, τ, for HNCO, see § V. The assumption that the source is homogeneous is discussed in § IV*b*.

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The assumption that the source fills the beam is justified in at least some important cases, as the following maps of Sgr B2 show: that of Morris *et al.* (1976) of HC_3N, where the intensity is above half the maximum intensity in a region $8' \times 8'$; Nagai *et al.* (1979) of CH_3OH, where the extent is $4' \times 6'$; Sweitzer *et al.* (1979) of the $(J, K) = (2,1)$ transition of NH_3, where the extent is $4' \times 4'$; and Buhl *et al.* (1973) of the $1_{0,1} \rightarrow 0_{0,0}$ transition of HNCO, where the extent is $4' \times 5'$. These extents can be compared with the BTL 7 m telescope's half-power beamwidth, which ranges from 2′ to 3′ over the range of our survey (Fig. 1). We obtained additional evidence that the source fills the beam from a previously made limited map of CH_3CN at 2′ N, E, S, and W of the central position and found that the antenna temperature averaged over these points was about half that found at the central position.

Using equation (1), for each molecule we made a two-parameter nonlinear least-squares fit (method described in Bevington 1969) for T_{rot} and N (Table 1) and used these to calculate slopes $-(\log e)/T_{rot}$ and intercepts $\log(N/Z)$ of the lines drawn on the plots of L versus E_u/k (Fig. 4 and § V).

For the fits for T_{rot} and N, we established criteria for inclusion and exclusion of a given line; Table 2 lists all the well-defined lines in the survey and Table 3, a subset of Table 2, includes only the transitions used in the fits for T_{rot} and N. When a line is a blend of several transitions, the line is excluded from the fit unless one particular molecular species predominates at the frequency and unless all the transitions of that species have approximately the same line strength and E_u. When the uncertainty in T_A^* was less than or equal to 0.04 K, the line was included only if the uncertainty in the integrated intensity divided by the integrated intensity, $\Delta W/W$, was less than 0.8. For a line with greater uncertainty in T_A^*, this restriction on $\Delta W/W$ was tightened: for example, for a line with an uncertainty in T_A^* of 0.07 K, $\Delta W/W$ was required to be less than 0.25. For those lines included in the fits, $T_R = T_A^*/\eta_l$ is given, as well as the energy of the upper state and the line strength (Table 3). Unless otherwise noted, both energy levels and line strengths are taken from the reference for the frequency (Table 2) or calculated from parameters given in the reference.

b) Rotational Temperatures: Kinetic Temperature and H_2 *Density*

When excitation temperatures equal a common value, we call that value T_{rot}; when sufficient H_2 is present, that common value equals the H_2 kinetic temperature T_{kin}, and collisional excitation and de-excitation dominate radiative processes. In earlier work with CH_3CN (Cummins *et al.* 1983), we estimated for Sgr B2 that $T_{kin} = 85 \pm 10$ K and that the average hydrogen density is $(1.1 \pm 0.5) \times 10^5$ cm^{-3}. Wilson *et al.* (1982) analyzed the metastable lines of ammonia and found both a higher kinetic temperature and a lower hydrogen density. They obtained $n(H_2) = 10^4$ cm^{-3} and a rotational excitation temperature of 175 K; they suggested that these parameters referred to a volume of gas somewhat different from that for CH_3CN, since the velocity of the ammonia absorption lines they observed was 63 km s^{-1}, compared with 59.5 km s^{-1} for the CH_3CN lines. The higher value for T_{kin} implied by their data is interesting for our study in relation to the high rotational temperatures implied by transitions of CH_3OH and SO_2 from high energy levels.

With the exception of these transitions of CH_3OH and SO_2, the values of T_{rot} we found are far below the estimates for T_{kin} based either on the CH_3CN or on the ammonia studies: most values of T_{rot} are between 10 and 30 K. We conclude that there is insufficient H_2 to thermalize the other species. This conclusion is corroborated by estimation of the H_2 density with a two-level model that, assuming the cross section is 2×10^{-15} cm^2, yields $n(H_2)$ ranging from 4×10^5 to 2×10^7 cm^{-3} in order to thermalize the molecules to 85 K, or more than our analysis of CH_3CN indicates is present.

The linear appearance of our data (§ IV*a*) implies a common excitation temperature T_{rot} for the transitions of a given molecule; since $T_{rot} < T_{kin}$, a state of quasi–thermal equilibrium apparently exists, similar to the situation found for CH_3CN, where analysis based on statistical equilibrium shows that the excitation temperatures for $J > 5$ are roughly constant, equal to a subkinetic temperature of about 15 K.

The quasi-equilibrium exhibited by the transitions of a given molecule is surprising, but the small variation in T_{rot} from molecule to molecule is even more surprising: nine of the 21 molecules discussed here (§ V) have a T_{rot} value between 10 and 20 K, and eight a value between 20 and 31 K. In marked contrast to the quasi–thermal equilibrium shown by the majority of the molecules discussed, the data for three molecules (HNCO, SO_2, and CH_3OH) seem poorly characterized by a single temperature.

The SO_2 data are particularly striking, with transitions detectable from levels as much as 643 K above ground. The slope of the line through the high-energy data gives a temperature of 290 ± 60 K, far higher than the kinetic temperatures inferred from either the CH_3CN or the NH_3 data.

The SO_2 data indicate that the Sgr B2 molecular cloud is less homogeneous than most of our observations suggest, and that it contains one or more regions of high temperature. Supporting evidence for hot molecular gas comes from the high-energy HNCO and CH_3OH data, as well as from the detectability of vibrationally excited HC_3N and CH_3CN, all described below.

V. INDIVIDUAL MOLECULES

The following discussion of 21 individual molecules adheres to the order of Table 1, which is the order of increasing column density, with three exceptions. The high- and low-energy transitions of the three exceptions (HNCO, SO_2, and CH_3OH) were fitted separately. For 20 of the 21 molecules the data included in the survey were sufficient to estimate the molecule's column density (N) and rotational temperature (T_{rot}). Table 3 lists molecule by molecule the transitions used for these estimates, and Figure 4 gives the excitation diagrams (L versus E_u/k) for every molecule except HNCS and CH_3CN, because these have already been published, and CH_3CCH, a special case for which the column density was estimated simply by comparing its intensity with that of CH_3CN.

In our analysis identical nuclei were accounted for by multiplying the line strength S in the expression for L (eq.

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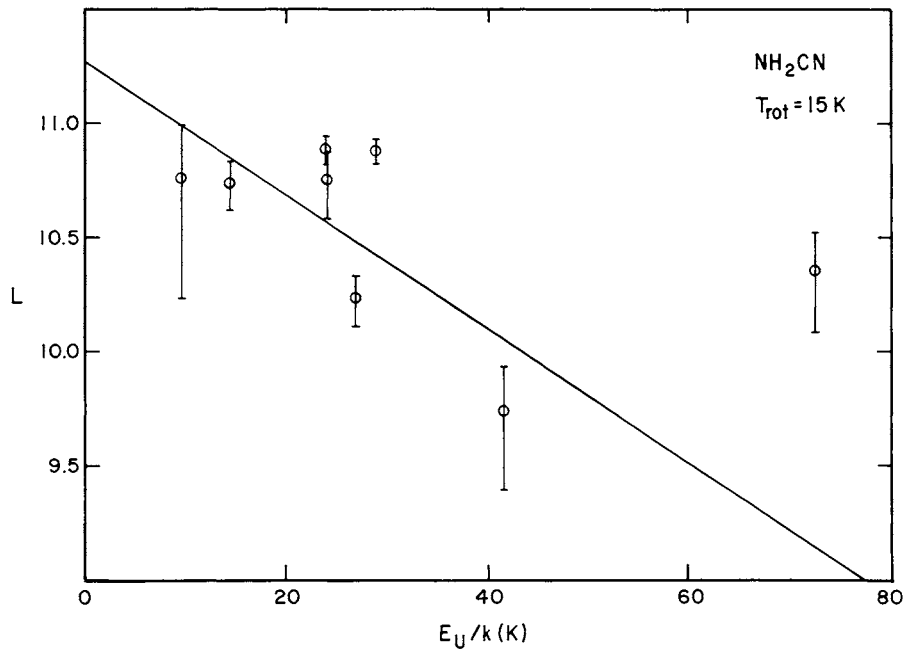

FIG. 4*a*

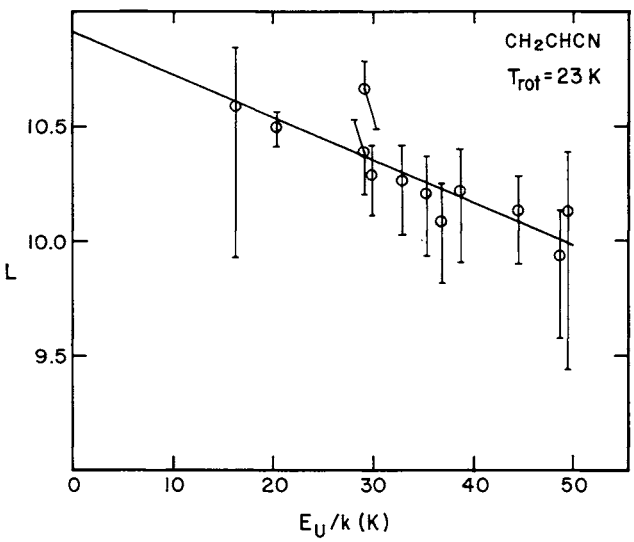

FIG. 4*b*

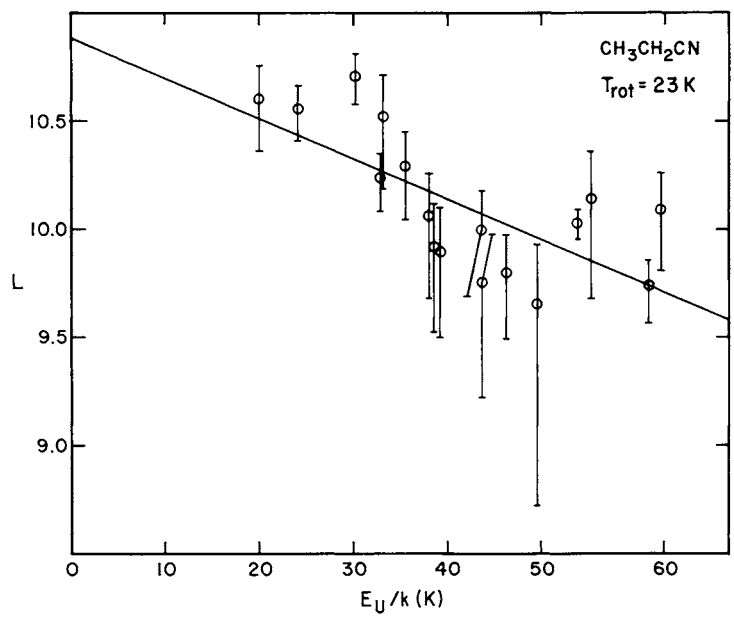

FIG. 4*c*

FIG. 4.—Excitation diagrams. (*a*) NH_2CN. (*b*) CH_2CHCN. (*c*) CH_3CH_2CN. (*d*) HC_5N. (*e*) NH_2CHO. (*f*) CH_3SH. (*g*) H_2CCO. (*h*) CH_3CHO. (*i*) $HCOOCH_3$. (*j*) HC_3N; the error bars are smaller than the symbols used to plot the intensities. (*k*) SO; the transition with $E_u/k = 51$ K is perhaps too intense to be attributed to SO alone. (*l*) CH_3CH_2OH; (*m*) CH_3OCH_3. (*n*) H_2CS; the intensity fitted to the transition with $E_u/k = 63$ K ($3_{2,1} \rightarrow 2_{2,0}$) is probably too high because the line is on the shoulder of the $3_{0,3} \rightarrow 2_{0,2}$ line. (*o*) HNCO; the steeper line is a fit to the $K_{-1} = 0$ and 1 data; the other line is a fit to the $K_{-1} = 1$, 2, and 3 data. (*p*) OCS. (*q*) SO_2; the steeper line is a fit to the data with $E_u/k < 150$ K; the other line is a fit to the data with $E_u/k > 70$ K. (*r*) CH_3OH; the steeper line is a fit to the data with $E_u/k < 70$ K; the other line is a fit to the data with $E_u/k > 70$ K; the (anomalously weak?) transition at 107014 MHz with $E_u/k = 28$ K was left out of the fit for the low-energy data.

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[1]) by S_I and by including a corresponding factor in the partition function Z. For NH_2CN, H_2CCO, and H_2CS, $S_I = 1$ for transitions with K_{-1}, $K_1 = e, e \leftrightarrow e, o, S_I = 3$ for K_{-1}, $K_1 = o, e \leftrightarrow o, o$, and a factor of 2 was included in Z. For CH_3OCH_3, $S_I = 7$ for K_{-1}, $K_1 = e, e \leftrightarrow o, o$, $S_I = 9$ for K_{-1}, $K_1 = e, o \leftrightarrow o, e$, and a factor of 8 was included in Z.

For molecules with A and E internal rotation species with transitions that do not overlap, a factor of 2 was included in Z so that N would be the sum of the A and E species.

a) NH_2CN

Cyanamide is one of the two known astrophysical molecules that contain two nitrogen atoms (the other is diazenylium, HN_2^+). Comparison of molecules with a nitrogen-containing functional group with those with a different functional group shows that the nitrogen-containing molecule is less abundant by a factor of at least 1.8 (§ VI*a*, Ratios of Abundances). With the discovery of NH_2CN, Turner *et al.* (1975) estimated the column density to be $2\times10^{13} < N < 6\times10^{14}$ cm^{-2} for $20 < T_{kin} < 60$ K and $10^5 < n(H_2) < 10^6$ cm^{-3}. We find that of all 21 molecules discussed here NH_2CN has the lowest column density, $(2.0\pm0.2)\times10^{13}$ cm^{-2}, an estimate that agrees with the lower limit of the estimate of Turner *et al.* We find T_{rot} to be 15 ± 3 K. The apparent strength of the $5_2 \rightarrow 4_2$ transitions with $E_u/k = 72$ K may indicate a variation in temperature and density within the source evident in the data for HNCO, SO_2, and CH_3OH (below). NH_2CN is evidently not present in Ori A, since the value of T_A^* for the $5_{1,4} \rightarrow 4_{1,3}$ transition at 100629.5 MHz is less than 0.015 K in the BTL data (compared with $T_A^* = 0.39$ K in Sgr B2). See Wannier and Linke (1978) on the apparent absence of NH_2CN in Ori A.

b) HNCS

Analysis of the isothiocyanic acid data in this survey (Frerking, Linke, and Thaddeus 1979) yielded a rotational temperature of 14 ± 5 K and a column density of $(2.5\pm1.0)\times10^{13}$ cm^{-2}. This molecule has been detected only in Sgr B2.

c) CH_2CHCN

Vinyl cyanide, one of the two known astrophysical molecules with a C=C double bond (the other is ketene, H_2CCO), acts as a tagged version of the double-bonded nonpolar molecule ethylene, CH_2CH_2. First detected in Sgr B2 (Gardner and Winnewisser 1975), vinyl cyanide has recently been observed in Ori A (Johannson *et al.* 1984). For Sgr B2, Johnson *et al.* (1977) assumed $T_{kin} = 20$ K and obtained a vinyl cyanide column density of 3×10^{13} cm^{-2}. We find $T_{rot} = 23\pm7$ K and $N = (4.7\pm0.6)\times10^{13}$ cm^{-2}.

d) CH_3CH_2CN

Ethyl cyanide acts as a tagged version of the saturated nonpolar hydrocarbon ethane, CH_3CH_3 (cf. CH_2CHCN, above). Detected in both Sgr B2 and Ori A (Johnson *et al.* 1977), the column density in Sgr B2 was estimated to be 9×10^{13} cm^{-2}, assuming $T_{kin} = 20$ K. We find $T_{rot} = 23\pm5$ K and $N = (6.2\pm0.8)\times10^{13}$ cm^{-2}.

e) HC_5N

Cyanodiacetylene is the less abundant of the two carbon chain molecules of the form HC_nN detected in Sgr B2 (cf. HC_3N, below). Avery *et al.* (1979) analyzed seven HC_5N transitions, five extending to low J and two with high J, and found evidence to support a three-component model of Sgr B2:

Region I.—$T_{kin} > 25$ K, $n(H_2) = 10^6$ cm^{-3}, $N = 1.5\times10^{13}$ cm^{-2}.

Region II.—$T_{kin} = 25$–35 K, $n(H_2) = 3\times10^4$ cm^{-3}, $N = 1.6\times10^{14}$ cm^{-2}.

Region III.—$T_{kin} = 10$–35 K, $n(H_2) = 10^2$ cm^{-3}, $N = 1.1\times10^{13}$ cm^{-2}.

We find $T_{rot} = 21\pm8$ K and $N = 7\times10^{13}$ cm^{-2}, with an estimated error of at least 50% owing to the low signal-to-noise ratios for the transitions of this molecule. Some evidence in BTL data indicates the presence of this molecule in both Ori A and IRC +10216, but the lines are weak ($T_A^* \lesssim 0.03$ K) in both sources.

f) NH_2CHO

The only known sources in which formamide has been detected remain Sgr B2 and Sgr A (Rubin *et al.* 1971). The three known interstellar molecules that contain the amide group (NH_2CHO, NH_2CN, and CH_3NH_2) are all found in Sgr B2, although none has been detected in Ori A. We find $T_{rot} = 12.8\pm0.9$ K and $N = (7.2\pm0.3)\times10^{13}$ cm^{-2}, a column density an order of magnitude less than previously obtained (Gottlieb *et al.* 1973) from observation of the $1_{1,0} \rightarrow 1_{1,1}$ transition seen in emission [Gottlieb *et al.* assumed $T_{kin} = 100$ K and $n(H_2) = 10^5$ cm^{-3}].

A line at 93872 MHz attributed to the $3_{2,2} \rightarrow 4_{1,3}$ transition of NH_2CHO (Clark, Lovas, and Johnson 1979) is a *b*-type transition from the lower level of one K doublet to the upper level of another; on the rotational temperature diagram, this line appears 160 times stronger than expected. A line at 102217 MHz, which coincides with another NH_2CHO lower-to-upper *b*-type transition, $2_{1,2} \rightarrow 1_{0,1}$, is seven times stronger than expected. The high intensities may arise from an anomalously high population of lower K doublet members, although the data of Gottlieb *et al.*, mentioned above, are evidence against such an anomaly. If such an anomalous population exists and these transitions can be attributed to NH_2CHO, then the $1_{1,1} \rightarrow 0_{0,0}$ and $4_{1,4} \rightarrow 3_{0,3}$ transitions of this molecule should be observable at 82550 and 139313 MHz. If these transitions are not observable, then, since no other molecule is known to be a candidate for 93870 and 102217 MHz, we would list these as unidentified lines, a designation supported by data on a molecule of similar structure for which transitions of this type are not found to be anomalously intense (see CH_3CHO, below).

g) CH_3CN

Analysis of the methyl cyanide data (Cummins *et al.* 1983) used two models to determine N and T_{kin} and either T_{rot} or $n(H_2)$. The first, a two-temperature model, found $T_{kin} = 81\pm1$ K, $T_{rot} = 16.4\pm0.3$ K, and $N = (1.35\pm0.01)\times10^{14}$ cm^{-2}. For

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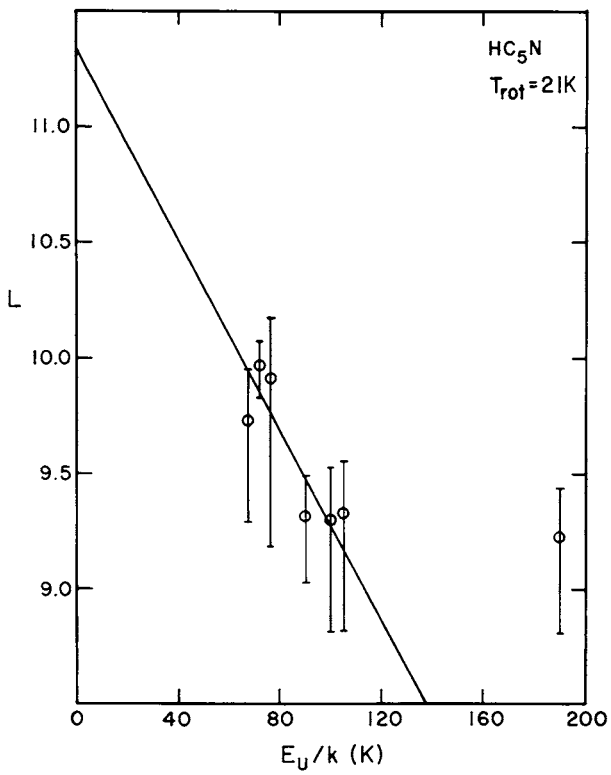

FIG. 4*d*

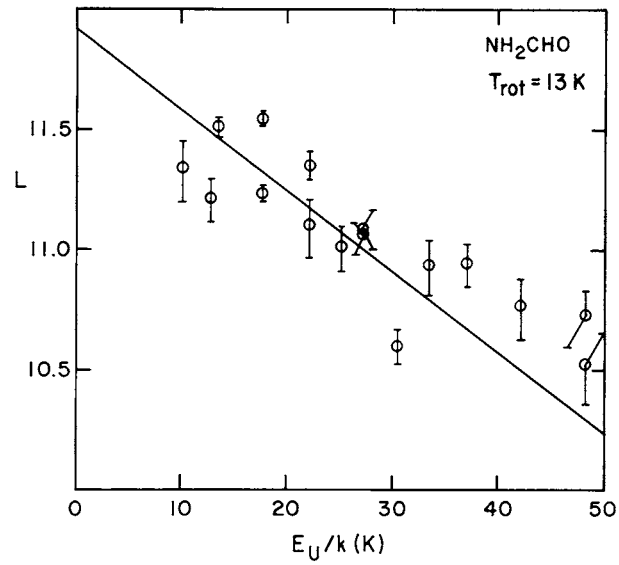

FIG. 4*e*

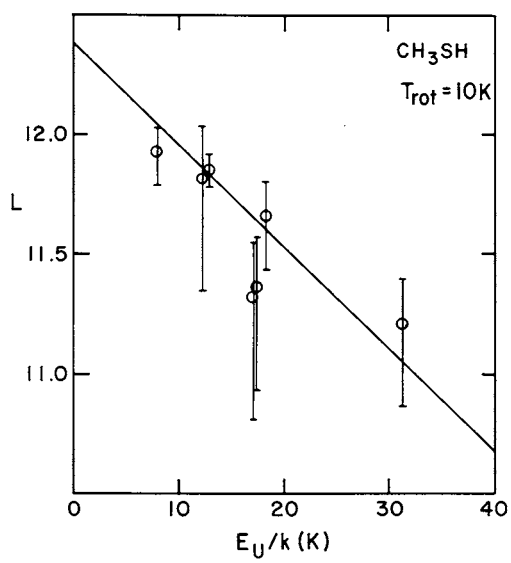

FIG. 4*f*

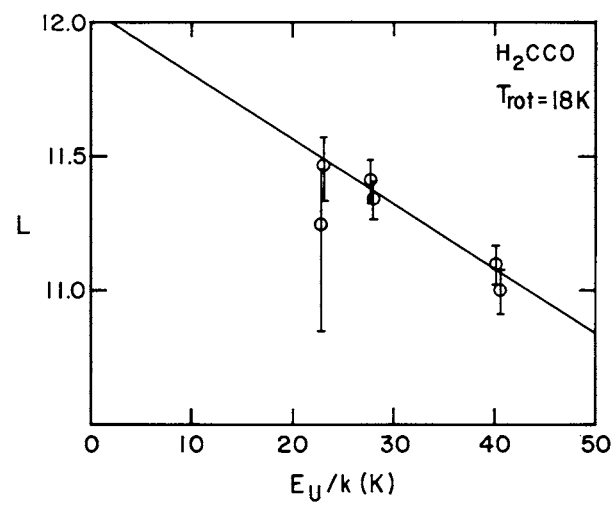

FIG. 4*g*

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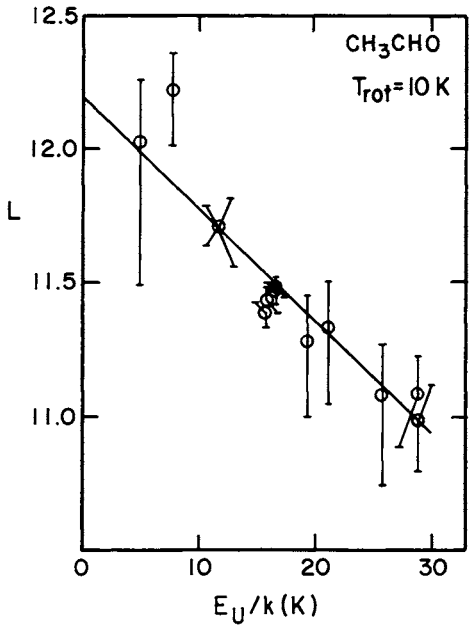

FIG. 4*h*

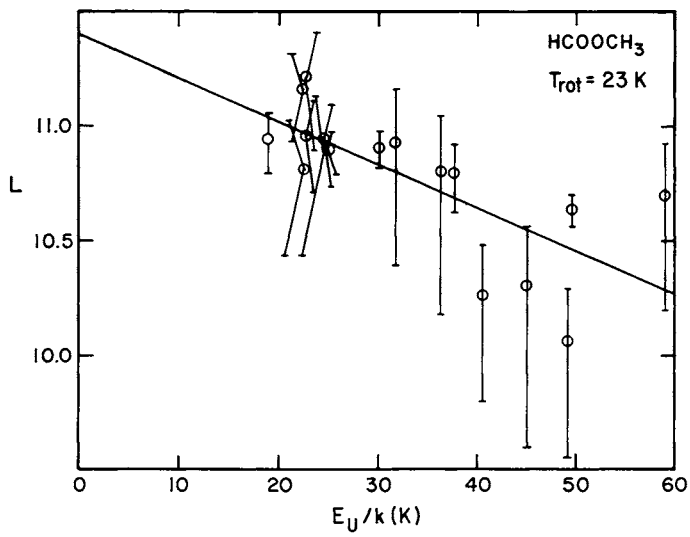

FIG. 4*i*

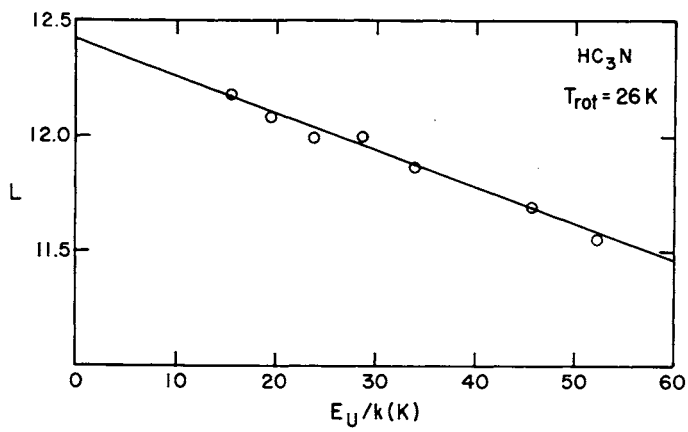

FIG. 4*j*

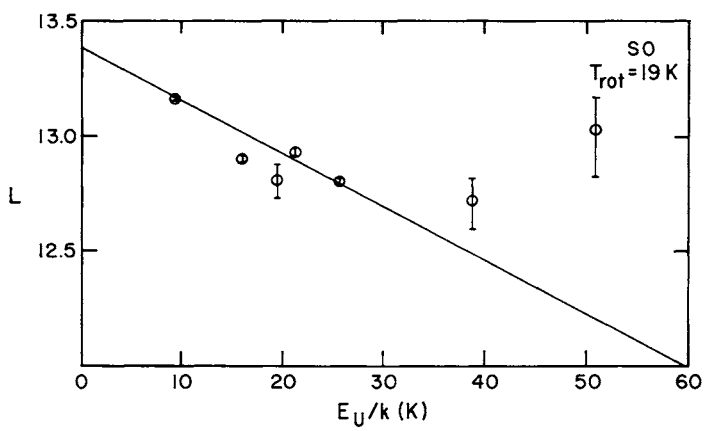

FIG. 4*k*

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the sake of this model, the CH_3CN data were fitted with overlapping Gaussians constrained to have the same FWHM and v_{LSR} for all transitions; the best fits found were $\Delta v = 20.7 \pm 0.1$ km s^{-1} and $v_{LSR} = 59.7 \pm 0.1$ km s^{-1} (Table 1). The Gaussian covering the $K=1$ transition was constrained so its intensity relative to that of the $K=0$ transition corresponded to $T_{kin} = 81$ K, a value determined iteratively (finding a temperature consistent with the value of T_{kin} given by the fit; for the 14 transitions considered see Table 3, CH_3CN). The second was a statistical equilibrium model which determined $n(H_2)$ as well as T_{kin}, N, Δv, and v_{LSR}. The values found for N, Δv, and v_{LSR} agreed with those found by the first model, although with the second model T_{kin} was higher. Actual collision rates being unknown, we used two sets that we believed bracketed reality in order to calculate $n(H_2)$ and T_{kin}: for set 1, $n(H_2)$ was found to be 1.6×10^5 cm^{-3} and T_{kin} was 88.7 K; for set 2, $n(H_2)$ was 6.2×10^4 cm^{-3} and T_{kin} was 92.1 K.

In addition to lines from the vibrational ground state of CH_3CN (a species which is strong in Ori A and which may be in IRC +10216; Johansson *et al.* 1984), we observed transitions in the ν_8 vibrational state in Sgr B2 (previously observed in Ori A by Goldsmith *et al.* 1983) that are 533 K above the corresponding ground-state transitions (Boucher *et al.* 1980). The detectability of these high-energy transitions supports our identification of high-energy transitions of HNCO, SO_2, and CH_3OH, and of the vibrationally excited transitions of HC_3N (see below).

h) CH_3SH

We find essentially the same column density and rotational temperature for methyl mercaptan that Linke, Frerking, and Thaddeus (1979) found. A line at 107316 MHz, the $3_{-1} \rightarrow 3_0$ A transition, is the only CH_3SH line in this survey not previously published. The largest sulfur-containing interstellar molecule, methyl mercaptan has been detected only in Sgr B2.

i) H_2CCO

Excluding from the fit one possible ketene line at 101002 MHz, we find $T_{rot} = 18 \pm 4$ K and $N = (1.7 \pm 0.2) \times 10^{14}$ cm^{-2}. Attribution of this line to the $5_3 \rightarrow 4_3$ transitions of ketene ($E_u/k = 132$ K) changes the estimate of T_{rot} to 73 ± 26 K. Since the lower T_{rot} (18 K) is generally consistent with the rotational temperatures of other molecules in the source, our identification of the line at 101002 MHz remains uncertain. This transition may be evidence of differences in temperature and density within the source, such as data for HNCO, SO_2, and CH_3OH indicate.

A more confident estimate of T_{rot} must await better data at 80832 and 141452 MHz to extend E_u/k down to 10 K and fill the gap between $E_u/k = 41$ and 132 K with a point at 79 K. Although the BTL survey includes the H_2CCO transitions at 101024 and 101032 MHz that have $E_u/k = 67$ K, unfortunately these transitions are blended with CH_3SH at 101029 MHz. The $5_{0,5} \rightarrow 4_{0,4}$ H_2CCO transition at 101037 MHz is excluded for the same reason.

All the transitions included in the fit for T_{rot} and N are ortho-ketene transitions. Not only do the para-ketene transitions at 80.8 GHz fall in a poorly observed part of the survey, but, owing to the nuclear spin statistics, the intensity of these transitions relative to the ortho transitions is expected to be lower by a factor of 3. The para transitions at 101.0 GHz are blended with CH_3SH; those at 141.4 GHz occur in a gap in the survey.

For ortho-ketene, Turner (1977) found a column density $3 \times 10^{13} < N < 5 \times 10^{14}$ cm^{-2}, which, if $T_{kin} < 40$ K, required H_2 densities $> 10^7$ cm^{-3} or, if $T_{kin} > 50$ K, H_2 densities $> 3 \times 10^6$ cm^{-3}. Turner's measurements for $J_u = 4$ and 5 and $K_{-1} = 1$ suggested that transitions between upper members of K doublets are stronger than those between lower members. We find, to the contrary, in our spectra that $5_{1,5} \rightarrow 4_{1,4}$ is somewhat stronger than $5_{1,4} \rightarrow 4_{1,3}$. The BTL data are too noisy at 80077 MHz for a comparison to be made for $J_u = 4$.

The presence of ketene in Ori A has recently been reported (Sutton *et al.* 1985).

j) CH_3CHO

For acetaldehyde we found $T_{rot} = 10 \pm 2$ K and $N = (2.4 \pm 0.2) \times 10^{14}$ cm^{-2}. The two lowest energy transitions plotted in Figure 4*h*, the only *b*-type transitions of CH_3CHO apparent in the survey, are transitions out of the lower members of K doublets. Neither is excessively intense, as both would be if the populations of lower K doublet members were anomalously high, a possibility considered for strong lines at the frequency of *b*-type transitions of NH_2CHO (above).

Gilmore *et al.* (1976) assumed $T_{rot} = 20$ K and obtained $N = 1.5 \times 10^{14}$ cm^{-2}; we find no evidence to support their hypothesis of a two-component velocity structure. Fourikis *et al.* (1974), taking the background temperature, T_{BB}, into consideration, obtained $N = 3.5 \times 10^{14} \times T_{rot}/(T_{rot} - T_{BB})$, which for our value of $T_{rot} = 10$ K and with $T_{BB} = 2.8$ K would give $N = 4.9 \times 10^{14}$ cm^{-2}.

We find no evidence of CH_3CHO in the BTL data for Ori A. The line at 83584 MHz (Lovas *et al.* 1976) in Ori A can be attributed to H 53β recombination (Johansson *et al.* 1984). The line at 236045 MHz in Ori A identified as the $12_{1,11} \rightarrow 11_{1,10}$ A transition of CH_3CHO by Erickson *et al.* (1981) is, as Blake *et al.* (1984) have shown, likely to be the $5_3 \rightarrow 4_3$ A and $5_2 \rightarrow 4_2$ A transitions of $^{13}CH_3OH$ (at 236042 and 236050 MHz; R. M. Lees 1984, private communication). (Relatedly, a line identified as CO^+ at 236063 MHz [Erickson *et al.* 1981] is probably the $5_{-2} \rightarrow 4_{-2}$ E and $5_2 \rightarrow 4_2$ E transitions of $^{13}CH_3OH$ at 236062 and 236065 MHz, as Blake *et al.* also noted.) Neither CH_3CHO nor the structurally similar species NH_2CHO appears present in Ori A, although both are abundant in Sgr B2.

k) $HCOOCH_3$

The column density of methyl formate we found is $(3.4 \pm 0.3) \times 10^{14}$ cm^{-2}, which is comparable to what Churchwell *et al.* (1980) found based on the $9_{0,9} \rightarrow 8_{0,8}$ and $8_{0,8} \rightarrow 7_{0,7}$ transitions. These column densities, about 2 orders of magnitude less than what Brown *et al.* (1975) inferred when the molecule was discovered in Sgr B2, seem to confirm the suspicions of both Brown *et al.* and Churchwell and Winnewisser (1975) that the $J=1$, $K_{-1}=1$ doublet observed at 1.6 GHz may be population-inverted.

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In the BTL survey there are more lines for $HCOOCH_3$ than for any other molecule. Many of the lines were classified as unidentified until Bauder (1979) published the microwave spectrum of methyl formate for J up to 12, later extended to 30 (Bauder 1981).

Methyl formate is abundant in Ori A. The lines at 76702 and 76711 MHz previously attributed to CH_4, the line at 85927 MHz attributed to NH_2D, and the line at 86227 MHz attributed to CH_3OCH_3, recently were all more convincingly identified as $HCOOCH_3$ (Elldér *et al.* 1980); analysis of BTL observations of Ori A supports this conclusion.

The line in Sgr B2 attributed to NH_2D at 85926 MHz (Turner *et al.* 1978) may be methyl formate. If so, an $HCOOCH_3$ line with $T_A^* = 0.02$ K at 85927 MHz would be expected; we observed a line with $T_A^* = 0.05$ K at that frequency. Given the noise, it is possible that this line is due entirely to $HCOOCH_3$.

l) HC_3N

Detected in at least 17 Galactic sources (Morris *et al.* 1976), in Sgr B2 cyanoacetylene is found to have $N = (3.48 \pm 0.02) \times 10^{14}$ cm^{-2} and $T_{rot} = 26.4 \pm 0.3$ K. Taking the 2.8 K background radiation into consideration made a slight difference: when the background intensity was assumed to be zero, our estimates changed from those given above to $N = 3.26 \times 10^{14}$ cm^{-2} and $T_{rot} = 27.1$ K.

On the basis of observations of this molecule, Morris *et al.* (1976) proposed a two-component model of Sgr B2 that predicted a dense core, where $n(H_2) = 10^6$ cm^{-3} and $N = 2 \times 10^{14}$ cm^{-2}, surrounded by a halo 2 orders of magnitude less dense where N is about the same. Given their calibration uncertainties (50%), the discrepancy between the estimate of Morris *et al.* and ours is not surprising. To test the two-component model, we compared data for low-J HC_3N transitions with our data (J_u between 8 and 15). The data for $J = 1 \rightarrow 0$, $J = 2 \rightarrow 1$, and $J = 4 \rightarrow 3$, taken with the Parkes 64 m radio telescope (McGee, Newton, and Butler 1975; McGee, Balister, and Newton 1977), and data for the $J = 5 \rightarrow 4$ transition, taken with the NRAO 11 m telescope at Kitt Peak (Morris *et al.* 1976), were plotted on an L versus E_u/k diagram (the beam sizes for these observations were comparable to BTL's): all but the $J = 1 \rightarrow 0$ transition lay on the line drawn through our data. The $J = 1 \rightarrow 0$ transition, found to be 10 times stronger than expected for a purely thermal population, may be a weak maser (Morris *et al.* 1976), as the same transition of HC_5N may be (Broten *et al.* 1976).

Three transitions of $H^{13}CCCN$ and four doublets formed from the adjoining transitions of $HC^{13}CCN$ and $HCC^{13}CN$ are included in the survey. The ratio of the intensity of the parent transition to that of the isotopic species varies from 16 to 25, with an average of 21.

Six transitions of HC_3N in vibrationally excited states are included in the survey: four in the ν_7 vibrational state and two, first observed in Ori A (Goldsmith *et al.* 1983), in the $2\nu_7$ vibrational state. These transitions are from levels 321 and 637 K above the levels of the corresponding ground-state transitions (Lafferty and Lovas 1978).

m) SO

Sulfur monoxide has been observed in at least 18 Galactic sources (Gottlieb *et al.* 1978); for Sgr B2 Gottlieb *et al.* assumed $T_{kin} = 20$ K and a collision rate of 10^{-5} s^{-1} and obtained $N = 1.5 \times 10^{14}$ cm^{-2}. We find $T_{rot} = 18.9 \pm 0.7$ K and $N = (4.38 \pm 0.06) \times 10^{14}$ cm^{-2}.

Two transitions of ^{34}SO apparent in the survey at 84411 and 97715 MHz are 6% and 13%, respectively, as intense as the corresponding SO transitions.

n) CH_3CH_2OH

Ethanol was detected in Sgr B2 by Zuckerman *et al.* (1975), who assumed $T_{kin} = 20$ K and a collision rate of 6×10^{-6} s^{-1} and obtained $N = 10^{15}$ cm^{-2}. We estimate $T_{rot} = 14 \pm 2$ K and $N = (5.3 \pm 0.4) \times 10^{14}$ cm^{-2}. To date, only two alcohols have been detected in interstellar sources: methanol is present in both Sgr B2 and Ori A, but there is no evidence of the presence of ethanol either in the BTL Ori A data or in the data of Johansson *et al.* (1984) (although CH_3OCH_3 [below], the isomer of ethanol, is seen in Ori A). Erickson *et al.* (1981) assigned a line at 233213 MHz in Ori A as the $15_{5,11} \rightarrow 15_{4,12}$ transition of CH_3CH_2OH, but Blake *et al.* (1984) suggest that it may be CH_3CH_2CN. The component of the dipole moment being far weaker along the a-axis than along the b-axis (0.05 compared with 1.44 debyes), all the observed CH_3CH_2OH transitions are b-type transitions.

o) CH_3OCH_3

Dimethyl ether was first detected in Ori A (Snyder *et al.* 1974), then in Sgr B2 (Winnewisser and Gardner 1976). For Sgr B2 we find $T_{rot} = 24 \pm 6$ K and $N = (5 \pm 1) \times 10^{14}$ cm^{-2}. Owing to small differences in frequency, and substantial differences in intensity, between the lines of the four torsional symmetry species of this molecule, we have not attempted to derive line widths or radial velocities. (Tables 2 and 3 give the laboratory frequency only for the strongest torsional component of each rotational transition.)

p) CH_3CCH

We estimated the column density of propyne by comparing the intensity of its $6_0 \rightarrow 5_0$ transition to that of another symmetric top molecule, CH_3CN (above). On the basis of our estimate of the column density of CH_3CN, we obtain a rough estimate of the column density of CH_3CCH of 6×10^{14} cm^{-2}, which is comparable to what Hollis *et al.* (1981) obtained, $(8.5 \pm 1.0) \times 10^{14}$ cm^{-2}, although it differs by a factor of 2 from the more recent estimate by Churchwell and Hollis (1983) of $(1.1 \pm 0.2) \times 10^{15}$ cm^{-2}.

Vibrationally excited CH_3CCH may possibly be present at 85.7 GHz, perhaps confused with C_4H, although its absence at 102.8 and 137.1 GHz leaves such identification highly doubtful.

q) H_2CS

Thioformaldehyde, first detected in Sgr B2 (Sinclair *et al.* 1973), is present in Ori A (Loren 1984). Gottlieb *et al.* (1978), assuming $T_{kin} = 20$ K and a collision rate of 10^{-5} s^{-1}, ob-

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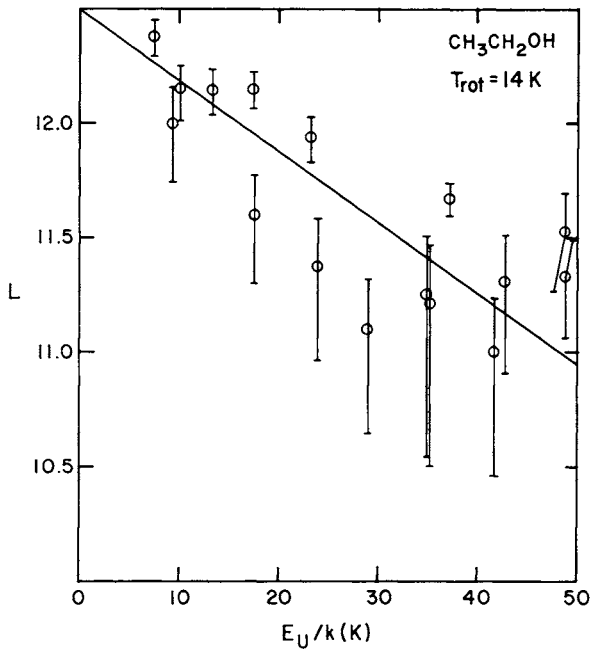

FIG. 4*l*

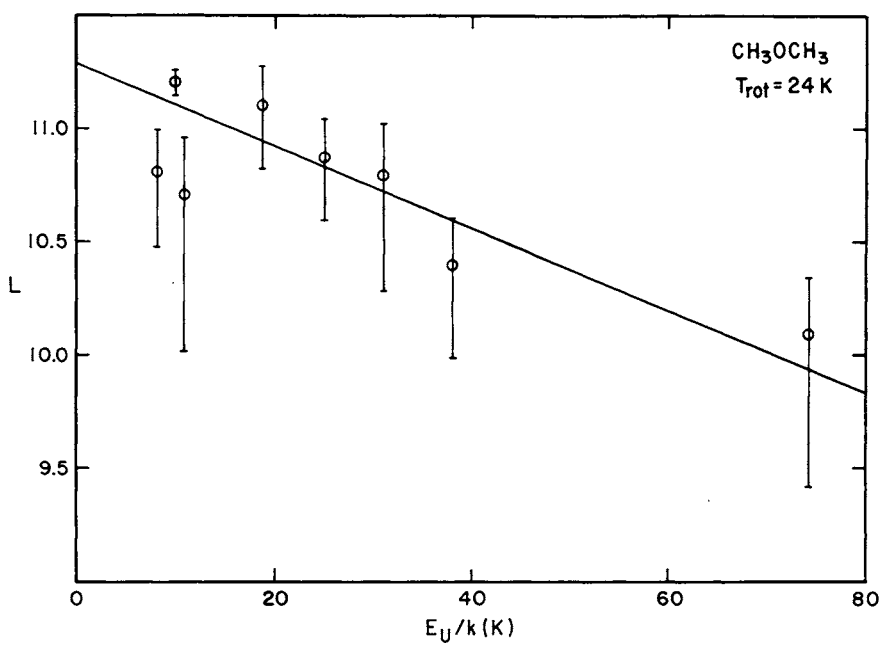

FIG. 4*m*

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tained $N = 3\times10^{14}$ cm^{-2} for Sgr B2. We find $T_{rot} = 25\pm2$ K and $N = (6.0\pm0.4)\times10^{14}$ cm^{-2}. Three weak lines at 97634, 130170, and 132086 MHz are probably attributable to $H_2^{13}CS$ because their intensities are fairly consistent (6%–17% as strong as the corresponding transitions of the parent species) and because there are no other frequencies in the survey where lines for this species ought to be seen but are not.

r) HNCO

Isocyanic acid was detected in Sgr B2 (Snyder and Buhl 1971), where $K_{-1} = 0$ lines are very strong, with $T_A^* = 4$ K, in contrast to Ori A, where $T_A^* < 0.1$ K in the BTL data. Recently, HNCO was detected in six other sources (Jackson, Armstrong, and Barrett 1984), where $T_A^* \leq 0.3$ K, with the exception of Sgr A, where T_A^* was as high as 3 K.

The BTL data for Sgr B2 can be fitted as a whole, giving $T_{rot} = 14.8$ K and $N = 1.5\times10^{15}$ cm^{-2}, but, owing to the high signal-to-noise ratios of the $K_{-1} = 0$ and 1 transitions and the low signal-to-noise ratios of the $K_{-1} = 2$ and 3 transitions, this is essentially only a fit to the $K_{-1} = 0$ and 1 data. The $K_{-1} = 1$, 2, and 3 points are approximately collinear, but on a line with less negative slope (higher temperature) than the line through the $K_{-1} = 0$ and 1 points, possibly the result of temperature and density structure within the source. We made separate fits, first for the $K_{-1} = 0$ and 1 data and then for the $K_{-1} = 1$, 2, 3 data (see Fig. 4*o* for the corresponding lines): the low K_{-1} data gave $T_{rot} = 14.8\pm0.2$ K and $N = (1.4\pm0.2)\times10^{15}$ cm^{-2} and the high K_{-1} data gave $T_{rot} = 61\pm10$ K and $N = (4.4\pm0.5)\times10^{14}$ cm^{-2}. Our estimates of the column density of isocyanic acid are for the parent species and an isotopically substituted species ($HN^{13}CO$) combined, because transitions for these species cannot be resolved.

Basing their calculations on the intensity ratio of the $4_{0,4} \rightarrow 3_{0,3}$ to the $1_{0,1} \rightarrow 0_{0,0}$ transition, Snyder and Buhl (1972) predicted $T_{rot} = 12.8$ K and $4.5\times10^{14} < N < 6.4\times10^{14}$ cm^{-2}, which, in relation to our estimates for the low K_{-1} data, is a comparable value for T_{rot} but the value of N is a factor of 2 less than our estimate.

Solomon *et al.* (1973) concluded that the HNCO transitions $4_{0,4} \rightarrow 3_{0,3}$ and $5_{0,5} \rightarrow 4_{0,4}$ were optically thick in Sgr B2; for optically thin lines in the same $K_{-1} = 0$ ladder they predicted

$$\frac{T_A(5\rightarrow4)}{T_A(4\rightarrow3)} = 1.56$$

instead of their observed ratio $1.2/2.5 = 0.44$ (for discussion of the validity of this prediction see Jackson, Armstrong, and Barrett 1984). Our BTL survey gives intensities (T_R) for these lines of 4.20 and 5.30 K, respectively, yielding a ratio of 1.26, which comes close to what Solomon *et al.* predicted for optically thin lines. But the optical depths we calculated for these transitions (0.44 and 0.50) and for the $6_{0,6} \rightarrow 5_{0,5}$ transition (0.55) are the highest optical depths of all transitions considered in the present study. Correction for optical depth, however, only raises T_{rot} by 0.5 K and N by 13%.

s) OCS

Carbonyl sulfide, a molecule that suggests that the nonpolar molecule CO_2 may be abundant in Sgr B2, was detected by Jefferts *et al.* (1971), who assumed $T_{rot} = 20$ K and obtained a lower bound for N of 3×10^{15} cm^{-2}. Akabane *et al.* (1974) compared the $J = 9 \rightarrow 8$ and $J = 6 \rightarrow 5$ lines and derived an excitation temperature of 40 K and a column density of 4.4×10^{15} cm^{-2}. Goldsmith and Linke (1981), who reported detection of OCS in nine other sources, obtained $N = 2\times10^{15}$ cm^{-2} for Sgr B2, assuming $T_{kin} = 20$ K and $n(H_2) = 3\times10^4$ cm^{-3}. Using the five transitions in the BTL survey of Sgr B2, we obtain $T_{rot} = 31\pm3$ K and $N = (2.1\pm0.1)\times10^{15}$ cm^{-2}.

Two $O^{13}CS$ transitions are included in the survey, at 84867 and 109112 MHz, as well as three $OC^{34}S$ transitions, at 83059, 106787, and 142381 MHz. The data at the lowest four of these five frequencies were discussed by Goldsmith and Linke (1981), who found that in Sgr B2 OCS was 21 times as abundant as $O^{13}CS$ and 16 times as abundant as $OC^{34}S$.

t) SO_2

The rotational temperature of sulfur dioxide is one of the most interesting derived for Sgr B2. Transitions from states with surprisingly high energies are detectable. Four clear-cut lines are from transitions with E_u/k greater than 350 K. One line, at 126981 MHz, has $E_u/k = 643$ K, the highest level of any transition seen of the 21 species studied here. The SO_2 data as a whole can be fitted with $T_{rot} = 46\pm3$ K and $N = (8.6\pm0.4)\times10^{14}$ cm^{-2}. But, as with HNCO and CH_3OH, the data were poorly characterized by a single rotational temperature. The same temperature is obtained when only data with $E_u/k < 150$ K are fitted, because the high-energy lines have lower signal-to-noise ratios and are given less weight in the fit. When the high-energy ($E_u/k > 150$ K) data alone are fitted, a T_{rot} of 210 ± 130 K and a column density of $(4\pm2)\times10^{15}$ cm^{-2} are obtained. Another estimate for the high-energy data, obtained by including data from transitions with E_u/k down to 70 K, is $T_{rot} = 290\pm60$ K and $N = (3.1\pm0.7)\times10^{15}$ cm^{-2}. This temperature, well above our estimate based on our study of CH_3CN (above) of 85 ± 10 K for the kinetic temperature of Sgr B2, is additional evidence for one or more clumps of very hot gas in Sgr B2.

There is no evidence of the $16_{2,14} \rightarrow 16_{1,15}$ transition of SO_2 at 143057 MHz ($E_u/k = 138$ K). The intensities of the other SO_2 transitions in Sgr B2 lead us to expect T_A^* for this transition to be at least 0.15 K, well above the 0.04 K noise. The $7_3 \rightarrow 8_2$ E transition of CH_3OH at 143170 MHz should appear in the same spectrum with T_A^* at least 0.08 K. The absence of these two lines is puzzling, an indication perhaps of receiver malfunction or an error in pointing which may affect the entire range 143.20 ± 0.25 GHz.

Four lines of $^{34}SO_2$ (Table 2) are seen at 104392, 124496, 124614, and 128669 MHz, and another is suggested at 102032 MHz. The transitions at 104392 and 128669 MHz are about 12% as intense as the corresponding SO_2 transitions, but the line at 124496 MHz, which is surprisingly intense, is about half as strong as the corresponding SO_2 transition. Another (unidentified) molecule may contribute at this frequency.

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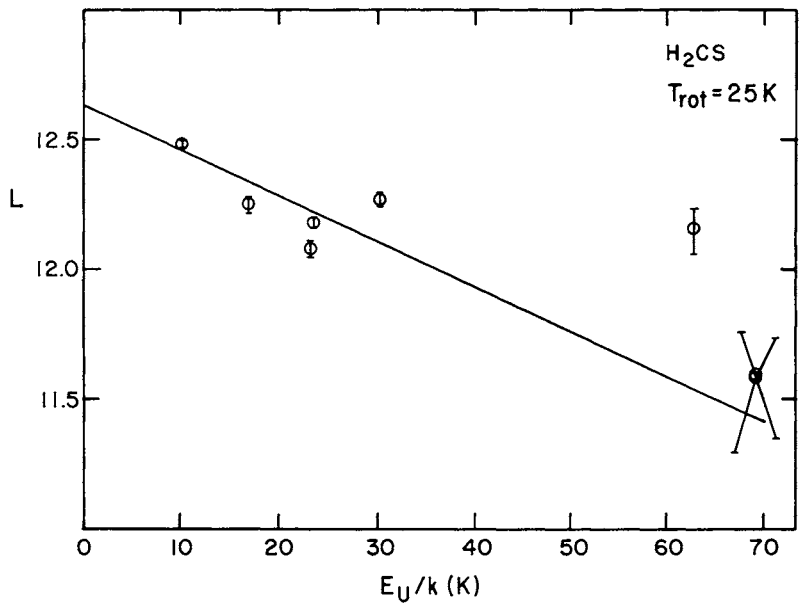

FIG. 4*n*

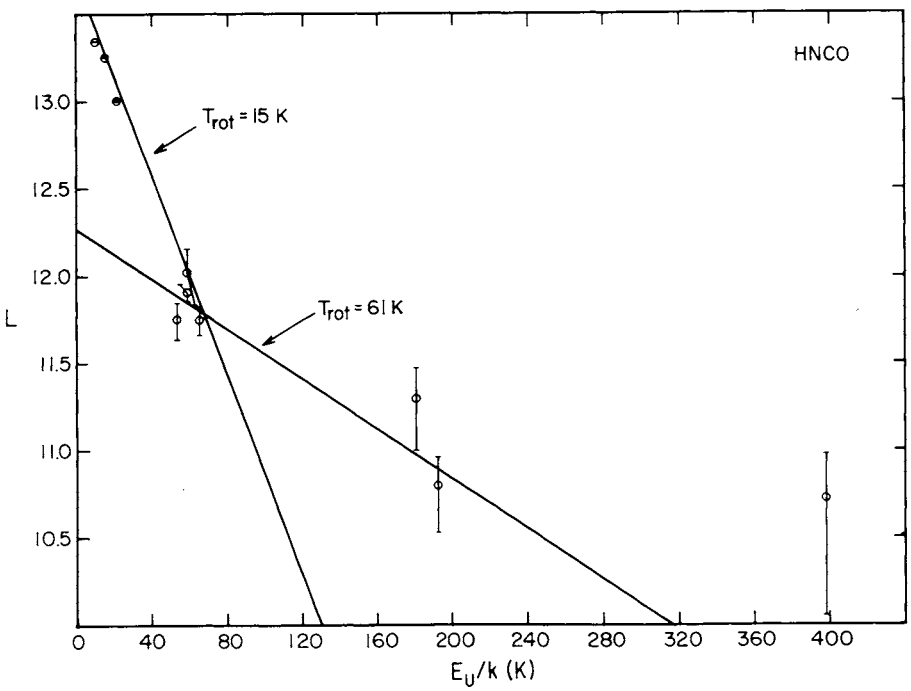

FIG. 4*o*

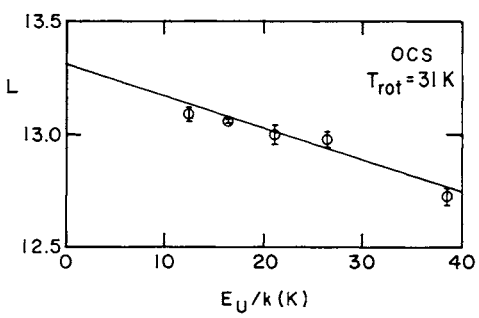

FIG. 4*p*

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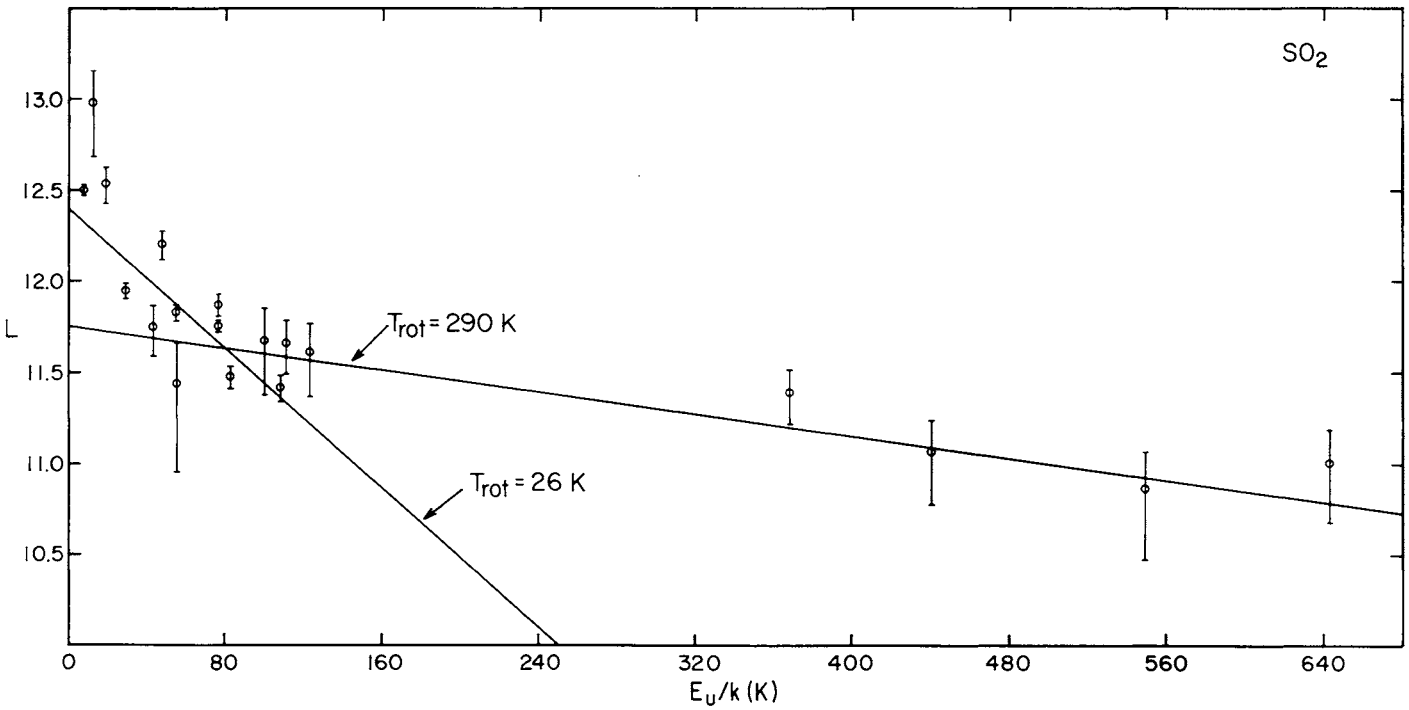

FIG. 4*q*

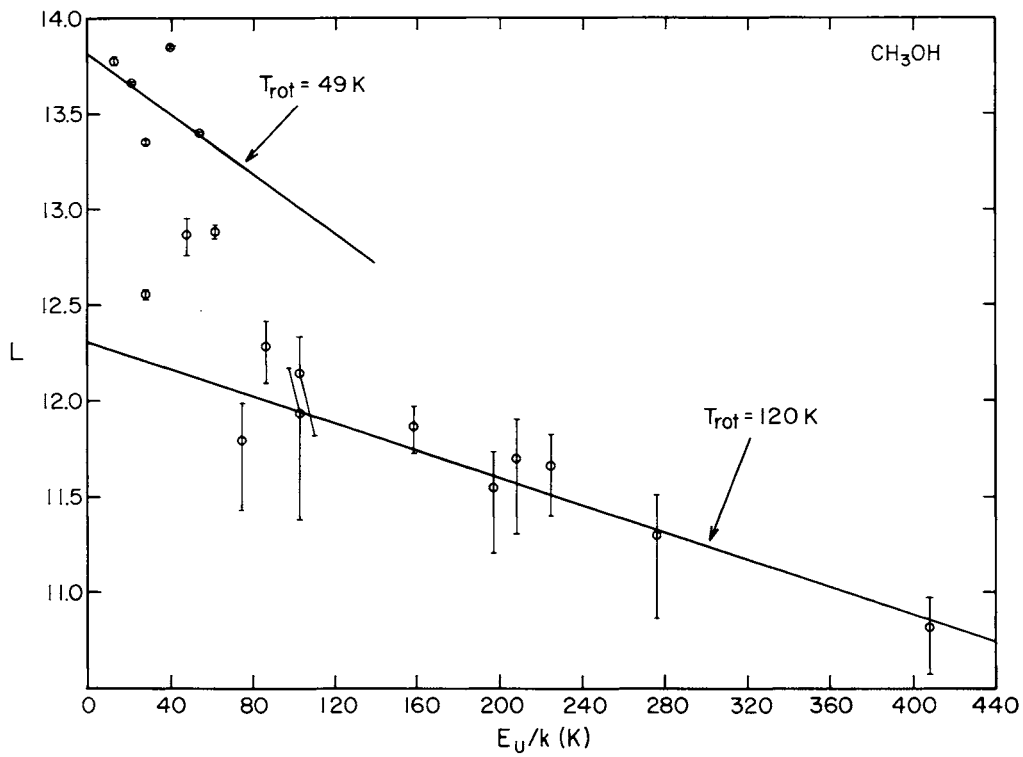

FIG. 4*r*

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u) CH_3OH

First detected in Sgr B2 and Sgr A by Ball *et al.* (1970), methanol was subsequently detected in at least 12 other sources (Gottlieb *et al.* 1979). For Sgr B2, Gottlieb *et al.* assumed $T_{kin} = 20$ K and a collision rate of 2.4×10^{-5} s^{-1}, and, based on their observation of the $2_1 \rightarrow 1_1$ E transition ($E_u/k = 20$ K), estimated the CH_3OH column density to be 2×10^{16} cm^{-2}. Nagai *et al.* (1979) assumed $n(H_2) = 5 \times 10^4$ cm^{-3} and $T_{kin} = 40$ K and, based on their observations of the $J = 2 \rightarrow 1$ transitions at 96.7 GHz ($E_u/k = 7$ K) and the $5_{-1} \rightarrow 4_0$ E transition at 84.5 GHz ($E_u/k = 40$ K), found that $N = 4 \times 10^{16}$ cm^{-2}. The BTL data can be fitted as a whole, giving $T_{rot} = 55 \pm 2$ K and a column density of $(1.2 \pm 0.04) \times 10^{16}$ cm^{-2}. Since the data seemed poorly characterized by this one-temperature model, we divided them into two sets (cf. HNCO and SO_2, above) according to whether E_u/k was less than or greater than 70 K. The fit obtained for the high-energy set was $T_{rot} = 120 \pm 20$ K and $N = (3.5 \pm 0.5) \times 10^{15}$ cm^{-2}; for the low-energy set $T_{rot} = 49 \pm 1$ K and $N = (2.75 \pm 0.07) \times 10^{16}$ cm^{-2}, in fair agreement with the estimate of Gottlieb.

Several methanol lines unassigned by Lees and Baker (1968) were recently assigned by Sastry, Lees, and De Lucia (1984) as transitions of mixed symmetry of the type $J_{-2} \rightarrow J_1$ E. Two of these transitions ($J = 13$ and $J = 14$) can be seen at 104337 and 105576 MHz (Fig. 7). The $J = 14$ transition, previously reported by Johansson *et al.* (1984) in Ori A, is seen in the BTL Ori A data where two additional transitions ($J = 15$ and $J = 16$) are evident. Since line strengths for these transitions have not yet been calculated because the symmetry species are mixed, we did not include transitions of this type in the fit for T_{rot} and N.

The only line of $^{13}CH_3OH$ clearly apparent in the present survey is a blend of the $3_0 \rightarrow 2_0$ E and A and $3_{-1} \rightarrow 2_{-1}$ E transitions at 141600 MHz, the lowest energy transitions of the $J = 3 \rightarrow 2$ *a*-type transitions. There is a suggestion of a line at 141629 MHz, the frequency of the $3_1 \rightarrow 2_1$ E transition, which would be blended with the nearby $K = 2$ transitions. Comparison of the intensity of this blend (only about 0.06 K) with the intensity of the lower energy transitions (0.44 K) indicates a low excitation temperature; the ratio of these intensities is comparable to what Kutner *et al.* (1973) found for the parent species at low excitation temperatures. Not surprisingly, the unblended $2_1 \rightarrow 1_1$ A+ transition of $^{13}CH_3OH$ at 93620 MHz is not detected. A gap occurs in the data for the remaining $2 \rightarrow 1$ *a*-type transitions.

VI. FURTHER COMMENTS ON THE DATA

In § VI*a* the calculated column densities for several molecules are compared in an attempt to predict by analogy or by extrapolation the abundance of molecules not yet detected. In § VI*b* the average line widths, v_{LSR}'s, rotational temperatures, and line intensities (plotted in Fig. 5) are compared in an attempt to find correlations between these parameters. An expected correlation between rotational temperatures and dipole moments was not found (Fig. 6).

a) *Ratios of Abundances*

In attempting to predict the detectability of new molecules in Sgr B2, ratios of column densities of known interstellar molecules which are structurally similar but differ in a functional group are compared. Based on the ratios, using analogy or extrapolation we attempted to predict abundances of as yet undetected species and, further, taking into account dipole moments and partition functions, the intensities. Column densities are indicated here by brackets enclosing the molecule.

Ratios of the methyl to the ethyl group are

$$\frac{[CH_3CN]}{[CH_3CH_2CN]} = 2.3,$$

$$\frac{[CH_3OH]}{[CH_3CH_2OH]} = 6.6 \quad \text{(high-energy } CH_3OH \text{ data)},$$

and

$$\frac{[CH_3OH]}{[CH_3CH_2OH]} = 53 \quad \text{(low-energy } CH_3OH \text{ data)}.$$

Even though these ratios differ by more than an order of magnitude, they suggest the abundance and detectability of as yet undetected species. For example, since we know $[CH_3CHO] = 24 \times 10^{13}$ cm^{-2}, then for the undetected species CH_3CH_2CHO we can assume either that the ratio $[CH_3CHO]/[CH_3CH_2CHO] = 2$, in which case $[CH_3CH_2CHO]$ would be predicted to be 10^{14} cm^{-2}, or that the ratio is 50, so $[CH_3CH_2CHO]$ would be 10^{13} cm^{-2}, both column densities in the range of those of many known species. Even if $[CH_3CH_2CHO]$ and $[CH_3CHO]$ were the same (the dipole moments being nearly the same but the partition functions differing), the maximum T_A^* for CH_3CH_2CHO would be expected to be only one-fifth that of CH_3CHO transitions. If the smaller of the two ratios (2, rather than 50) is used optimistically to predict the relative abundance of CH_3CH_2CHO, the maximum intensity would be expected to be only 0.03 K in the frequency range of the survey. Similar reasoning applied to $CH_3CH_2OCH_3$, CH_3CH_2CCH, and $HCOOCH_2CH_3$ gives T_A^* of 0.04, 0.03, and 0.02 K, respectively, as the maximum intensity expected for these molecules, results somewhat below the current threshold for detectability.

Since no known interstellar molecules contain the propyl group, efforts to predict their abundance rely on extrapolation, that is, on the assumption that the ratio of propyl to ethyl is the same as that of ethyl to methyl. If the column densities for $CH_3CH_2CH_2CN$ and CH_3CH_2CN were the same (and even though the dipole moments are roughly the same), owing to the relative values of the partition functions the values of T_A^* for $CH_3CH_2CH_2CN$ compared with those of CH_3CH_2CN would be down by a factor of 2.7; the values of T_A^* for $CH_3CH_2CH_2OH$ compared with CH_3CH_2OH would be down by the same factor. Then, if the abundances of the propyl molecules compared with the ethyl molecules were down by only a factor of 2, the maximum T_A^* for $CH_3CH_2CH_2CN$ would be only 0.03 K and that for $CH_3CH_2CH_2OH$ would be only 0.04 K, again beneath the threshold for detectability.

These predictions are at least consistent with our observations; unfortunately, other predictions based on similar reasoning proved to be false. For example, two ratios of the

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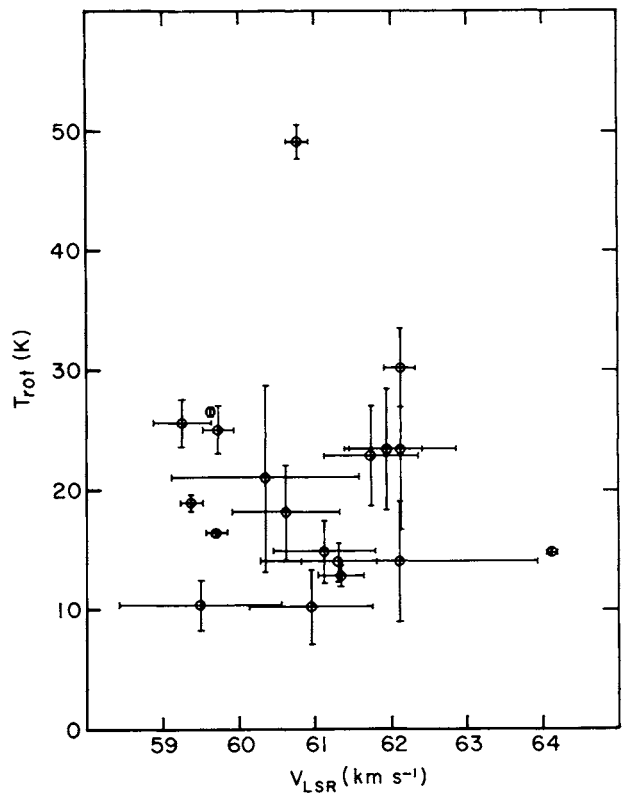

FIG. 5*a*

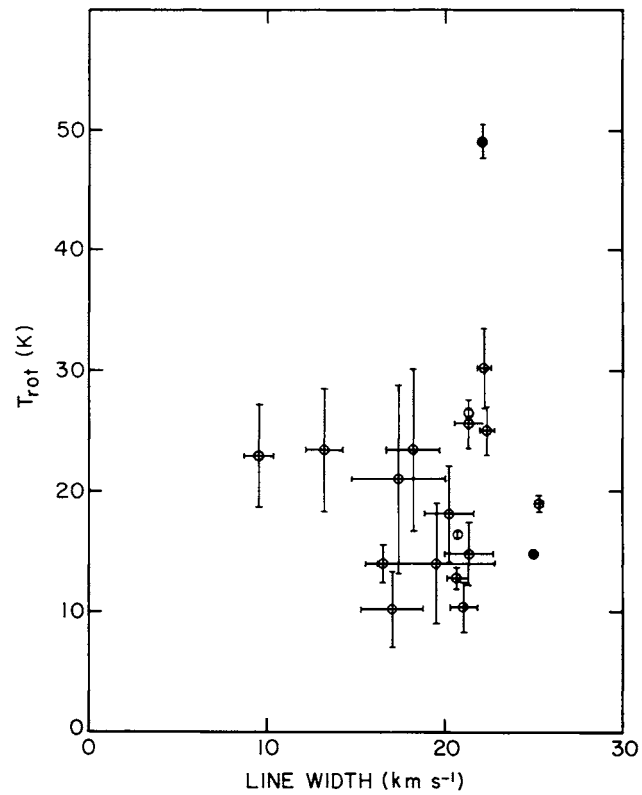

FIG. 5*b*

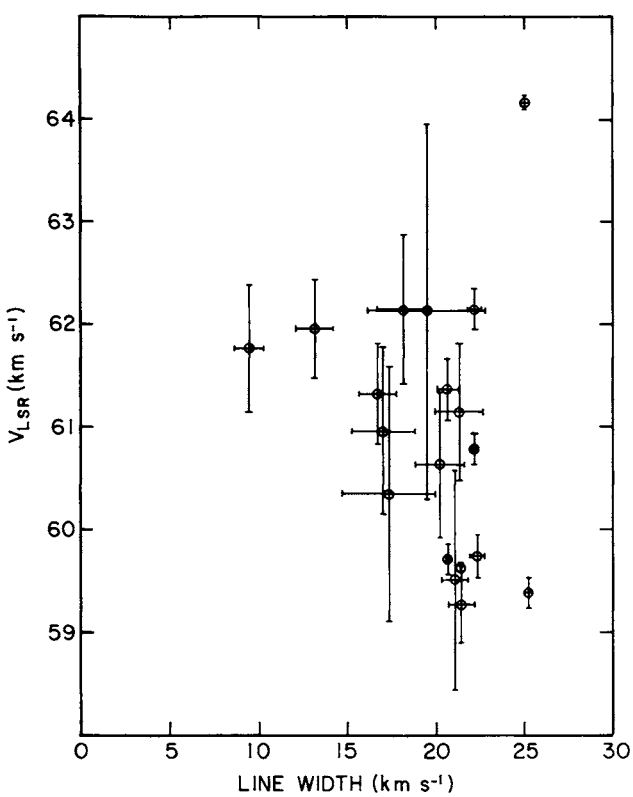

FIG. 5*c*

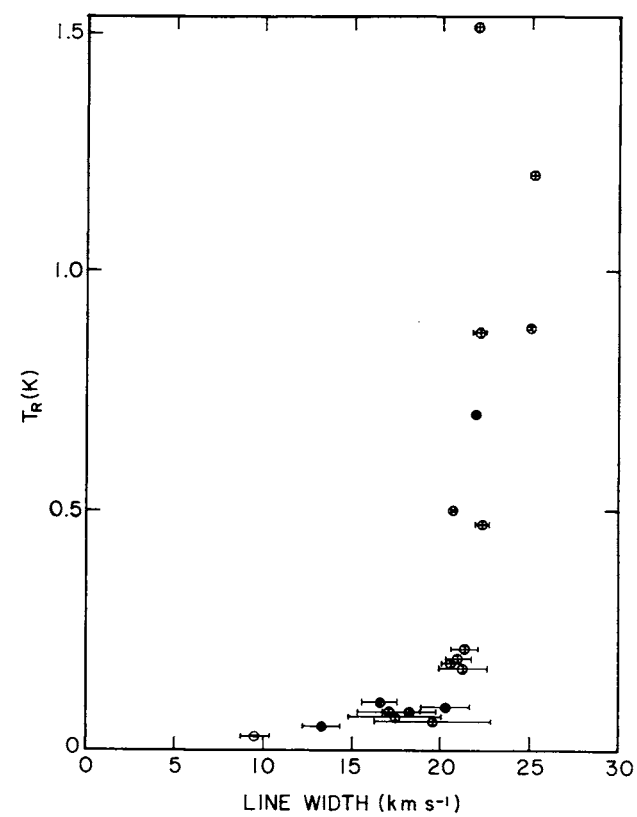

FIG. 5*d*

FIG. 5.—Correlation diagrams of average parameters: (*a*) rotational temperature versus v_{LSR}; (*b*) rotational temperature versus line width; (*c*) v_{LSR} versus line width; (*d*) line intensity T_R versus line width.

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methyl group to the amide group can be formed:

$$\frac{[CH_3CN]}{[NH_2CN]} = 7$$

and

$$\frac{[CH_3CHO]}{[NH_2CHO]} = 3.5.$$

Using these ratios, NH_2OH, NH_2OCH_3, and NH_2CH_2CN are compared with CH_3OH, CH_3OCH_3, and CH_3CH_2CN. As in the examples given above, NH_2OCH_3 and NH_2CH_2CN are predicted to be too weak to be detectable, but NH_2OH, which is predicted to have intensities possibly as high as 0.2 K, is demonstrably not present.

As another example, ratios of the hydroxyl group to the cyano group can be formed:

$$\frac{[CH_3CH_2OH]}{[CH_3CH_2CN]} = 8.5,$$

$$\frac{[CH_3OH]}{[CH_3CN]} = 26 \quad \text{(high-energy } CH_3OH \text{ data)},$$

and

$$\frac{[CH_3OH]}{[CH_3CN]} = 200 \quad \text{(low-energy } CH_3OH \text{ data)}.$$

Using these ratios, CH_2CHOH and NH_2OH are compared with CH_2CHCN and NH_2CN. With the lowest of these ratios, CH_2CHOH and NH_2OH would be expected to have T_A^* values as high as 0.09 and 0.06 K, but, again, there is no evidence of these species in the survey.

Last, ratios of the formyl group to the cyano group are

$$\frac{[CH_3CHO]}{[CH_3CN]} = 1.8$$

and

$$\frac{[NH_2CHO]}{[NH_2CN]} = 3.6.$$

Then, [HCCCHO], [CH_2CHCHO], and [CH_3CH_2CHO] would be expected to be approximately the same as those for [HC_3N], [CH_2CHCN], and [CH_3CH_2CN]; using the lower ratio, the predicted T_A^* values would be as high as 0.9, 0.2, and 0.1 K, respectively. But none of these species has been detected.

b) Comparison of Average Line Width, v_{LSR}, Rotational Temperature, Intensity, and Dipole Moment

Considerable variation from molecule to molecule occurs in the average line width and average v_{LSR} computed for 19 species: the average line width varies from 9 to 25 km s^{-1}, and the average v_{LSR} varies from 59.3 to 65 km s^{-1} (Table 1). A correlation between these parameters or between these and T_{rot} might have provided evidence for different chemical composition within different parts of the cloud and might have offered information about the small-scale structure of the source. Although no such correlations were found (Figs. 5*a*–5*c*, where each point represents the averages for a given species), a correlation does exist between average line intensity and line width (Fig. 5*d*): the fullest range of velocities in the source is detectable for only the more intense transitions. For some molecules an inverse correlation exists between the energy of the upper state of a transition and its line width, signifying simply that transitions from states of high energy generally have lower intensity.

Our expectation that T_{rot} might be lower for molecules with large dipole moments was not confirmed: no correlation between T_{rot} and dipole moment is discernible (Fig. 6).

VII. SUMMARY

We present spectra of 49 GHz of the millimeter-wave spectrum of Sgr B2, identify 426 of the lines detected, and list 31 which remain unidentified. Identification of transitions of 20 out of 21 molecules discussed here (§ V) was confirmed by plotting the intensities on excitation (L versus E_u/k)

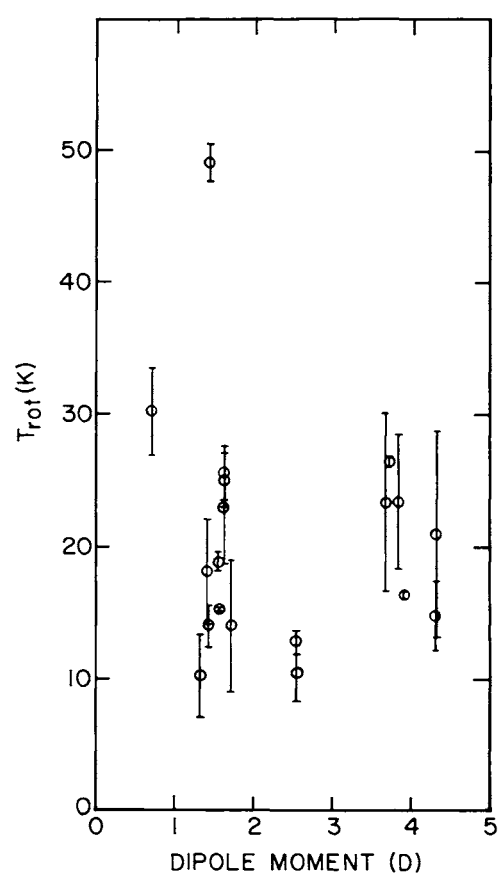

FIG. 6.—Rotational temperature versus dipole moment

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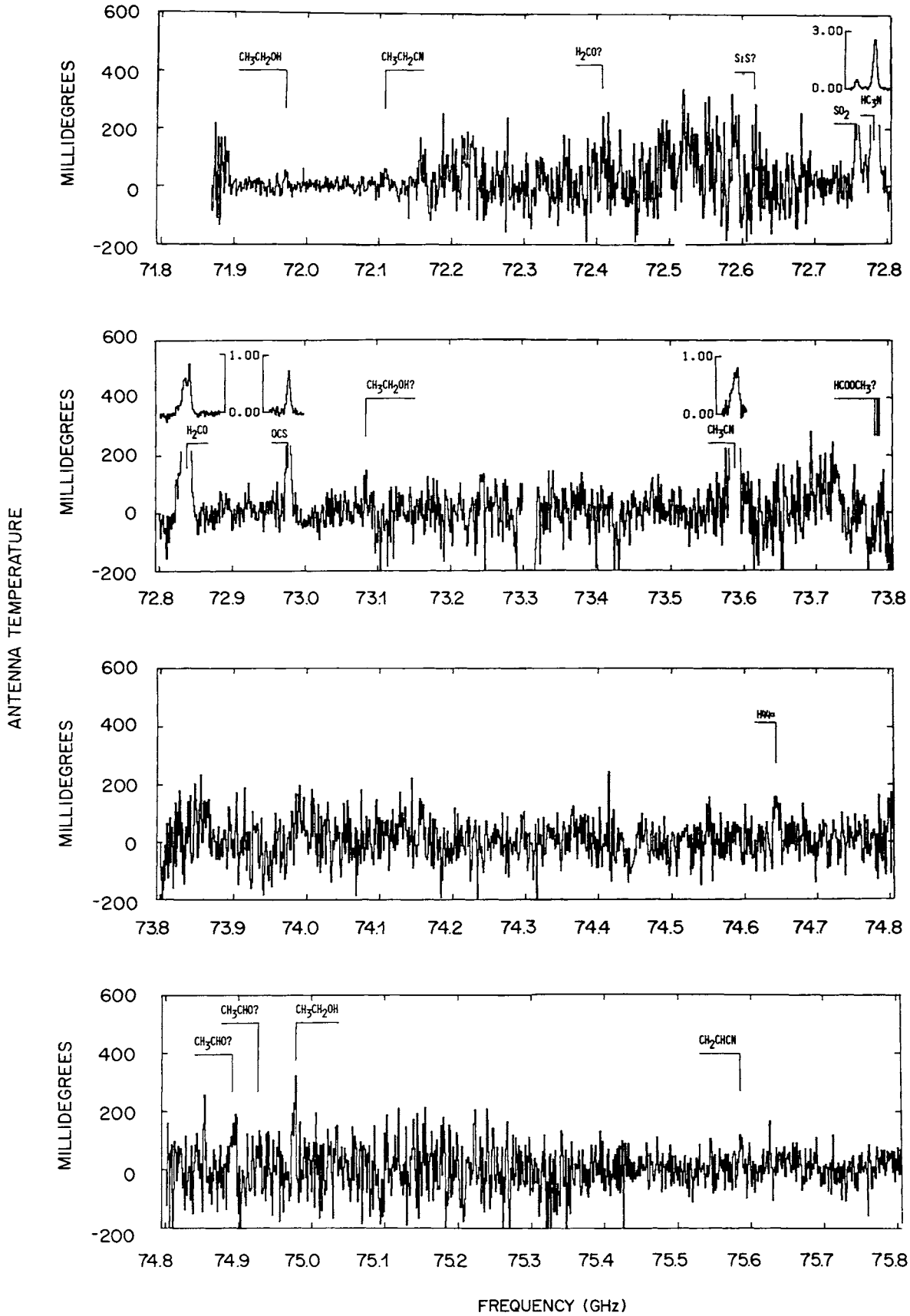

FIG. 7.—Spectra of the survey of Sgr B2. The vertical axis is antenna temperature T_A^*, corrected for atmospheric attenuation but not for antenna efficiency η_l (given as a function of frequency in Fig. 1). A question mark follows an identification when the signal-to-noise ratio (S/N) is low but the line has approximately the right intensity for a particular molecule; when for a transition of a known astrophysical molecule to date no quantum numbers have been assigned or line strength calculated; or, last, when the intensity is anomalous although the frequency is correct (see comments in Table 2). A question mark also follows any unidentified line when whether it is real or merely an artifact of the noise remains unclear.

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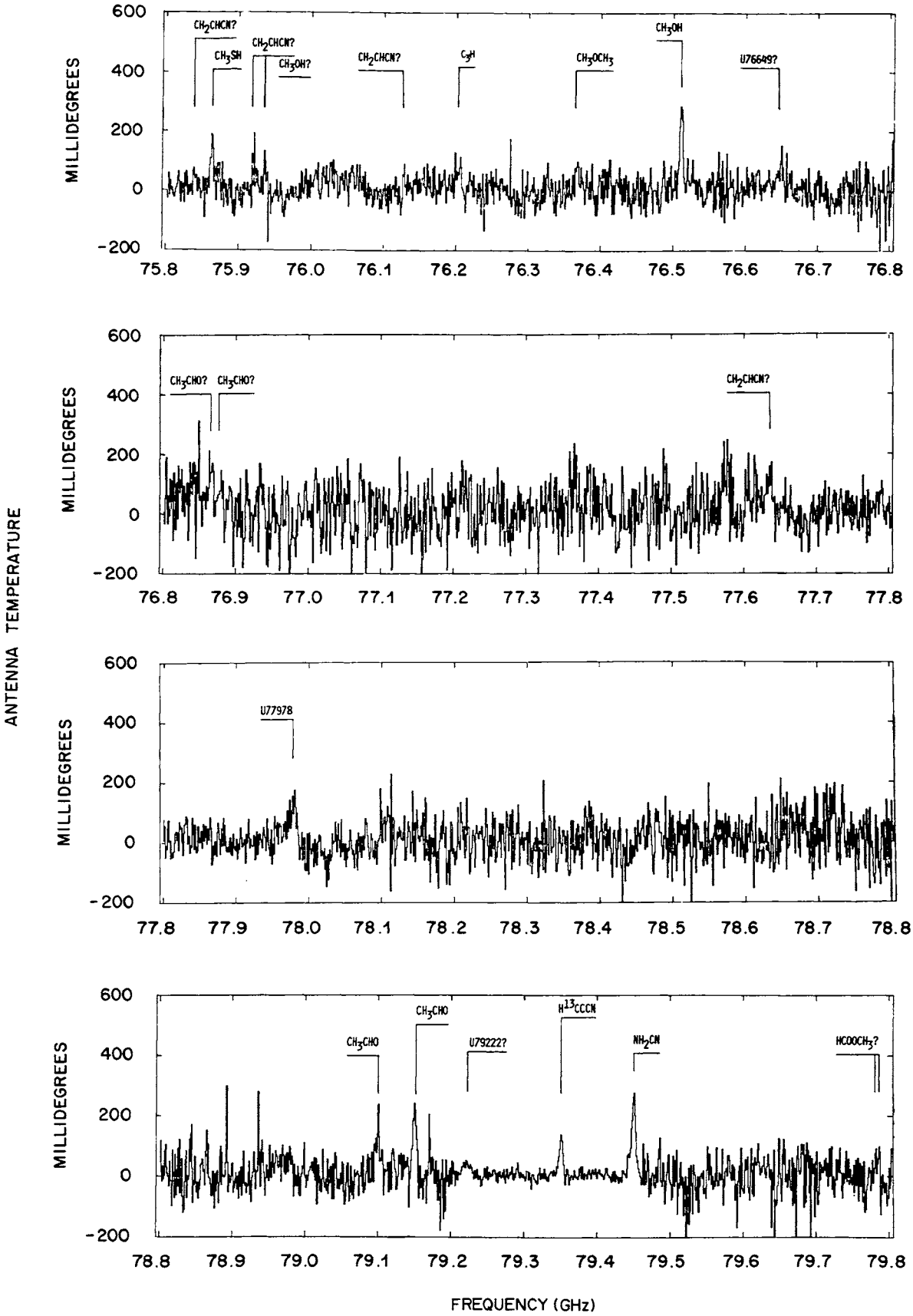

FIG. 7—*Continued*

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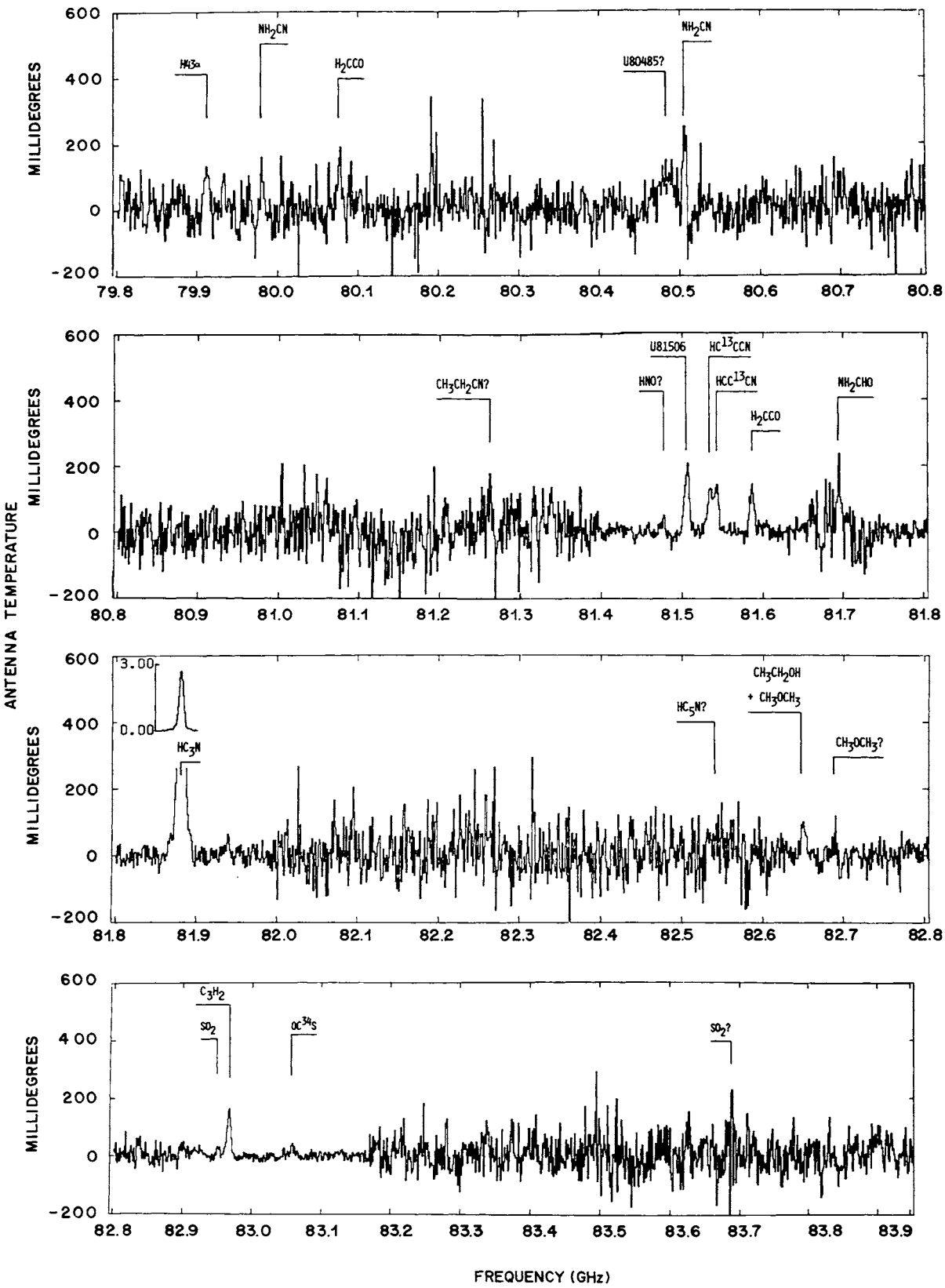

FIG. 7—*Continued*

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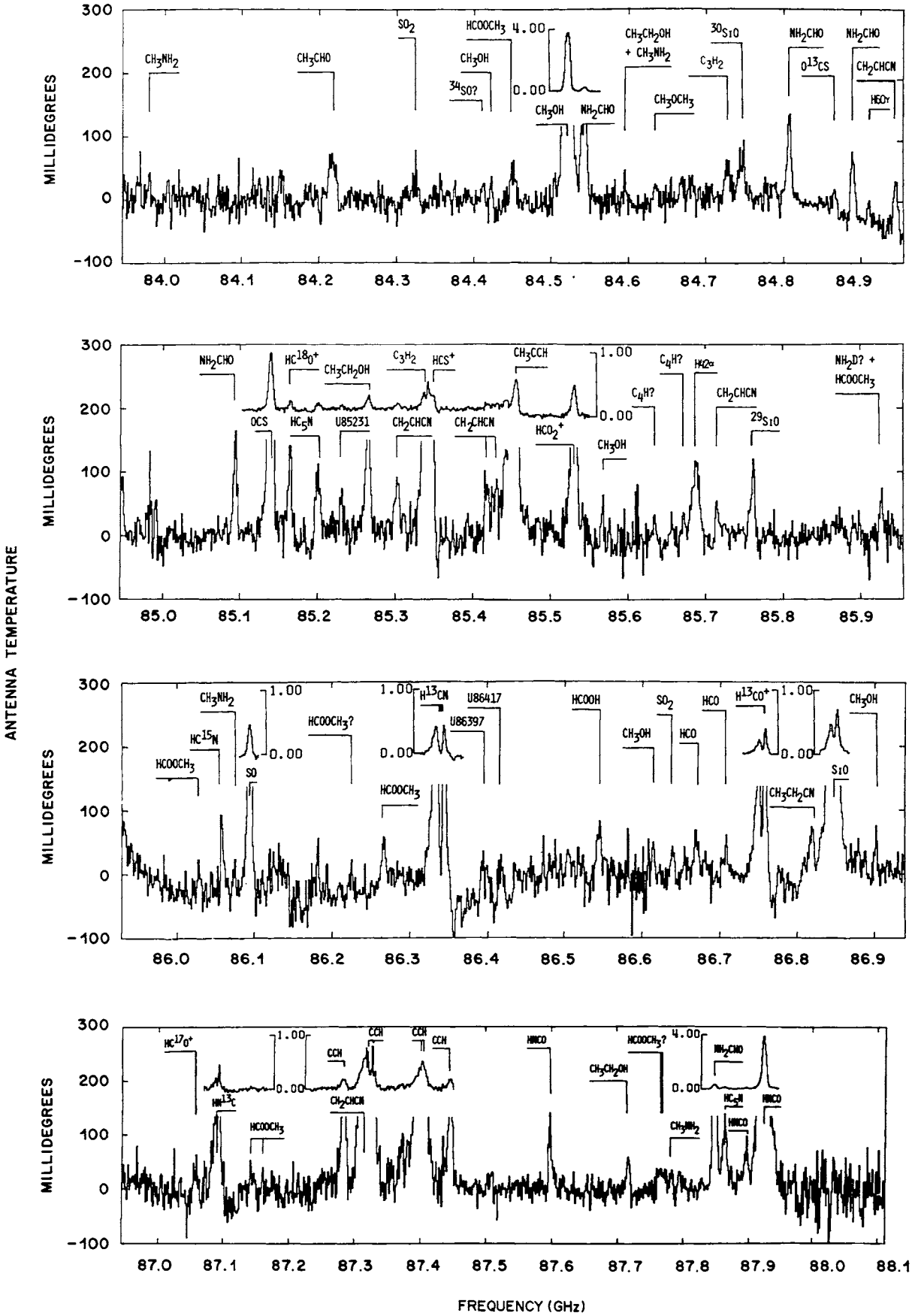

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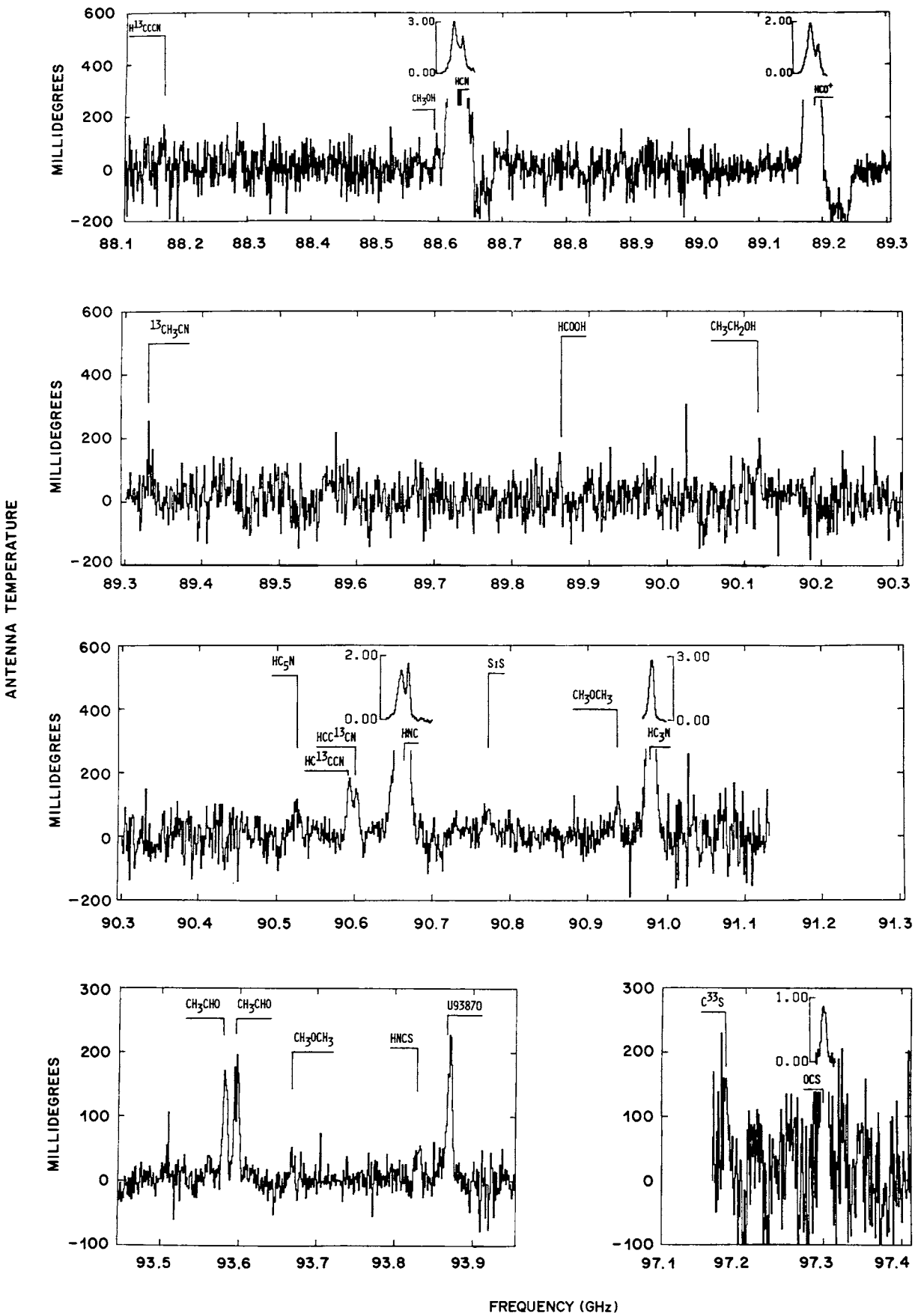

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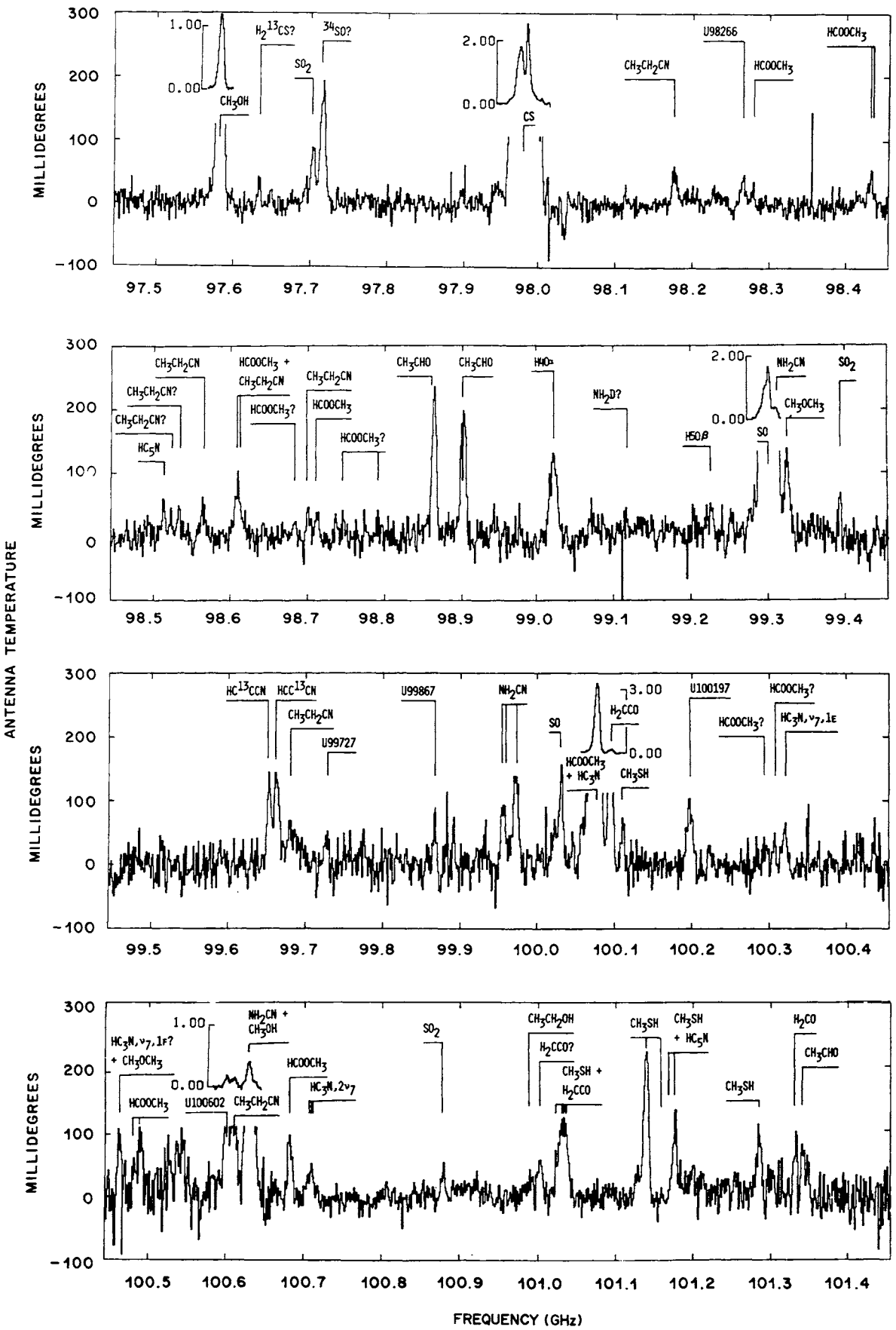

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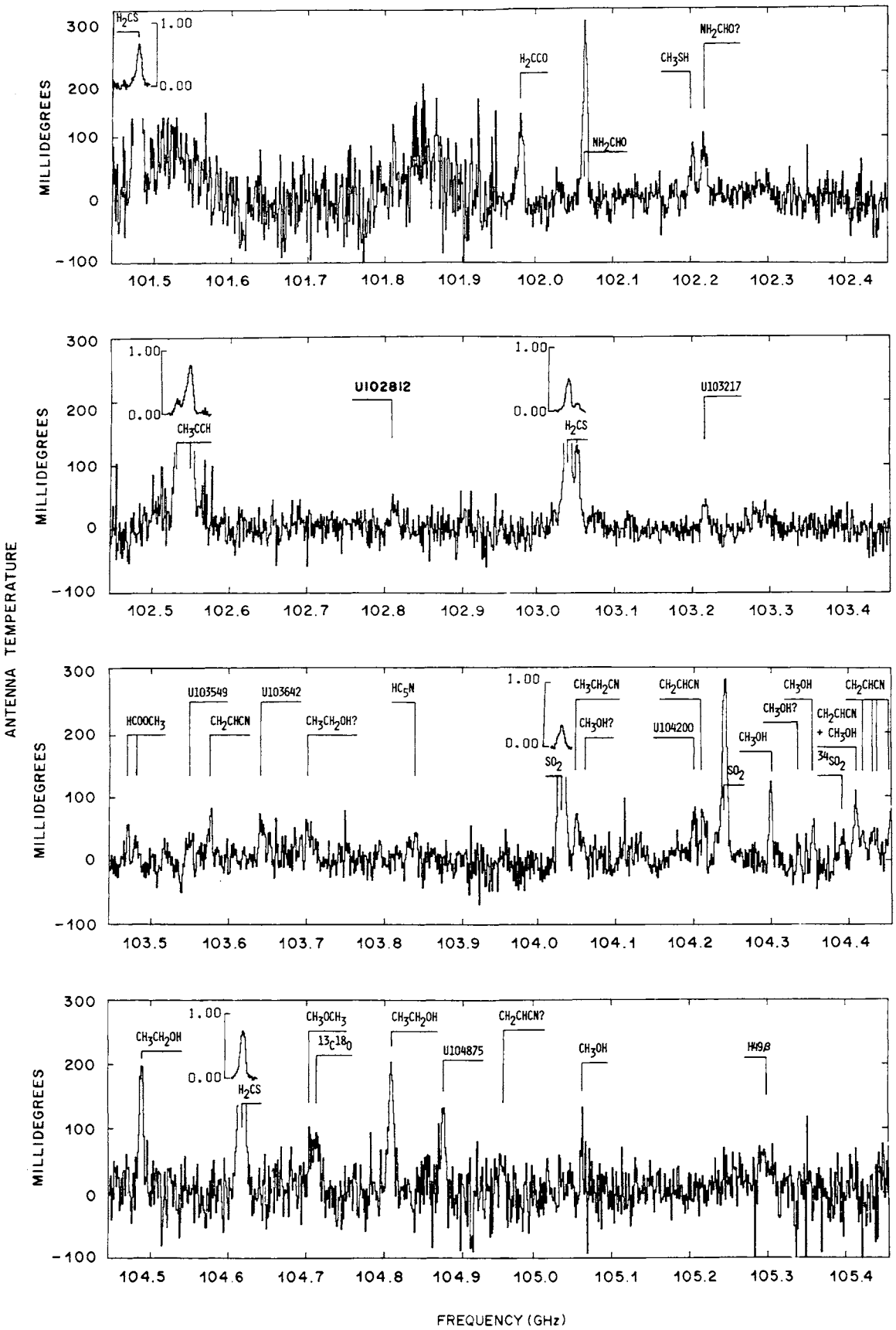

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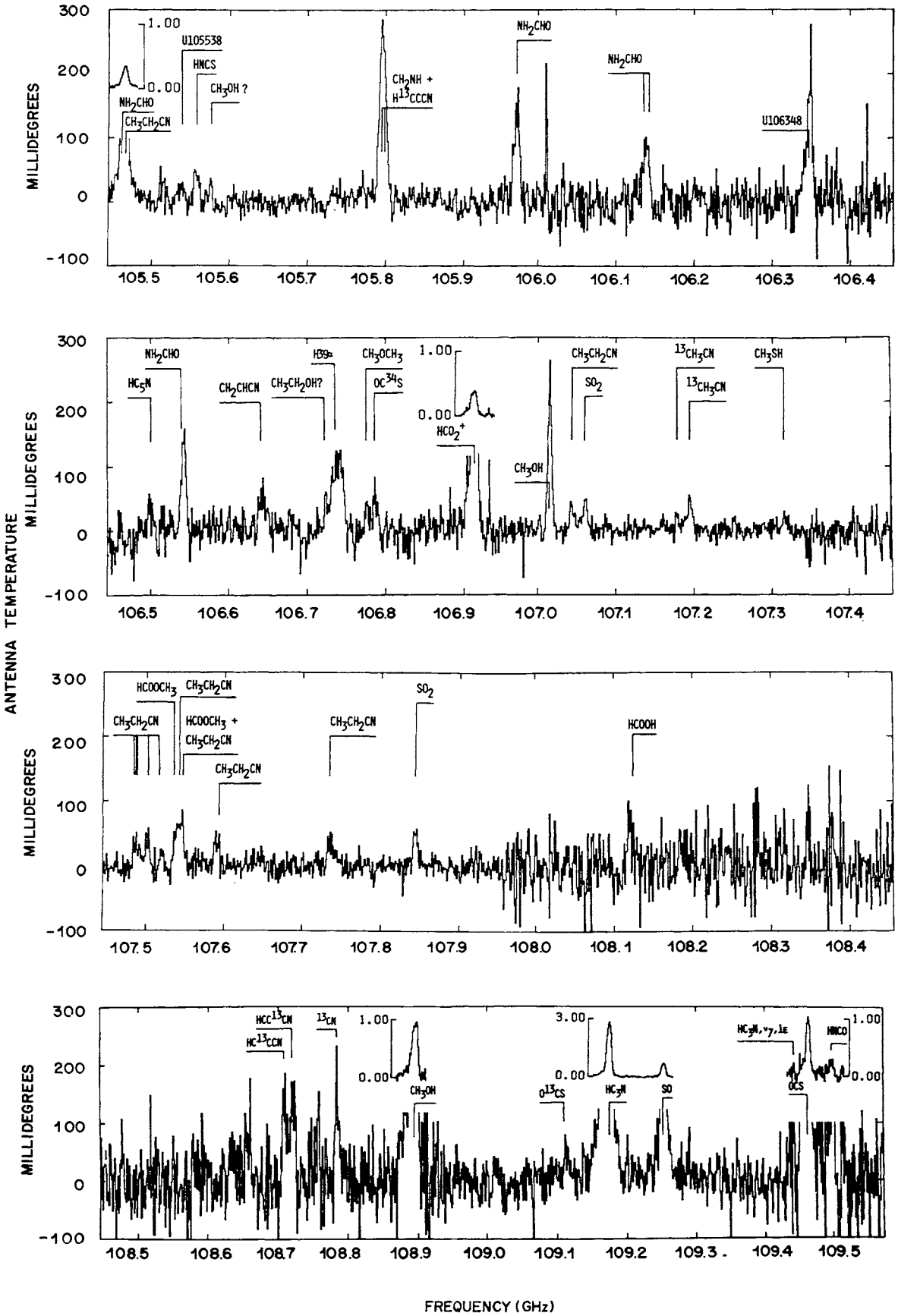

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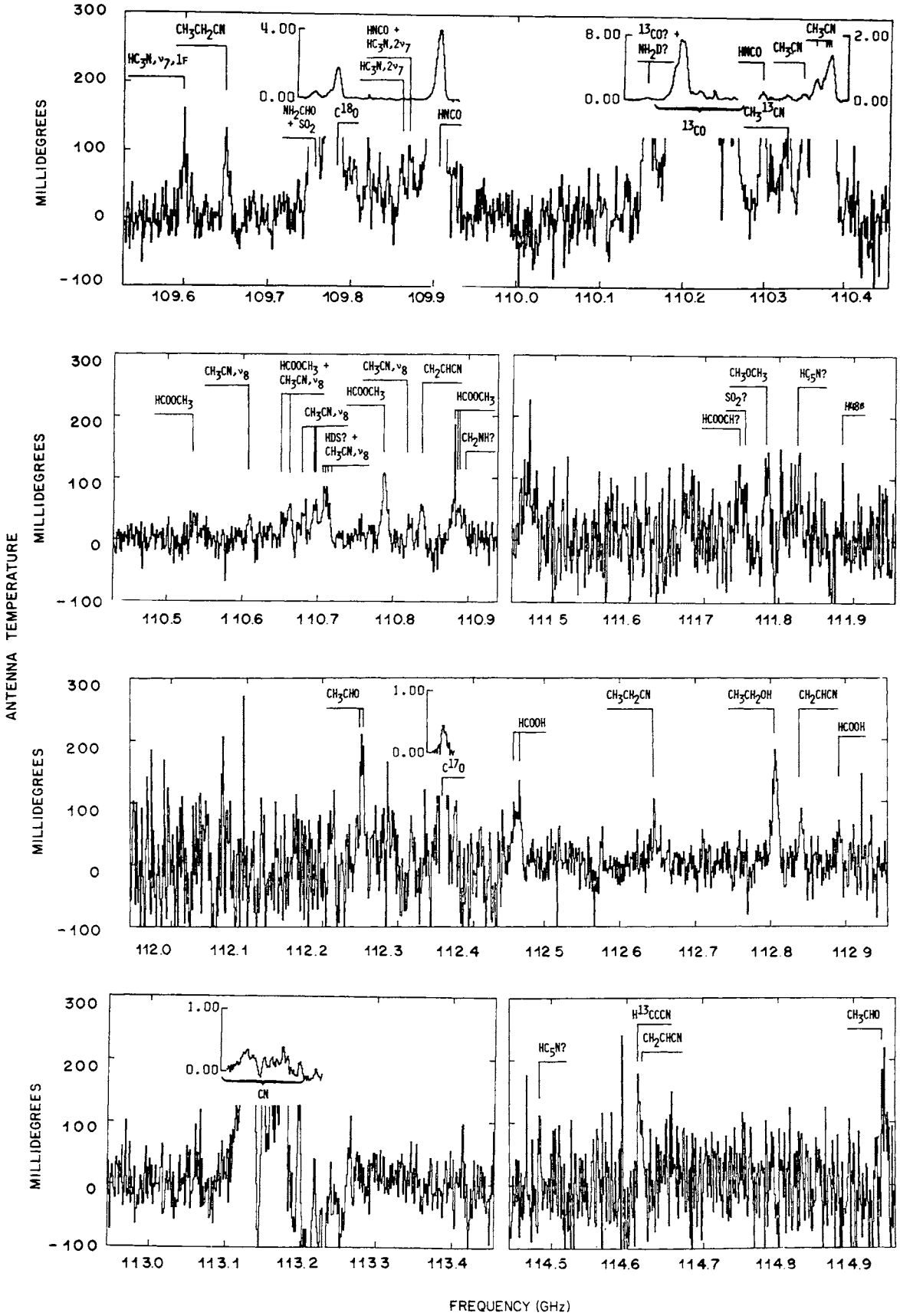

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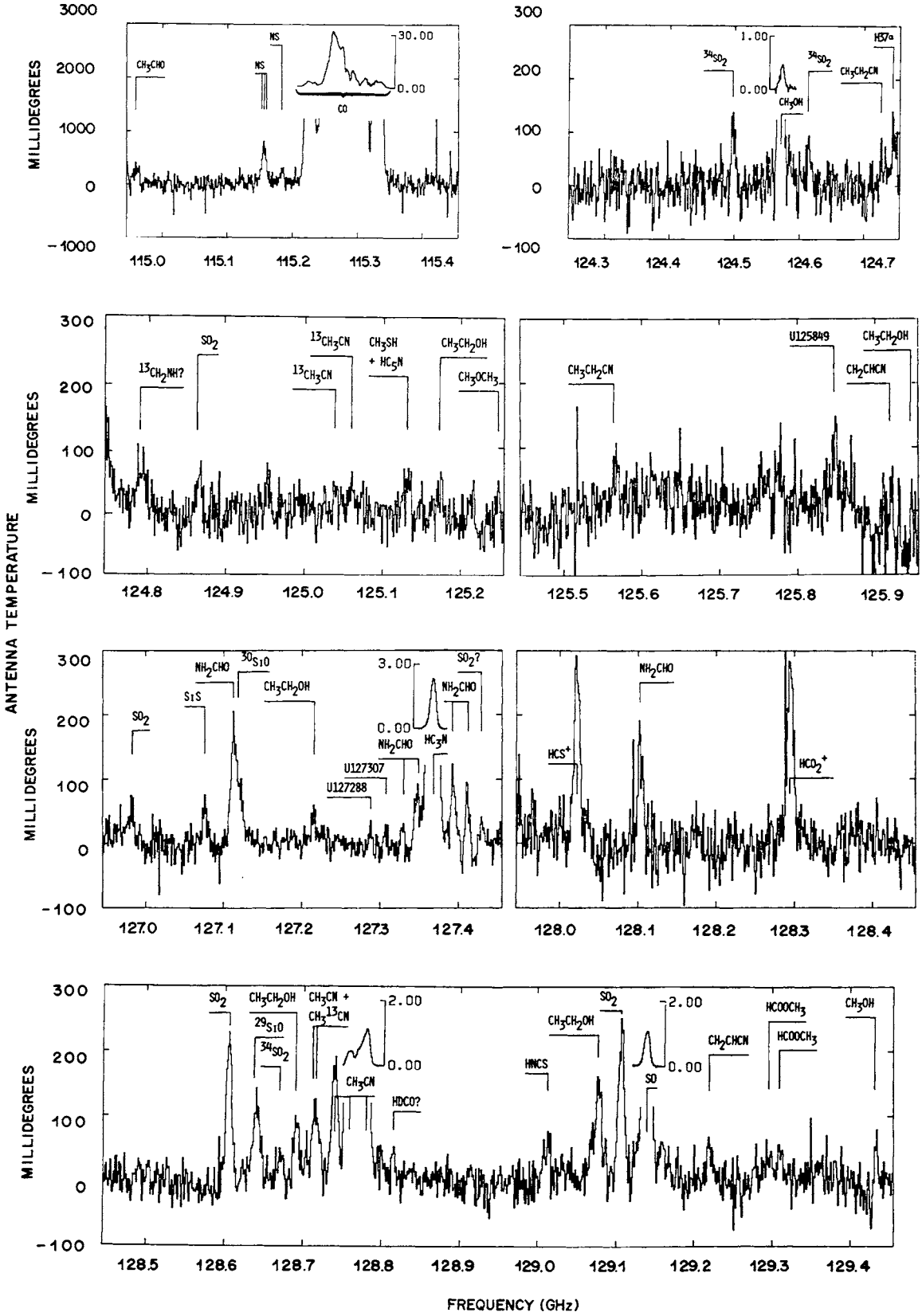

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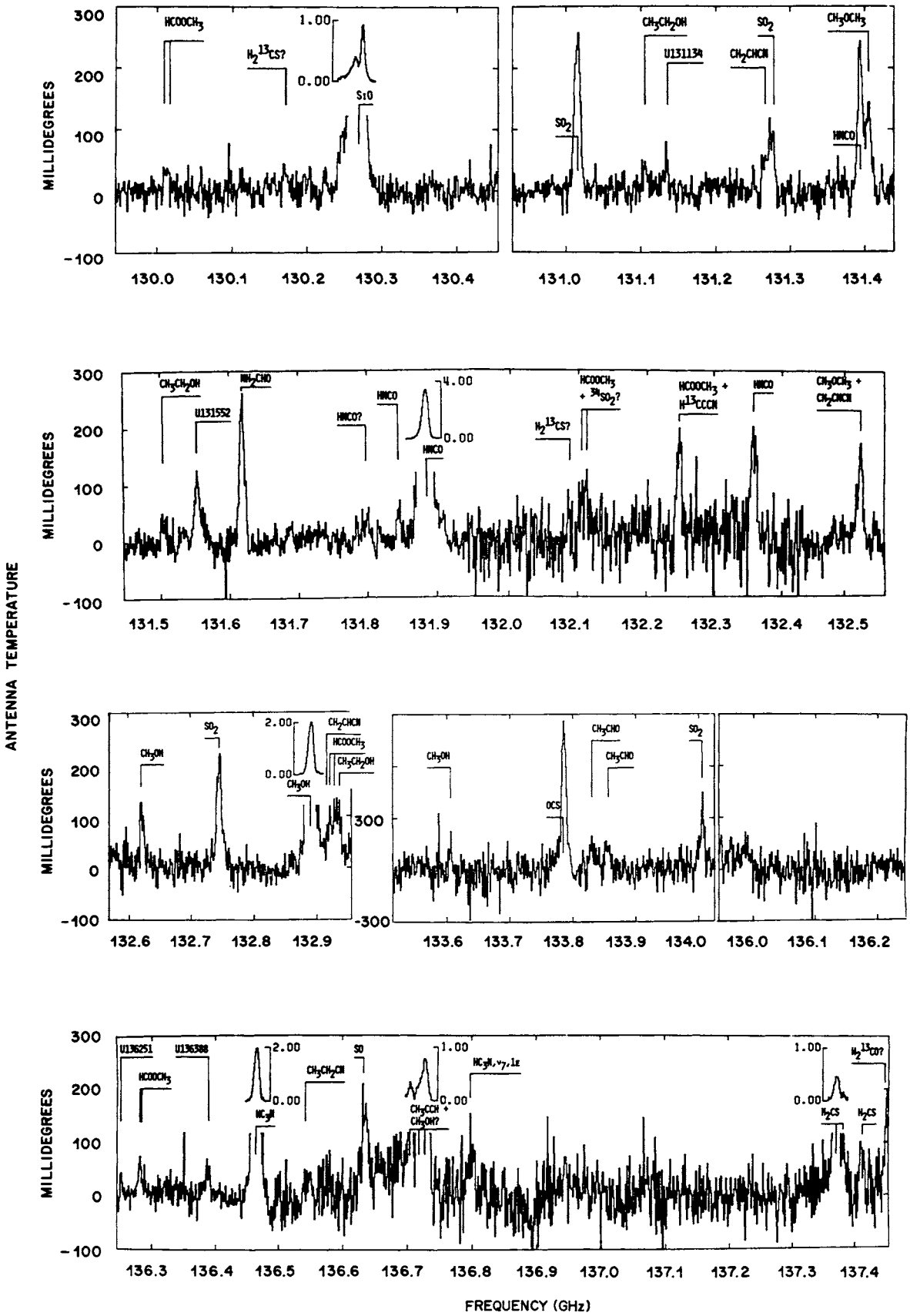

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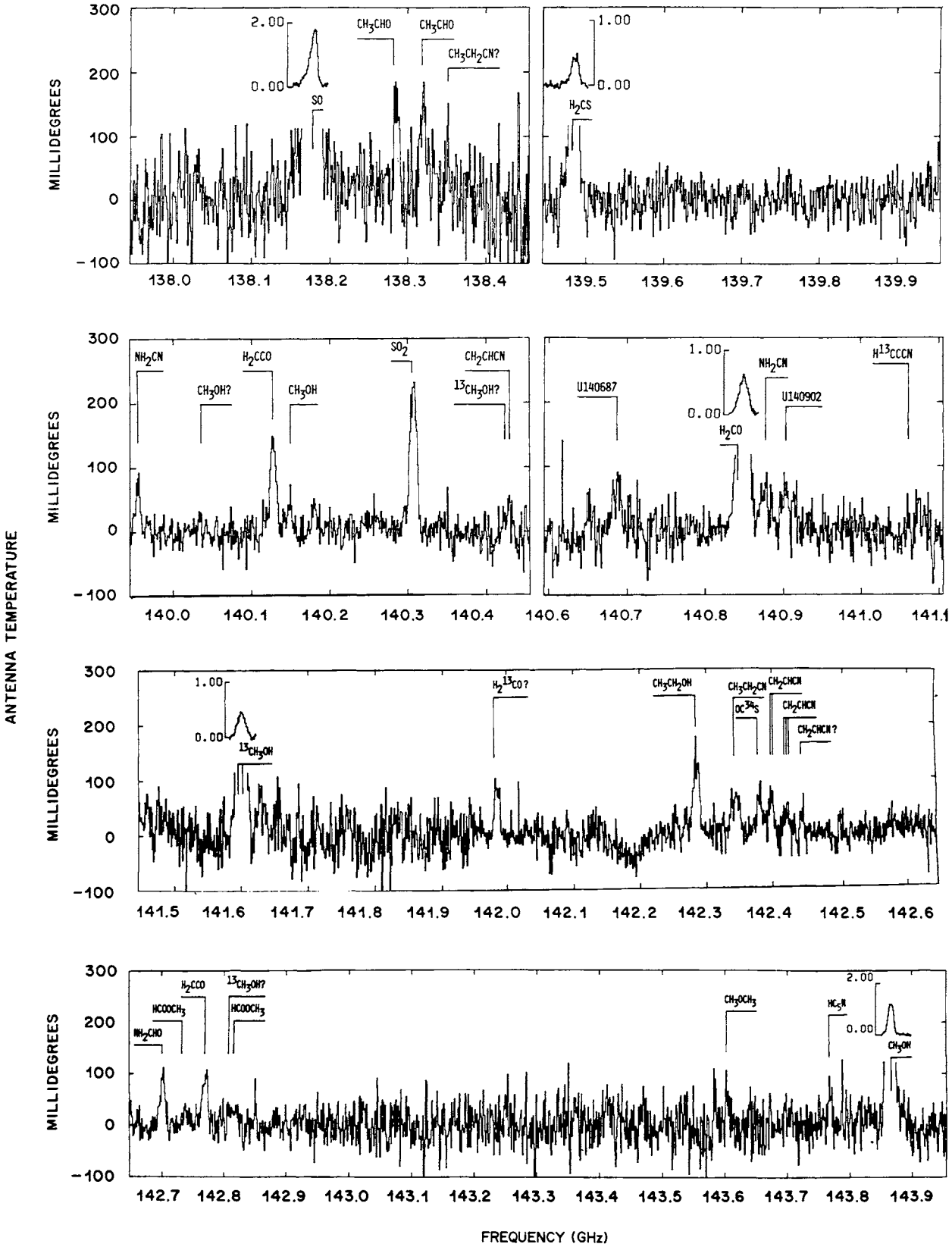

FIG. 7—*Continued*

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TABLE 2

LINES DETECTED IN THE SAGITTARIUS B2 SURVEY

Astronomical Frequency (MHz)	Molecule or Atom	Transition	T_A^* (K)	Δv(FWHM) (km s^{-1})	Rest Frequency (MHz)	v_{LSR} (km s^{-1})	Comments
71970.95 ± 0.80	CH_3CH_2OH	$10_{1,9} \rightarrow 10_{0,10}$	0.05 ± 0.01	18 ± 8	71971.7 ± 1.0 a	65 ± 5	
72109.69 ± 0.90	CH_3CH_2CN	$8_{2,6} \rightarrow 7_{2,5}$	0.07 ± 0.02	25 ± 9	72108.62 ± 0.02 b	58 ± 4	
72409.4 ± 1.1	H_2CO?	$5_{1,4} \rightarrow 5_{1,5}$	0.18 ± 0.06		72409.10 ± 0.02 c	61 ± 5	Low signal-to-noise ratio (S/N)
72618.51 ± 0.50	SiS?	$4 \rightarrow 3$	0.28 ± 0.08	12 ± 8	72618.10 ± 0.01 d	60 ± 2	Low S/N
72759.20 ± 0.47	SO_2	$6_{0,6} \rightarrow 5_{1,5}$	0.47 ± 0.07	23 ± 4	72758.24 ± 0.05 e	58 ± 2	
72784.86 ± 0.11	HC_3N	$8 \rightarrow 7$	2.57 ± 0.08	25 ± 1	72783.824 ± 0.002 f	57.7 ± 0.5	
72838.25 ± 0.26	H_2CO	$1_{0,1} \rightarrow 0_{0,0}$	0.66 ± 0.02	52 ± 2	72837.96 ± 0.02 c	61 ± 1	
72977.78 ± 0.16	OCS	$6 \rightarrow 5$	0.68 ± 0.03	22 ± 1	72976.80 ± 0.02 g	58.0 ± 0.7	
73083.4 ± 1.3	CH_3CH_2OH?	$4_{2,2} \rightarrow 4_{1,3}$	0.10 ± 0.05	16 ± 12	73081.19 ± 0.07 b	53 ± 5	Low S/N
73589.17 ± 0.24	CH_3CN	$4_3 \rightarrow 3_3$	0.72 ± 0.03	45 ± 2	73577.453 ± 0.001 h		
		$4_2 \rightarrow 3_2$			73584.545 ± 0.001		
		$4_1 \rightarrow 3_1$			73588.801 ± 0.001		
		$4_0 \rightarrow 3_0$			73590.220 ± 0.001		
73786.6 ± 1.2	$HCOOCH_3$?	$6_{4,2} \rightarrow 5_{4,1}$ E	0.17 ± 0.08	15 ± 11	73782.91 ± 0.10 i	56 ± 5	Low S/N
		$6_{4,3} \rightarrow 5_{4,2}$ A			73784.52 ± 0.02		
		$6_{4,3} \rightarrow 5_{4,2}$ E			73787.88 ± 0.10		
74644.3 ± 1.3	H	44α	0.15 ± 0.04	32 ± 11	74644.56 ± 0.02	63 ± 5	
74893.2 ± 2.6	CH_3CHO?	$4_{1,4} \rightarrow 3_{1,3}$ A	0.13 ± 0.06	34 ± 36	74892.05 ± 0.90 j	58 ± 11	
74926.	CH_3CHO?	$4_{1,4} \rightarrow 3_{1,3}$ E	0.07 ± 0.08	19 ± 94	74923.74 ± 0.91 j	54	Should be same intensity as 74892 MHz.
74976.2 ± 1.1	CH_3CH_2OH	$3_{1,3} \rightarrow 2_{0,2}$	0.23 ± 0.08	22 ± 11	74976.06 ± 0.07 a	62 ± 5	
75586.0 ± 1.1	CH_2CHCN	$8_{0,8} \rightarrow 7_{0,7}$	0.10 ± 0.04	17 ± 12	75585.70 ± 0.02 k	61 ± 4	
75840.2 ± 1.9	CH_2CHCN?	$8_{2,7} \rightarrow 7_{2,6}$	0.06 ± 0.04	20 ± 30	75838.87 ± 0.02 k	57 ± 8	Low S/N
75864.19 ± 0.46	CH_3SH	$3_0 \rightarrow 2_0$ A+	0.19 ± 0.03	19 ± 4	75862.87 ± 0.07 l	60 ± 2	
		$3_0 \rightarrow 2_0$ E			75864.43 ± 0.07		
75925.8 ± 2.0	CH_2CHCN?	$8_{4,5} \rightarrow 7_{4,4}$	0.06 ± 0.04	15 ± 20	75921.98 ± 0.01 k		
		$8_{4,4} \rightarrow 7_{4,3}$			75922.00 ± 0.01		
		$8_5 \rightarrow 7_5$			75926.80 ± 0.01		
		$8_{3,6} \rightarrow 7_{3,5}$			75927.71 ± 0.01		
		$8_{3,5} \rightarrow 7_{3,4}$			75931.86 ± 0.01		
75936.30 ± 0.52	CH_2CHCN?	$8_6 \rightarrow 7_6$	0.13 ± 0.06	8 ± 4	75937.82 ± 0.01 k		
	CH_3OH?	$20_5 \rightarrow 19_6$ E			75943.6 ± 0.1 m		
76128.56 ± 0.97	CH_2CHCN?	$8_{2,6} \rightarrow 7_{2,5}$	0.09 ± 0.05	9 ± 8	76128.89 ± 0.02 k	63 ± 4	Low S/N

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TABLE 2—*Continued*

Astronomical Frequency (MHz)	Molecule or Atom	Transition	T_A^* (K)	Δv(FWHM) (km s^{-1})	Rest Frequency (MHz)		v_{LSR} (km s^{-1})	Comments
76202.7 ± 2.0	C_3H	7/2 → 5/2	0.08 ± 0.03	38 ± 16	76199.2 ± 0.5 76204.7 ± 0.5	ww	59 ± 8	Λ-type doublet in $^2\Pi_{1/2}$ ladder. There is also evidence of the J = 9/2 → 7/2 transition at 98012 MHz.
76367.5 ± 1.1	CH_3OCH_3	$7_{2,5} \rightarrow 7_{1,6}$	0.11 ± 0.04	18 ± 10	76364.26 ± 0.06	n		
76511.08 ± 0.42	CH_3OH	$5_0 \rightarrow 4_1$ E	0.28 ± 0.04	19 ± 3	76509.7 ± 0.1	m	56 ± 2	
76648.6 ± 1.5	U?		0.09 ± 0.03	30 ± 14				
76866.5 ± 1.9	CH_3CHO?	$4_{0,4} \rightarrow 3_{0,3}$ E	0.13 ± 0.06		76866.1 ± 1.0	j	60 ± 8	Width uncertain due to noise
76879.6 ± 3.5	CH_3CHO?	$4_{0,4} \rightarrow 3_{0,3}$ A	0.10 ± 0.06	35 ± 92	76879.5 ± 1.0	j	62 ± 14	Should be same intensity as 76866 MHz
77635.1 ± 2.8	CH_2CHCN?	$8_{1,7} \rightarrow 7_{1,6}$	0.12 ± 0.04	44 ± 52	77633.83 ± 0.02	k	57 ± 11	Low S/N
77978.5 ± 1.3	U		0.13 ± 0.02	47 ± 12				Unusually wide. Johansson et al. (1984) report a tentative line at 77983 MHz in Ori A.
79100.75 ± 0.85	CH_3CHO	$4_{1,3} \rightarrow 3_{1,2}$ E	0.15 ± 0.02	35 ± 9	79098.65 ± 0.96	j	54 ± 5	
79150.92 ± 0.40	CH_3CHO	$4_{1,3} \rightarrow 3_{1,2}$ A	0.24 ± 0.03	22 ± 3	79150.26 ± 0.94	j	60 ± 4	
79221.9 ± 5.0	U?		0.05 ± 0.03	49 ± 64				
79351.00 ± 0.33	$H^{13}CCCN$	9 → 8	0.13 ± 0.01	23 ± 2	79350.48 ± 0.01	f	60 ± 1	
79449.87 ± 0.39	NH_2CN	$4_{1,4} \rightarrow 3_{1,3}$	0.25 ± 0.02	27 ± 3	79449.73 ± 0.05	o	61 ± 1	
79784.1 ± 2.3	$HCOOCH_3$?	$7_{0,7} \rightarrow 6_{0,6}$ E $7_{0,7} \rightarrow 6_{0,6}$ A	0.08 ± 0.03		79781.71 ± 0.16 79783.89 ± 0.03	i	57 ± 9	Low S/N
79912.1 ± 1.4	H	43α	0.12 ± 0.04	26 ± 11	79912.65 ± 0.02		64 ± 5	Previously reported as NH_2CN, v = 1
79980.30 ± 0.81	NH_2CN	$4_{0,4} \rightarrow 3_{0,3}$	0.14 ± 0.06	13 ± 7	79979.60 ± 0.05	o	59 ± 3	
80077.33 ± 0.70	H_2CCO	$4_{1,4} \rightarrow 3_{1,3}$	0.15 ± 0.05	11 ± 6	80076.61 ± 0.03	p	59 ± 3	
80484.5 ± 2.8	U?		0.11 ± 0.02	80 ± 25				Also observed by Turner et al. (1975) in Sgr B2
80504.17 ± 0.58	NH_2CN	$4_{1,3} \rightarrow 3_{1,2}$	0.26 ± 0.04	20 ± 6	80504.60 ± 0.05	o	64 ± 2	
81261.7 ± 1.6	CH_3CH_2CN?	$9_{2,7} \rightarrow 8_{2,6}$	0.12 ± 0.05	18 ± 20	81261.44 ± 0.01	xx	61 ± 6	Low S/N
81476.87 ± 0.75	HNO?	$1_{0,1} \rightarrow 0_{0,0}$	0.04 ± 0.01		81477.49 ± 0.10	q	64 ± 3	Questionable identification because reported by Johansson et al. (1984) in IRC+10216
81506.08 ± 0.56	U		0.19 ± 0.03	24 ± 4				Reported by Johansson et al. (1984) in IRC+10216
81535.28 ± 0.70	$HC^{13}CCN$	9 → 8	0.13 ± 0.02	29 ± 8	81534.13 ± 0.01	f		
81541.59 ± 0.66	$HCC^{13}CN$	9 → 8	0.14 ± 0.02	30 ± 6	81541.98 ± 0.01	f		
81586.72 ± 0.64	H_2CCO	$4_{1,3} \rightarrow 3_{1,2}$	0.13 ± 0.02	22 ± 5	81586.19 ± 0.03	p	60 ± 2	

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81695.66 ± 0.42	NH_2CHO	$4_{1,4} \rightarrow 3_{1,3}$	0.18 ± 0.02	19 ± 3	81693.50 ± 0.04	c	54 ± 2	
81881.97 ± 0.04	HC_3N	9 → 8	2.64 ± 0.03	24.7 ± 0.3	81881.468 ± 0.002	f	60.2 ± 0.1	
82542.8 ± 2.1	HC_5N?	31 → 30	0.09 ± 0.10	5 ± 15	82539.24 ± 0.16	s	49 ± 7	Low S/N
82651.2 ± 1.0	CH_3CH_2OH CH_3OCH_3	$11_{1,10} \rightarrow 11_{0,11}$ $3_{1,3} \rightarrow 2_{0,2}$	0.09 ± 0.02	22 ± 8	82650.3 ± 1.5 82650.35 ± 0.01	a n		
82690.7 ± 1.9	CH_3OCH_3?	$4_{2,2} \rightarrow 4_{1,3}$	0.05 ± 0.02		82688.72 ± 0.04	n		Low S/N
82952.37 ± 0.80	SO_2	$13_{4,10} \rightarrow 14_{3,11}$	0.05 ± 0.01	18 ± 6	82952.02 ± 0.01	e	61 ± 3	
82967.30 ± 0.41	C_3H_2	$3_{1,2} \rightarrow 3_{0,3}$	0.16 ± 0.02	24 ± 3	82966.19 ± 0.09	bbb	58 ± 2	
83058.86 ± 0.54	$OC^{34}S$	7 → 6	0.04 ± 0.01	20 ± 4	83057.99 ± 0.05	g	59 ± 2	
83688.81 ± 0.33	SO_2?	$8_{1,7} \rightarrow 8_{0,8}$	0.25 ± 0.11	7 ± 2	83688.07 ± 0.01	e	59 ± 1	Low S/N
83979.19 ± 0.73	CH_3NH_2	$5_{1,5} \rightarrow 5_{0,5}$	0.05 ± 0.02	9 ± 6	83978.60 83979.57	t	62	
84221.51 ± 0.92	CH_3CHO	$2_{1,2} \rightarrow 1_{0,1}$ A	0.05 ± 0.02	11 ± 6	84221.9 ± 1.4	j	64 ± 6	
84324.84 ± 0.31	SO_2	$32_{5,27} \rightarrow 31_{6,26}$	0.09 ± 0.03	5 ± 2	84320.92 ± 0.02	e	48 ± 1	Frequency too high?
84411.4 ± 1.8	^{34}SO?	J,K: 2,2 → 1,1	0.03 ± 0.02	15 ± 20	84410.60 ± 0.12	u	59 ± 6	See comment on 97716 MHz
84422.09 ± 0.74	CH_3OH	$13_{-3} \rightarrow 14_{-2}$ E	0.04 ± 0.02	10 ± 5	84423.8 ± 0.1	m	68 ± 3	
84450.91 ± 0.82	$HCOOCH_3$	$7_{2,6} \rightarrow 6_{2,5}$ E $7_{2,6} \rightarrow 6_{2,5}$ A	0.05 ± 0.01	25 ± 6	84449.19 ± 0.16 84454.76 ± 0.03	i	66 ± 3	
84521.41 ± 0.05	CH_3OH	$5_{-1} \rightarrow 4_0$ E	3.79 ± 0.05	24.2 ± 0.3	84521.2 ± 0.1	v	61.3 ± 0.4	
84542.64 ± 0.80	NH_2CHO	$4_{0,4} \rightarrow 3_{0,3}$	0.21 ± 0.04	24 ± 5	84542.37 ± 0.04	c	61 ± 3	
84595.19 ± 0.42	CH_3CH_2OH CH_3NH_2	$4_{2,3} \rightarrow 4_{1,4}$ $2_1 \rightarrow 2_0$	0.06 ± 0.02	7 ± 4	84595.83 ± 0.13 84597.64 84598.54	a t		
84635.26 ± 1.51	CH_3OCH_3	$3_{2,1} \rightarrow 3_{1,2}$	0.03 ± 0.01	19 ± 13	84634.39 ± 0.04	n		
84728.2 ± 1.6	C_3H_2	$3_{2,2} \rightarrow 3_{1,3}$	0.04 ± 0.01	29 ± 17	84727.68 ± 0.07	bbb	60 ± 6	
84746.9 ± 1.0	CH_3OH ^{30}SiO	$19_4 \rightarrow 18_5$ E 2 → 1	0.06 ± 0.01	32 ± 9	84744.2 ± 0.1 84745.90 ± 0.18	m w		
84807.45 ± 0.31	NH_2CHO	$4_{2,3} \rightarrow 3_{2,2}$	0.18 ± 0.02	22 ± 2	84807.88 ± 0.05	c	64 ± 1	
84866.69 ± 0.68	$O^{13}CS$	7 → 6	0.04 ± 0.01	17 ± 5	84865.17 ± 0.01	g	57 ± 2	
84890.03 ± 0.44	NH_2CHO	$4_{3,2} \rightarrow 3_{3,1}$ $4_{3,1} \rightarrow 3_{3,0}$	0.10 ± 0.01	18 ± 3	84889.14 ± 0.08 84891.13 ± 0.08	c	62 ± 2	

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84910.62 ± 0.82	H	60γ	0.04 ± 0.01	14 ± 6	84914.39 ± 0.03		75 ± 3	Frequency too low?
84945.76 ± 0.39	CH_2CHCN	$9_{0,9} \rightarrow 8_{0,8}$	0.09 ± 0.01	20 ± 2	84946.00 ± 0.02	k	63 ± 1	
85094.28 ± 0.56	NH_2CHO	$4_{2,2} \rightarrow 3_{2,1}$	0.12 ± 0.02	19 ± 4	85093.36 ± 0.05	c	59 ± 2	
85138.84 ± 0.07	OCS	7 → 6	0.81 ± 0.01	22.9 ± 0.5	85139.12 ± 0.01	g	63.0 ± 0.2	
85164.00 ± 0.37	$HC^{18}O^+$	1 → 0	0.14 ± 0.01	20 ± 3	85162.16 ± 0.05	e	56 ± 1	
85201.8 ± 1.5	HC_5N	32 → 31	0.06 ± 0.02	24 ± 13	85201.56 ± 0.17	s	61 ± 5	
85230.56 ± 0.63	U		0.07 ± 0.02	14 ± 5				Guélin *et al.* (1982) suggest this may be $C^{13}CH$
85264.86 ± 0.48	CH_3CH_2OH	$6_{0,6} \rightarrow 5_{1,5}$	0.18 ± 0.02	24 ± 3	85265.47 ± 0.07	b	64 ± 2	
85303.25 ± 0.66	CH_2CHCN	$9_{2,8} \rightarrow 8_{2,7}$	0.12 ± 0.02	20 ± 6	85302.65 ± 0.02	k	60 ± 2	
85341.44 ± 0.13	C_3H_2 HCS^+	$2_{1,2} \rightarrow 1_{0,1}$ 2 → 1	0.40 ± 0.02	50 ± 6	85338.87 ± 0.07 85347.90 ± 0.03	bbb x		
85418.22 ± 0.65	CH_2CHCN	$9_{4,6} \rightarrow 8_{4,5}$ $9_{4,5} \rightarrow 8_{4,4}$ $9_5 \rightarrow 8_5$	0.08 ± 0.01	22 ± 5	85416.76 ± 0.01 85416.81 ± 0.01 85419.98 ± 0.01	k		
85430.26 ± 0.54	CH_2CHCN CH_3CCH CH_2CHCN CH_3CCH	$9_{3,7} \rightarrow 8_{3,6}$ $5_4 \rightarrow 4_4$ $9_{3,6} \rightarrow 8_{3,5}$ $5_3 \rightarrow 4_3$ $5_2 \rightarrow 4_2$	0.09 ± 0.02	17 ± 5	85426.93 ± 0.02 85431.173 ± 0.003 85434.54 ± 0.02 85442.601 ± 0.001 85450.766 ± 0.001	k y k y		
85455.33 ± 0.14	CH_3CCH	$5_1 \rightarrow 4_1$ $5_0 \rightarrow 4_0$	0.54 ± 0.01	33 ± 1	85455.667 ± 0.001 85457.300 ± 0.001	y		
85531.67 ± 0.56	HCO_2^+	$4_{0,4} \rightarrow 3_{0,3}$	0.34 ± 0.06	19 ± 4	85531.05 ± 0.15	aaa	60 ± 2	
85567.44 ± 0.61	CH_3OH	$6_{-2} \rightarrow 7_{-1}$ E	0.06 ± 0.02	10 ± 4	85568.0 ± 0.1	m	64 ± 2	
85634.0 ± 1.6	C_4H?	9 → 8	0.03 ± 0.01		85634.00 ± 0.01	z	62 ± 6	Presence unclear at other frequencies
85671.9 ± 1.2	C_4H?	9 → 8	0.04 ± 0.02	13 ± 19	85672.57 ± 0.01	z	64 ± 4	
85687.44 ± 0.80	H	42α	0.11 ± 0.01	36 ± 5	85688.39 ± 0.03		65 ± 3	
85715.62 ± 0.78	CH_2CHCN	$9_{2,7} \rightarrow 8_{2,6}$	0.06 ± 0.01	23 ± 7	85715.43 ± 0.02	k	61 ± 3	
85760.86 ± 0.58	^{29}SiO	2 → 1	0.10 ± 0.02	21 ± 5	85759.00 ± 0.18	w	55 ± 2	
85927.64 ± 0.84	NH_2D? $HCOOCH_3$	$1_{1,1} \rightarrow 1_{0,1}$ $7_{6,2} \rightarrow 6_{6,1}$ A $7_{6,1} \rightarrow 6_{6,0}$ A $7_{6,2} \rightarrow 6_{6,1}$ E	0.07 ± 0.02	17 ± 7	85926.2 85927.20 ± 0.04 85927.21 ± 0.04 85927.22 ± 0.22	aa i		Evidence for NH_2D, or attributable solely to $HCOOCH_3$?

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86029.86 ± 0.80	$HCOOCH_3$	$7_{5,3} \rightarrow 6_{5,2}$ E $7_{5,3} \rightarrow 6_{5,2}$ A $7_{5,2} \rightarrow 6_{5,1}$ A	0.07 ± 0.01		86028.24 ± 0.19 86029.42 ± 0.03 86030.19 ± 0.03	i	60 ± 3	
86057.06 ± 0.98	$HC^{15}N$	1 → 0	0.12 ± 0.02	14 ± 7	86054.96 ± 0.03	bb	55 ± 3	
86074.55 ± 0.67	CH_3NH_2	$4_{1,4} \rightarrow 4_{0,4}$	0.07 ± 0.03	9 ± 4	86074.20 86074.44 86075.43	t	62	
86093.86 ± 0.40	SO	J,K: 2,2 → 1,1	0.50 ± 0.05	21 ± 3	86093.94 ± 0.03	u	62 ± 1	
86225.39 ± 0.91	$HCOOCH_3$?	$7_{4,3} \rightarrow 6_{4,2}$ E $7_{4,4} \rightarrow 6_{4,3}$ E	0.05 ± 0.03	8 ± 9	86223.53 ± 0.17 86224.53 ± 0.17	i	57 ± 3	Low S/N
86267.01 ± 0.83	$HCOOCH_3$	$7_{3,5} \rightarrow 6_{3,4}$ A $7_{3,5} \rightarrow 6_{3,4}$ E	0.09 ± 0.02	21 ± 8	86265.80 ± 0.03 86268.73 ± 0.17	i	63 ± 3	
86333.03 ± 0.53	$H^{13}CN$	J=1 → 0,F=1→1 2→1	0.43 ± 0.05	27 ± 4	86338.77 ± 0.03 86340.18 ± 0.03	e		
86344.69 ± 0.35	$H^{13}CN$	J=1 → 0,F=0→1	0.46 ± 0.06	14 ± 3	86342.27 ± 0.03	e		
86395.8 ± 1.5	U		0.06 ± 0.01	38 ± 11				
86416.9 ± 1.3	U		0.05 ± 0.02	23 ± 8				Reported by Johansson et al. (1984) in Ori A as a doublet with frequencies 86413 and 86418 MHz.
86545.26 ± 0.90	HCOOH	$4_{1,4} \rightarrow 3_{1,3}$	0.07 ± 0.02	22 ± 7	86546.18 ± 0.01	cc	65 ± 3	
86614.48 ± 0.77	CH_3OH	$7_2 \rightarrow 6_3$ A−	0.06 ± 0.02	14 ± 6	86615.8 ± 0.1	m	66 ± 3	
86640.1 ± 1.0	SO_2	$8_{3,5} \rightarrow 9_{2,8}$	0.03 ± 0.02	12 ± 6	86639.14 ± 0.01	e	59 ± 3	
86669.8 ± 1.2	HCO	$1_{0,1} \rightarrow 0_{0,0}$	0.06 ± 0.02	22 ± 9	86670.55 ± 0.20	dd	64 ± 4	
86707.9 ± 1.6	HCO	$1_{0,1} \rightarrow 0_{0,0}$	0.04 ± 0.01		86707.87 ± 0.20	dd	62 ± 6	Width unclear -- see spectrum
86749.09 ± 0.51	$H^{13}CO^+$	1 → 0	0.18 ± 0.02	30 ± 4	86754.33 ± 0.05	e	80 ± 2	Two peaks
86757.42 ± 0.16	$H^{13}CO^+$	1 → 0	0.36 ± 0.02	13 ± 1	86754.33 ± 0.05	e	51.3 ± 0.6	
86818.1 ± 1.0	CH_3CH_2CN	$10_{1,10} \rightarrow 9_{1,9}$	0.07 ± 0.01	34 ± 8	86819.86 ± 0.02	b	68 ± 3	
86846.96 ± 0.26	SiO	2 → 1	0.49 ± 0.01 0.67 ± 0.01	58 ± 2	86846.86 ± 0.18	w	62 ± 1	Two peaks, at 86841 and 86850 MHz.
86902.53 ± 0.57	CH_3OH	$7_2 \rightarrow 6_3$ A+	0.07 ± 0.03	8 ± 5	86903.1 ± 0.1	m	64 ± 2	
87058.3 ± 1.9	$HC^{17}O^+$	1 → 0	0.04 ± 0.02	19 ± 15	87057.5 ± 0.5	ee	59 ± 7	
87092.19 ± 0.40	$HN^{13}C$	1 → 0	0.35 ± 0.04	34 ± 3	87090.85 ± 0.04	ff	57 ± 1	
87143.06 ± 0.55	$HCOOCH_3$	$7_{3,4} \rightarrow 6_{3,3}$ E	0.05 ± 0.02	9 ± 4	87143.40 ± 0.17	i	63 ± 2	

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87160.91 ± 0.80	$HCOOCH_3$	$7_{3,4} \rightarrow 6_{3,3}$ A	0.06 ± 0.03	7 ± 5	87161.29 ± 0.03	i	63 ± 3	
87283.51 ± 0.47	CCH	N=1→0;J,F:3/2,1 → 1/2,1	0.18 ± 0.02	28 ± 3	87284.16 ± 0.03	gg	64 ± 2	
87318.55 ± 0.25	CH_2CHCN CCH	$9_{1,8} \rightarrow 8_{1,7}$ N=1→0;J,F:3/2,2 → 1/2,1	0.56 ± 0.01	72 ± 2	87312.82 ± 0.02 87316.925 ± 0.004	k gg		Expected to contribute 10% to line
87327.73 ± 0.23	CCH	3/2,1 → 1/2,0	0.45 ± 0.02	27 ± 2	87328.62 ± 0.01	gg	65.1 ± 0.8	
87402.75 ± 0.28	CCH	1/2,1 → 1/2,1 1/2,0 → 1/2,1	0.45 ± 0.01	57 ± 2	87402.00 ± 0.01 87407.17 ± 0.01	gg		
87446.48 ± 0.28	CCH	1/2,1 → 1/2,0	0.19 ± 0.01	26 ± 2	87446.51 ± 0.02	gg	62 ± 1	
87597.31 ± 0.43	HNCO	$4_{1,4} \rightarrow 3_{1,3}$	0.14 ± 0.02	17 ± 3	87597.333 ± 0.003	hh	62 ± 1	
87716.66 ± 0.90	CH_3CH_2OH	$5_{2,4} \rightarrow 5_{1,5}$	0.06 ± 0.02	15 ± 5	87715.98 ± 0.07	b	60 ± 3	
87767.6 ± 2.4	$HCOOCH_3$?	$8_{0,8} \rightarrow 7_{1,7}$ E $8_{0,8} \rightarrow 7_{1,7}$ A	0.03 ± 0.01	51 ± 28	87766.42 ± 0.26 87769.02 ± 0.04	i	63 ± 8	b-type; too strong?
87782.5 ± 1.1	CH_3NH_2	$3_{1,3} \rightarrow 3_{0,3}$	0.03 ± 0.01	17 ± 8	87782.23 87783.09	t	63	
87848.61 ± 0.22	NH_2CHO	$4_{1,3} \rightarrow 3_{1,2}$	0.31 ± 0.02	24 ± 2	87848.93 ± 0.04	c	63.1 ± 0.8	
87863.67 ± 0.71	HC_5N	33 → 32	0.10 ± 0.02	26 ± 5	87863.87 ± 0.19	s	63 ± 3	
87896.9 ± 1.0	HNCO	$4_{2,3} \rightarrow 3_{2,2}$ $4_{2,2} \rightarrow 3_{2,1}$	0.06 ± 0.02	22 ± 8	87898.416 ± 0.004 87898.620 ± 0.004	hh	67 ± 3	
87924.50 ± 0.03	HNCO	$4_{0,4} \rightarrow 3_{0,3}$	3.90 ± 0.01	25.6 ± 0.01	87925.238 ± 0.004	hh	64.5 ± 0.1	
88167.0 ± 2.3	$H^{13}CCCN$	10 → 9	0.11 ± 0.04	31 ± 30	88166.81 ± 0.01	f	62 ± 8	
88597.8 ± 1.7	CH_3OH	$15_3 \rightarrow 14_4$ A+	0.10 ± 0.05	19 ± 14	88595.0 ± 0.1	m	53 ± 6	
88627.94 ± 0.12	HCN	J=1 → 0, F=1 → 1 2 → 1 0 → 1	2.95 ± 0.03 2.09 ± 0.03	71 ± 1	88630.416 ± 0.001 88631.847 ± 0.001 88633.936 ± 0.001	ii		Two peaks, at 88626 and 88638 MHz.
89182.17 ± 0.08	HCO^+	1 → 0	1.90 ± 0.03 1.10 ± 0.03	44 ± 1	89188.52 ± 0.02	e	83.4 ± 0.3	Two peaks, at 89183 and 89195 MHz.
89331.17 ± 0.43	$^{13}CH_3CN$	$5_0 \rightarrow 4_0$	0.22 ± 0.11	4 ± 2	89331.30 ± 0.03	h		
89862.1 ± 1.3	HCOOH	$4_{2,3} \rightarrow 3_{2,2}$	0.13 ± 0.05	15 ± 13	89861.48 ± 0.01	cc	60 ± 4	
90119.30 ± 0.90	CH_3CH_2OH	$4_{1,4} \rightarrow 3_{0,3}$	0.15 ± 0.04	16 ± 6	90117.61 ± 0.10	a	56 ± 3	
90525.8 ± 1.8	HC_5N	34 → 33	0.09 ± 0.03	28 ± 21	90526.15 ± 0.20	s	63 ± 6	
90593.89 ± 0.80	$HC^{13}CCN$	10 → 9	0.17 ± 0.03	27 ± 6	90593.06 ± 0.01	f		
90597.2 ± 1.5	$HCC^{13}CN$	10 → 9	0.19 ± 0.03	60 ± 12	90601.79 ± 0.01	f		Fit width too large

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TABLE 2—*Continued*

Astronomical Frequency (MHz)	Molecule or Atom	Transition	T_A^* (K)	Δv(FWHM) (km s^{-1})	Rest Frequency (MHz)		v_{LSR} (km s^{-1})	Comments
90662.48 ± 0.19	HNC	1 → 0	1.55 ± 0.04 1.76 ± 0.04	64 ± 2	90663.59 ± 0.04	ff	65.7 ± 0.6	Two peaks, at 90660 and 90667 MHz.
90770.6 ± 2.4	SiS	5 → 4	0.08 ± 0.02	43 ± 22	90771.55 ± 0.03	d	65 ± 8	
90938.6 ± 1.0	CH_3OCH_3	$6_{0,6} \rightarrow 5_{1,5}$	0.12 ± 0.04	19 ± 7	90938.24 ± 0.03	n		
90980.17 ± 0.05	HC_3N	10 → 9	2.79 ± 0.04	22.7 ± 0.4	90978.993 ± 0.002	f	58.1 ± 0.2	
91130 → 93450	No data							
93581.69 ± 0.33	CH_3CHO	$5_{1,5} \rightarrow 4_{1,4}$ A	0.17 ± 0.01	21 ± 2	93581.35 ± 0.95	j	61 ± 3	
93596.20 ± 0.35	CH_3CHO	$5_{1,5} \rightarrow 4_{1,4}$ E	0.17 ± 0.01	24 ± 2	93594.55 ± 0.95	j	57 ± 3	
93667.22 ± 0.60	CH_3OCH_3	$12_{1,11} \rightarrow 12_{0,12}$	0.05 ± 0.02	8 ± 5	93666.65 ± 0.12	n		
93830.3 ± 1.3	HNCS	$8_{0,8} \rightarrow 7_{0,7}$	0.05 ± 0.01	24 ± 7	93829.91 ± 0.42	r	61 ± 4	
93870.16 ± 0.31	U(NH_2CHO?)	$3_{2,2} \rightarrow 4_{1,3}$	0.21 ± 0.01	22 ± 2	93871.73 ± 0.12	c	67 ± 1	b-type; probably too strong to be NH_2CHO — see text
93950 → 97160	No data							
97174.0 ± 1.5	$C^{33}S$	2 → 1	0.17 ± 0.06	18 ± 21	97172.09 ± 0.06	w	56 ± 5	
97301.41 ± 0.28	OCS	8 → 7	0.89 ± 0.06	22 ± 2	97301.21 ± 0.02	g	61 ± 1	
97410 → 97440	No data							
97583.06 ± 0.04	CH_3OH	$2_1 \rightarrow 1_1$ A−	1.20 ± 0.01	21.9 ± 0.2	97582.8 ± 0.1	v	61.3 ± 0.3	
97633.58 ± 0.92	$H_2{}^{13}CS$?	$3_{1,3} \rightarrow 2_{1,2}$	0.04 ± 0.01	11 ± 6	97633.7 ± 1.3	jj	62 ± 5	Identification tentative
97703.31 ± 0.49	SO_2	$7_{3,5} \rightarrow 8_{2,6}$	0.09 ± 0.01	22 ± 3	97702.39 ± 0.01	e	59 ± 2	
97715.72 ± 0.24	^{34}SO?	J,K: 3,2 → 2,1	0.18 ± 0.01	23 ± 2	97715.34 ± 0.32	u	61 ± 1	Too strong compared to 84411 MHz
97975.23 ± 0.03	CS	2 → 1	1.78 ± 0.01	33.6 ± 0.2	97981.01 ± 0.03	w	79.7 ± 0.1	Two peaks
97985.01 ± 0.02	CS	2 → 1	2.27 ± 0.01	20.3 ± 0.1	97981.01 ± 0.03	w	49.8 ± 0.1	
98177.00 ± 0.85	CH_3CH_2CN	$11_{2,10} \rightarrow 10_{2,9}$	0.05 ± 0.01	25 ± 6	98177.58 ± 0.01	xx	64 ± 3	
98265.92 ± 0.88	U(CH_3OH?)	$30_{-5} \rightarrow 29_{-6}$ E	0.04 ± 0.01	21 ± 6	98267.7 ± 0.1	m	67 ± 3	Too strong?
98279.16 ± 0.70	$HCOOCH_3$	$8_{6,3} \rightarrow 7_{6,2}$ E $8_{6,3} \rightarrow 7_{6,2}$ A $8_{6,2} \rightarrow 7_{6,1}$ A	0.04 ± 0.01	8 ± 5	98279.65 ± 0.31 98279.70 ± 0.05 98279.74 ± 0.05	i	64 ± 2	
98432.69 ± 0.95	$HCOOCH_3$	$8_{5,4} \rightarrow 7_{5,3}$ E $8_{5,4} \rightarrow 7_{5,3}$ A $8_{5,3} \rightarrow 7_{5,2}$ A	0.04 ± 0.01	26 ± 7	98432.36 ± 0.29 98432.73 ± 0.05 98435.78 ± 0.05	i	65 ± 3	
98513.36 ± 0.65	HC_5N	37 → 36	0.06 ± 0.02	12 ± 5	98512.86 ± 0.25	s	60 ± 2	

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98522.7 ± 1.1	CH_3CH_2CN?	$11_6 \rightarrow 10_6$ $11_7 \rightarrow 10_7$	0.04 ± 0.02	14 ± 9	98523.88 ± 0.01 98524.66 ± 0.01	xx		High K blend, low S/N
98532.83 ± 0.81	CH_3CH_2CN?	$11_8 \rightarrow 10_8$ $11_{5,7} \rightarrow 10_{5,6}$ $11_{5,6} \rightarrow 10_{5,5}$	0.05 ± 0.02	12 ± 6	98532.07 ± 0.01 98533.98 ± 0.01 98533.99 ± 0.01	xx	66 ± 2	High K blend, low S/N
98564.8 ± 1.0	CH_3CH_2CN	$11_{4,8} \rightarrow 10_{4,7}$ $11_{4,7} \rightarrow 10_{4,6}$	0.05 ± 0.01	18 ± 8	98564.83 ± 0.01 98566.80 ± 0.01	xx	65 ± 3	
98609.66 ± 0.68	$HCOOCH_3$ CH_3CH_2CN $HCOOCH_3$	$8_{3,6} \rightarrow 7_{3,5}$ E $11_{3,9} \rightarrow 10_{3,8}$ $8_{3,6} \rightarrow 7_{3,5}$ A	0.08 ± 0.01	26 ± 5	98606.87 ± 0.27 98610.10 ± 0.01 98611.14 ± 0.04	i xx i		
98683.2 ± 1.9	$HCOOCH_3$?	$8_{4,5} \rightarrow 7_{4,4}$ A	0.02 ± 0.02	14 ± 25	98682.59 ± 0.04	i	60 ± 6	Low S/N
98700.83 ± 0.92	CH_3CH_2CN	$11_{3,8} \rightarrow 10_{3,7}$	0.04 ± 0.01	13 ± 7	98701.11 ± 0.01	xx	63 ± 3	
98712.2 ± 1.4	$HCOOCH_3$	$8_{4,5} \rightarrow 7_{4,4}$ E	0.04 ± 0.01	18 ± 11	98712.28 ± 0.28	i	62 ± 4	
98746.19 ± 0.73	$HCOOCH_3$?	$8_{4,4} \rightarrow 7_{4,3}$ E	0.04 ± 0.02	7 ± 5	98747.88 ± 0.28	i	67 ± 2	Low S/N
98791.87 ± 0.53	$HCOOCH_3$?	$8_{4,4} \rightarrow 7_{4,3}$ A	0.05 ± 0.03	4 ± 3	98792.27 ± 0.04	i	63 ± 2	Low S/N
98863.73 ± 0.21	CH_3CHO	$5_{1,4} \rightarrow 4_{1,3}$ E	0.23 ± 0.01	20 ± 1	98862.65 ± 0.98	j	59 ± 3	
98901.48 ± 0.30	CH_3CHO	$5_{1,4} \rightarrow 4_{1,3}$ A	0.18 ± 0.01	24 ± 2	98901.05 ± 0.97	j	61 ± 3	
99022.51 ± 0.65	H	40α	0.12 ± 0.01	32 ± 4	99022.95 ± 0.03		63 ± 2	
99117.4 ± 1.3	NH_2D?	$5_{2,4} \rightarrow 5_{1,4}$	0.04 ± 0.02	9 ± 11	99118.6	aa	66	See comment on 85926 MHz
99224.9 ± 1.2	H	50β	0.05 ± 0.02	15 ± 8	99225.21 ± 0.03		63 ± 4	
99300.64 ± 0.07	SO	J,K: 3,2 → 2,1	1.37 ± 0.01	35.7 ± 0.4	99299.88 ± 0.06	u	59.7 ± 0.3	
99309.55 ± 0.26	NH_2CN	$5_{1,5} \rightarrow 4_{1,4}$	0.40 ± 0.01	32 ± 2	99311.20 ± 0.04	o		On shoulder of SO
99324.94 ± 0.37	CH_3OCH_3	$4_{1,4} \rightarrow 3_{0,3}$	0.12 ± 0.01	25 ± 2	99325.24 ± 0.01	n		
99393.87 ± 0.57	SO_2	$29_{4,26} \rightarrow 28_{5,23}$	0.07 ± 0.03	9 ± 3	99392.61 ± 0.02	e	58 ± 2	
99653.23 ± 0.58	$HC^{13}CCN$	11 → 10	0.13 ± 0.02	23 ± 4	99651.86 ± 0.01	f		
99662.50 ± 0.57	$HCC^{13}CN$	11 → 10	0.14 ± 0.02	23 ± 4	99661.47 ± 0.01	f		
99682.4 ± 2.5	CH_3CH_2CN	$11_{2,9} \rightarrow 10_{2,8}$	0.05 ± 0.01	48 ± 23	99681.51 ± 0.01	xx	59 ± 8	
99727.0 ± 1.6	U		0.04 ± 0.02	18 ± 12				Also in BTL survey of IRC+10216. Therefore the identification of this line in Ori A as CH_3OH, v=1 seems questionable
99866.98 ± 0.64	U		0.08 ± 0.02	11 ± 4				

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TABLE 2—*Continued*

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99955.7 ± 1.3	NH_2CN	$5_{2,4} \rightarrow 4_{2,3}$ $5_{2,3} \rightarrow 4_{2,2}$	0.08 ± 0.02	20 ± 7	99953.27 ± 0.06 99956.60 ± 0.04	o	60 ± 4	Too strong?
99972.66 ± 0.60	NH_2CN	$5_{0,5} \rightarrow 4_{0,4}$	0.12 ± 0.02	20 ± 4	99972.66 ± 0.08	o	62 ± 2	
100030.92 ± 0.51	SO	J,K: 4,5 → 4,4	0.13 ± 0.02	17 ± 3	100029.63 ± 0.10	u	58 ± 2	
100077.11 ± 0.03	HC_3N $HCOOCH_3$	11 → 10 $9_{1,9} \rightarrow 8_{1,8}$ E $9_{1,9} \rightarrow 8_{1,8}$ A	3.27 ± 0.02	22.0 ± 0.2	100076.388 ± 0.002 100078.64 ± 0.40 100080.50 ± 0.07	f i	59.8 ± 0.1	Expected to contribute only 4% of line
100095.08 ± 0.44	H_2CCO	$5_{1,5} \rightarrow 4_{1,4}$	0.17 ± 0.02	21 ± 3	100094.47 ± 0.03	p	60 ± 1	
100110.87 ± 0.96	CH_3SH	$4_1 \rightarrow 3_1$ A+	0.06 ± 0.02	12 ± 6	100110.2 ± 0.1	l	60 ± 3	
100197.23 ± 0.78	U		0.09 ± 0.01	26 ± 5				Also reported by Turner (1977) in Sgr B2
100295.0 ± 2.3	$HCOOCH_3$?	$8_{3,5} \rightarrow 7_{3,4}$ E	0.03 ± 0.02	21 ± 18	100294.69 ± 0.27	i	61 ± 7	Low S/N
100306.9 ± 1.2	$HCOOCH_3$?	$8_{3,5} \rightarrow 7_{3,4}$ A	0.04 ± 0.02	11 ± 8	100308.16 ± 0.04	i	66 ± 4	Low S/N
100320.4 ± 1.2	HC_3N, ν_7, 1e	11 → 10	0.06 ± 0.02	20 ± 7	100322.35 ± 0.03	f	68 ± 4	
100463.2 ± 1.1	CH_3OCH_3 HC_3N, ν_7, 1f	$6_{2,5} \rightarrow 6_{1,6}$ 11 → 10	0.08 ± 0.03	13 ± 6	100463.11 ± 0.03 100466.11 ± 0.03	n f		
100482.48 ± 0.82	$HCOOCH_3$	$8_{1,7} \rightarrow 7_{1,6}$ E	0.06 ± 0.01	16 ± 6	100482.27 ± 0.27	i	61 ± 3	
100490.7 ± 1.0	$HCOOCH_3$	$8_{1,7} \rightarrow 7_{1,6}$ A	0.10 ± 0.03	16 ± 7	100490.66 ± 0.05	i	62 ± 3	
100601.64 ± 0.29	U		0.19 ± 0.01	21 ± 2				
100610.37 ± 0.87	CH_3CH_2CN	$11_{1,10} \rightarrow 10_{1,9}$	0.15 ± 0.02	27 ± 6	100614.31 ± 0.02	b	74 ± 3	
100630.11 ± 0.36	NH_2CN CH_3OH	$5_{1,4} \rightarrow 4_{1,3}$ $13_2 \rightarrow 12_3$ E	0.39 ± 0.03	25 ± 2	100629.50 ± 0.06 100638.9 ± 0.1	o m	60 ± 1	Expected to contribute 15% to line
100682.59 ± 0.51	$HCOOCH_3$	$9_{0,9} \rightarrow 8_{0,8}$ E $9_{0,9} \rightarrow 8_{0,8}$ A	0.10 ± 0.01	18 ± 3	100681.58 ± 0.40 100683.33 ± 0.07	i	62 ± 2	
100710.4 ± 1.1	HC_3N, $2\nu_7^0$, 0 HC_3N, $2\nu_7^2$, 2e HC_3N, $2\nu_7^2$, 2f	11 → 10	0.05 ± 0.01	18 ± 9	100708.84 ± 0.05 100710.97 ± 0.05 100714.31 ± 0.05	f	65 ± 3	
100880.5 ± 1.3	SO_2	$2_{2,0} \rightarrow 3_{1,3}$	0.08 ± 0.02	25 ± 11	100878.09 ± 0.08	e	55 ± 4	
100990.8 ± 1.7	CH_3CH_2OH	$8_{2,7} \rightarrow 8_{1,8}$	0.03 ± 0.01	20 ± 14	100989.95 ± 0.10	b	59 ± 5	
101002.48 ± 0.81	H_2CCO?	$5_{3,3} \rightarrow 4_{3,2}$ $5_{3,2} \rightarrow 4_{3,1}$	0.06 ± 0.01	21 ± 5	101002.32 ± 0.02 101002.33 ± 0.02	p	62 ± 2	Too strong? See text

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101031.73 ± 0.79	H_2CCO	$5_{2,4} \rightarrow 4_{2,3}$		0.13 ± 0.01		101024.40	± 0.02	p		
	CH_3SH	$4_{-1} \rightarrow 3_{-1}$	E			101029.7	± 0.1	l		
	H_2CCO	$5_{2,3} \rightarrow 4_{2,2}$				101032.21	± 0.02	p		
		$5_{0,5} \rightarrow 4_{0,4}$				101036.56	± 0.03			
101139.75 ± 0.45	CH_3SH	$4_0 \rightarrow 3_0$	A+	0.23 ± 0.02	21 ± 3	101139.4	± 0.1	l	61 ± 1	
		$4_0 \rightarrow 3_0$	E			101139.6	± 0.1			
101159.64 ± 0.81	CH_3SH	$4_2 \rightarrow 3_2$	A−	0.03 ± 0.01	14 ± 7	101159.5	± 0.1	l	61 ± 2	
101177.00 ± 0.54	CH_3SH	$4_{-2} \rightarrow 3_{-2}$	E	0.13 ± 0.03	11 ± 4	101167.1	± 0.1	l		
		$4_2 \rightarrow 3_2$	E			101168.2	± 0.1			
	HC_5N	$38 \rightarrow 37$				101175.05	± 0.27	s		
101284.92 ± 0.92	CH_3SH	$4_1 \rightarrow 3_1$	E	0.09 ± 0.02	16 ± 5	101284.3	± 0.1	l	60 ± 3	
101332.30 ± 0.60	H_2CO	$6_{1,5} \rightarrow 6_{1,6}$		0.11 ± 0.03	12 ± 3	101333.00	± 0.03	c	64 ± 2	
101341.55 ± 0.76	CH_3CHO	$3_{1,3} \rightarrow 2_{0,2}$	E	0.08 ± 0.02	16 ± 5	101341.0	± 1.5	j	60 ± 5	
101478.47 ± 0.21	H_2CS	$3_{1,3} \rightarrow 2_{1,2}$		0.60 ± 0.03	21 ± 1	101477.75	± 0.05	c	59.9 ± 0.6	
101981.78 ± 0.54	H_2CCO	$5_{1,4} \rightarrow 4_{1,3}$		0.12 ± 0.01	26 ± 4	101981.39	± 0.03	p	61 ± 2	
102064.89 ± 0.22	NH_2CHO	$5_{1,5} \rightarrow 4_{1,4}$		0.27 ± 0.01	19 ± 1	102064.35	± 0.06	c	60.4 ± 0.7	
102202.83 ± 0.81	CH_3SH	$4_1 \rightarrow 3_1$	A−	0.07 ± 0.03	10 ± 5	102202.4	± 0.1	l	61 ± 2	
102217.2 ± 1.0	U(NH_2CHO?)	$2_{1,2} \rightarrow 1_{0,1}$		0.08 ± 0.02	26 ± 7	102217.62	± 0.06	c	63 ± 3	b-type; probably too strong to be NH_2CHO -- see text
102515.67 ± 0.47	CH_3CCH	$6_5 \rightarrow 5_5$		0.07 ± 0.04	5 ± 2	102499.016	± 0.005	y		
		$6_4 \rightarrow 5_4$				102516.636	± 0.003			
		$6_3 \rightarrow 5_3$				102530.346	± 0.001			
		$6_2 \rightarrow 5_2$				102540.144	± 0.001			
102546.51 ± 0.10	CH_3CCH	$6_1 \rightarrow 5_1$		0.81 ± 0.02		102546.023	± 0.001	y		
		$6_0 \rightarrow 5_0$				102547.984	± 0.001			
102812.0 ± 1.6	U			0.04 ± 0.01						
103040.95 ± 0.11	H_2CS	$3_{2,2} \rightarrow 2_{2,1}$		0.51 ± 0.01	23 ± 1	103039.85	± 0.05	c	60.4 ± 0.4	K=2 expected to be 7% of K=0 intensity
		$3_{0,3} \rightarrow 2_{0,2}$				103040.40	± 0.05			
103052.48 ± 0.48	H_2CS	$3_{2,1} \rightarrow 2_{2,0}$		0.14 ± 0.01	23 ± 4	103051.79	± 0.05	c	60 ± 1	On shoulder of 103041 MHz. Fit intensity is probably too high
103216.6 ± 1.2	U			0.04 ± 0.01	21 ± 8					
103468.76 ± 0.58	$HCOOCH_3$	$8_{2,6} \rightarrow 7_{2,5}$	E	0.07 ± 0.02	12 ± 3	103466.60	± 0.26	i	56 ± 2	
103478.9 ± 1.3	$HCOOCH_3$	$8_{2,6} \rightarrow 7_{2,5}$	A	0.04 ± 0.01	18 ± 11	103478.64	± 0.04	i	61 ± 4	
103549.0 ± 1.9	U			0.04 ± 0.01	22 ± 9					

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103575.65 ± 0.86	CH_2CHCN	$11_{0,11} \rightarrow 10_{0,10}$	0.07 ± 0.01	20 ± 6	103575.40	± 0.02	k	61 ± 2	
103641.8 ± 1.1	U		0.05 ± 0.01	22 ± 8					
103703.4 ± 2.2	CH_3CH_2OH?	$9_{1,8} \rightarrow 8_{2,7}$	0.04 ± 0.01		103702.71	± 0.55	a	60 ± 7	Width unclear
103839.5 ± 1.2	HC_5N	39 → 38	0.05 ± 0.02	14 ± 7	103837.21	± 0.29	s	56 ± 4	
104031.06 ± 0.24	SO_2	$3_{1,3} \rightarrow 2_{0,2}$	0.33 ± 0.01	25 ± 1	104029.42	± 0.08	e	57 ± 1	
		$16_{2,14} \rightarrow 15_{3,13}$			104033.56	± 0.08			Expected to contribute 10% to line
104050.33 ± 0.94	CH_3CH_2CN	$12_{1,12} \rightarrow 11_{1,11}$	0.07 ± 0.02	20 ± 6	104051.29	± 0.02	b		
	CH_3OH?	$13_{-4} \rightarrow 12_{-3}$ E			104060.76		kk		
104200.06 ± 0.80	U		0.07 ± 0.02	17 ± 5					
104212.3 ± 1.1	CH_2CHCN	$11_{2,10} \rightarrow 10_{2,9}$	0.06 ± 0.02	19 ± 8	104212.65	± 0.02	k	63 ± 3	
104239.64 ± 0.24	SO_2	$10_{1,9} \rightarrow 10_{0,10}$	0.29 ± 0.02	20 ± 1	104239.28	± 0.08	e	61.0 ± 0.7	
104299.55 ± 0.46	CH_3OH	$11_{-1} \rightarrow 10_{-2}$ E	0.12 ± 0.02	12 ± 3	104300.5	± 0.1	v	65 ± 1	
104335.3 ± 1.7	CH_3OH?	$13_{-2} \rightarrow 13_{1}$ E	0.03 ± 0.02	10 ± 7	104336.5	± 0.1	m	66 ± 5	Line strength not yet calculated
104354.58 ± 0.95	CH_3OH	$10_{4} \rightarrow 11_{3}$ A−	0.06 ± 0.02	10 ± 5	104354.85		kk	63	
104392.2 ± 1.7	$^{34}SO_2$	$10_{1,9} \rightarrow 10_{0,10}$	0.04 ± 0.02	17 ± 12	104391.64	± 0.03	e	60 ± 5	
104409.70 ± 0.78	CH_2CHCN	$11_{5} \rightarrow 10_{5}$	0.08 ± 0.02	16 ± 6	104408.90	± 0.01	k		
	CH_3OH	$10_{4} \rightarrow 11_{3}$ A+			104410.48		kk		
	CH_2CHCN	$11_{4,8} \rightarrow 10_{4,7}$			104411.26	± 0.01	k		
		$11_{4,7} \rightarrow 10_{4,6}$			104411.49	± 0.01			
		$11_{6} \rightarrow 10_{6}$			104419.31	± 0.02			
104432.9 ± 1.5	CH_2CHCN	$11_{3,9} \rightarrow 10_{3,8}$	0.04 ± 0.01	29 ± 12	104432.79	± 0.02	k		
		$11_{7} \rightarrow 10_{7}$			104437.52	± 0.02			
104455.2 ± 1.4	CH_2CHCN	$11_{3,8} \rightarrow 10_{3,7}$	0.06 ± 0.03	15 ± 10	104453.93	± 0.02	k	58 ± 4	
104488.12 ± 0.47	CH_3CH_2OH	$7_{0,7} \rightarrow 6_{1,6}$	0.20 ± 0.03	18 ± 3	104487.22	± 0.07	b	59 ± 1	
104618.01 ± 0.14	H_2CS	$3_{1,2} \rightarrow 2_{1,1}$	0.73 ± 0.02	22 ± 1	104616.98	± 0.05	c	59.0 ± 0.4	
104711.7 ± 2.4	CH_3OCH_3	$7_{2,6} \rightarrow 7_{1,7}$	0.08 ± 0.02	30 ± 40	104703.33	± 0.04	n		
	$^{13}C^{18}O$	1 → 0			104711.42	± 0.02	w		
104808.73 ± 0.67	CH_3CH_2OH	$5_{1,5} \rightarrow 4_{0,4}$	0.19 ± 0.02	23 ± 5	104808.63	± 0.09	b	62 ± 2	
104874.78 ± 0.97	U		0.12 ± 0.03	21 ± 7					
104960.8 ± 2.1	CH_2CHCN?	$11_{2,9} \rightarrow 10_{2,8}$	0.06 ± 0.07	27 ± 32	104960.55	± 0.02	k	61 ± 6	Low S/N
105062.70 ± 0.58	CH_3OH	$13_{1} \rightarrow 12_{2}$ A+	0.11 ± 0.03	9 ± 3	105063.70		kk	65	
105300.6 ± 3.3	H	49β	0.04 ± 0.03	12 ± 67	105301.86	± 0.03		66 ± 9	

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Astronomical Frequency (MHz)	Molecule or Atom	Transition	T_A^* (K)	Δv(FWHM) (km s^{-1})	Rest Frequency (MHz)			v_{LSR} (km s^{-1})	Comments
105465.26 ± 0.15	NH_2CHO CH_3CH_2CN	$5_{0,5} \rightarrow 4_{0,4}$ $12_{0,12} \rightarrow 11_{0,11}$	0.31 ± 0.01	25 ± 1	105464.29 ± 0.05 105469.30 ± 0.01	c xx			
105537.5 ± 2.2	U		0.02 ± 0.01	28 ± 13					Reported by Johansson et al. (1984) in Ori A
105557.39 ± 0.90	HNCS	$9_{0,9} \rightarrow 8_{0,8}$	0.04 ± 0.01	28 ± 5	105557.95 ± 0.51	r		64 ± 3	
105575.65 ± 0.76	CH_3OH?	$14_{-2} \rightarrow 14_1$ E	0.04 ± 0.02	9 ± 4	105576.4 ± 0.1	m		64 ± 2	Line strength not yet calculated
105796.19 ± 0.20	CH_2NH $H^{13}CCCN$	$4_{0,4} \rightarrow 3_{1,3}$ $12 \rightarrow 11$	0.27 ± 0.01	27 ± 1	105794.12 ± 0.05 105799.09 ± 0.01	11 f			
105972.95 ± 0.59	NH_2CHO	$5_{2,4} \rightarrow 4_{2,3}$	0.14 ± 0.02	23 ± 4	105972.73 ± 0.08	c		61 ± 2	
106138.81 ± 0.85	NH_2CHO	$5_{3,3} \rightarrow 4_{3,2}$ $5_{3,2} \rightarrow 4_{3,1}$	0.10 ± 0.02	24 ± 5	106134.62 ± 0.12 106141.59 ± 0.12	c		60 ± 2	
106347.97 ± 0.50	U		0.19 ± 0.02	24 ± 3					
106498.9 ± 1.7	HC_5N	$40 \rightarrow 39$	0.04 ± 0.01	20 ± 12	106499.35 ± 0.31	s		63 ± 5	
106542.20 ± 0.45	NH_2CHO	$5_{2,3} \rightarrow 4_{2,2}$	0.15 ± 0.01	20 ± 3	106541.81 ± 0.08	c		61 ± 1	
106642.9 ± 1.5	CH_2CHCN	$11_{1,10} \rightarrow 10_{1,9}$	0.05 ± 0.01	28 ± 10	106641.39 ± 0.02	k		58 ± 4	
106723.90 ± 0.84	CH_3CH_2OH?	$9_{2,8} \rightarrow 9_{1,9}$	0.06 ± 0.02	13 ± 6	106723.41 ± 0.12	b		61 ± 2	On shoulder of H 39α
106738.9 ± 1.0	H ^{34}SO?	39α J,K: $2,3 \rightarrow 1,2$	0.11 ± 0.01	50 ± 7	106737.36 ± 0.03 106742.92 ± 0.15	 u		58 ± 3	
106776.1 ± 1.0	CH_3OCH_3	$9_{1,8} \rightarrow 8_{2,7}$	0.05 ± 0.02	11 ± 7	106777.52 ± 0.09	n			
106786.9 ± 1.4	$OC^{34}S$	$9 \rightarrow 8$	0.05 ± 0.02	21 ± 13	106787.38 ± 0.08	g		63 ± 4	
106913.31 ± 0.21	HCO_2^+	$5_{0,5} \rightarrow 4_{0,4}$	0.38 ± 0.02	25 ± 1	106913.01 ± 0.19	aaa		61 ± 1	
107015.33 ± 0.14	CH_3OH	$3_1 \rightarrow 4_0$ A+	0.32 ± 0.01	16 ± 1	107013.9 ± 0.1	v		57.9 ± 0.5	
107043.9 ± 1.2	CH_3CH_2CN	$12_{2,11} \rightarrow 11_{2,10}$	0.05 ± 0.02	18 ± 9	107043.52 ± 0.01	xx		61 ± 3	
107061.14 ± 0.62	SO_2	$27_{3,25} \rightarrow 26_{4,22}$	0.07 ± 0.02	14 ± 4	107060.19 ± 0.08	e		59 ± 2	
107177.78 ± 0.90	$^{13}CH_3CN$	$6_3 \rightarrow 5_3$ $6_2 \rightarrow 5_2$	0.04 ± 0.02	10 ± 7	107178.49 ± 0.03 107188.55 ± 0.03	h			
107194.87 ± 0.80	$^{13}CH_3CN$	$6_1 \rightarrow 5_1$ $6_0 \rightarrow 5_0$	0.07 ± 0.01	18 ± 5	107194.58 ± 0.03 107196.59 ± 0.03	h			
107315.6 ± 1.2	CH_3SH	$3_{-1} \rightarrow 3_0$ A	0.04 ± 0.01	15 ± 9	107316.5 ± 0.1	l		65 ± 3	
107487.3 ± 1.6	CH_3CH_2CN	$12_7 \rightarrow 11_7$ $12_6 \rightarrow 11_6$ $12_8 \rightarrow 11_8$	0.05 ± 0.01	22 ± 12	107485.18 ± 0.01 107486.96 ± 0.01 107491.58 ± 0.01	xx			

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107501.67 ± 0.73	CH_3CH_2CN	$12_{5,8} \rightarrow 11_{5,7}$ $12_{5,7} \rightarrow 11_{5,6}$	0.05 ± 0.01	17 ± 4	107502.44 ± 0.02 107502.49 ± 0.02	b	64 ± 2	
107521.4 ± 2.2	CH_3CH_2CN?	$12_{10} \rightarrow 11_{10}$	0.03 ± 0.02	16 ± 16	107519.94 ± 0.01	xx	58 ± 6	Too strong?
107542.5 ± 1.2	$HCOOCH_3$ CH_3CH_2CN $HCOOCH_3$ CH_3CH_2CN	$9_{2,8} \rightarrow 8_{2,7}$ E $12_{11} \rightarrow 11_{11}$ $9_{2,8} \rightarrow 8_{2,7}$ A $12_{4,9} \rightarrow 11_{4,8}$ $12_{4,8} \rightarrow 11_{4,7}$	0.07 ± 0.01	34 ± 6	107537.27 ± 0.40 107539.85 ± 0.01 107543.66 ± 0.07 107543.92 ± 0.01 107547.60 ± 0.01	i xx i xx		
107593.50 ± 0.64	CH_3CH_2CN	$12_{3,10} \rightarrow 11_{3,9}$	0.06 ± 0.03	7 ± 4	107594.06 ± 0.02	b	64 ± 2	
107735.5 ± 1.3	CH_3CH_2CN	$12_{3,9} \rightarrow 11_{3,8}$	0.04 ± 0.01	19 ± 8	107734.75 ± 0.02	b	60 ± 4	
107843.49 ± 0.80	SO_2	$12_{4,8} \rightarrow 13_{3,11}$	0.06 ± 0.01	18 ± 4	107843.46 ± 0.08	e	62 ± 2	
108124.80 ± 0.80	HCOOH	$5_{1,5} \rightarrow 4_{1,4}$	0.06 ± 0.06	4 ± 4	108126.71 ± 0.01	cc	67 ± 2	
108708.7 ± 2.1	$HC^{13}CCN$	12 → 11	0.15 ± 0.04	22 ± 65	108710.52 ± 0.01	f		
108721.3 ± 1.6	$HCC^{13}CN$	12 → 11	0.15 ± 0.04	24 ± 16	108721.01 ± 0.01	f		
108783.66 ± 0.82	^{13}CN N = 1→0, F_1 = 1, F_2 = 2→1	F: 3 → 2 2 → 1 1 → 0	0.18 ± 0.04	16 ± 5	108780.20 ± 0.20 108782.37 ± 0.11 108786.98 ± 0.05	zz		
108894.37 ± 0.23	CH_3OH	$0_0 \rightarrow 1_{-1}$ E	0.98 ± 0.03	29 ± 1	108893.9 ± 0.1	v	60.8 ± 0.7	
109111.67 ± 0.86	$O^{13}CS$	9 → 8	0.08 ± 0.04	8 ± 6	109110.86 ± 0.01	g	60 ± 2	
109174.81 ± 0.04	HC_3N	12 → 11	2.86 ± 0.02	20.5 ± 0.2	109173.639 ± 0.002	f	58.8 ± 0.1	
109252.92 ± 0.15	SO	J,K: 2,3 → 1,2	0.72 ± 0.02	21 ± 1	109252.13 ± 0.04	u	59.8 ± 0.4	
109442.34 ± 0.51	$HC_3N, v_7, 1e$	12 → 11	0.22 ± 0.13	5 ± 3	109441.94 ± 0.03	f	61 ± 1	
109463.22 ± 0.24	OCS	9 → 8	0.98 ± 0.05	22 ± 1	109463.06 ± 0.01	g	62.6 ± 0.7	
109497.4 ± 1.1	HNCO	$5_{1,5} \rightarrow 4_{1,4}$	0.24 ± 0.05	25 ± 7	109496.007 ± 0.004	hh	58 ± 3	
109599.7 ± 1.4	$HC_3N, v_7, 1f$	12 → 11	0.08 ± 0.03	18 ± 12	109598.75 ± 0.03	f	59 ± 4	
109649.53 ± 0.86	CH_3CH_2CN	$12_{1,11} \rightarrow 11_{1,10}$	0.11 ± 0.03	15 ± 5	109650.32 ± 0.02	b	64 ± 2	
109754.30 ± 0.27	NH_2CHO SO_2	$5_{1,4} \rightarrow 4_{1,3}$ $17_{5,13} \rightarrow 18_{4,14}$	0.40 ± 0.02	27 ± 1	109753.59 ± 0.06 109757.60 ± 0.08	c e	60 ± 1	 Expected to contribute 10% to line
109780.91 ± 0.07	$C^{18}O$	1 → 0	1.76 ± 0.02	25.8 ± 0.4	109782.18 ± 0.02	w	65.5 ± 0.2	
109861.0 ± 1.0	HC_3N, $2v_7^0$, 0 HC_3N, $2v_7^2$, 2e	12 → 11	0.09 ± 0.02	19 ± 7	109862.83 ± 0.05 109865.85 ± 0.05	f		

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109871.6 ± 1.2	HC_3N, $2\nu_7^2$, 2f	12 → 11	0.08 ± 0.01	28 ± 9	109870.19 ± 0.05 f		
	HNCO	$5_{2,4} \rightarrow 4_{2,3}$			109872.366 ± 0.005 hh		
		$5_{2,3} \rightarrow 4_{2,2}$			109872.773 ± 0.005		
109904.56 ± 0.04	HNCO	$5_{0,5} \rightarrow 4_{0,4}$	4.18 ± 0.02	25.7 ± 0.2	109905.753 ± 0.005 hh	65.3 ± 0.1	
110156.59 ± 0.80	NH_2D?(+^{13}CO?)	$1_{1,1} \rightarrow 1_{0,1}$	0.22 ± 0.02	40 ± 6	110153.4 aa		
110198.73 ± 0.06	^{13}CO	1 → 0	7.35 ± 0.04	41.6 ± 0.3	110201.37 ± 0.02 w	69.2 ± 0.2	
110297.75 ± 0.32	HNCO	$5_{1,4} \rightarrow 4_{1,3}$	0.23 ± 0.02	20 ± 2	110298.098 ± 0.004 hh	63 ± 1	
110328.22 ± 0.63	$CH_3{}^{13}CN$	$6_1 \rightarrow 5_1$	0.14 ± 0.01	29 ± 4	110326.78 ± 0.03 h		
		$6_0 \rightarrow 5_0$			110328.89 ± 0.03		
	CH_3CN	$6_5 \rightarrow 5_5$			110330.347 ± 0.002		
110349.8 ± 1.9	CH_3CN	$6_4 \rightarrow 5_4$	0.15 ± 0.06	21 ± 14	110349.473 ± 0.002 h		
110365.26 ± 0.50	CH_3CN	$6_3 \rightarrow 5_3$	0.59 ± 0.05	27 ± 3	110364.357 ± 0.001 h		
110379.73 ± 0.40	CH_3CN	$6_2 \rightarrow 5_2$	1.11 ± 0.04	49 ± 3	110374.992 ± 0.001 h		
		$6_1 \rightarrow 5_1$			110381.376 ± 0.001		
		$6_0 \rightarrow 5_0$			110383.504 ± 0.001		
110535.9 ± 1.8	$HCOOCH_3$	$9_7 \rightarrow 8_7$ A	0.03 ± 0.01	21 ± 12	110535.11 ± 0.08 i	62 ± 5	
		$9_{7,3} \rightarrow 8_{7,2}$ E			110536.99 ± 0.48		
110608.7 ± 1.3	CH_3CN, ν_8	$6_1 \rightarrow 5_1$	0.04 ± 0.02	15 ± 7	110609.55 ± 0.06 h	64 ± 4	
110652.2 ± 1.1	$HCOOCH_3$	$9_{6,3} \rightarrow 8_{6,2}$ E	0.04 ± 0.02	10 ± 8	110652.71 ± 0.45 i	63 ± 3	
110661.5 ± 1.1	CH_3CN, ν_8	$6_4 \rightarrow 5_4$	0.05 ± 0.01	19 ± 6	110660.87 h		
	$HCOOCH_3$	$9_{6,4} \rightarrow 8_{6,3}$ E			110663.10 ± 0.45 i		
		$9_{6,4} \rightarrow 8_{6,3}$ A			110663.19 ± 0.07		
		$9_{6,3} \rightarrow 8_{6,2}$ A			110663.39 ± 0.07		
110681.0 ± 1.1	CH_3CN, ν_8	$6_3 \rightarrow 5_3$	0.05 ± 0.01	16 ± 7	110680.35 h	60	
110696.4 ± 1.1	CH_3CN, ν_8	$6_2 \rightarrow 5_2$	0.05 ± 0.01	24 ± 8	110695.51 h		
		$6_4 \rightarrow 5_4$			110698.70		
110708.45 ± 0.74	HDS?	$4_{2,3} \rightarrow 3_{3,0}$	0.08 ± 0.02	15 ± 8	110706.22 ± 0.02 mm		
	CH_3CN, ν_8	$6_1 \rightarrow 5_1$			110706.25 ± 0.06 h		
		$6_3 \rightarrow 5_3$			110709.31		
		$6_0 \rightarrow 5_0$			110712.17 ± 0.05		
		$6_2 \rightarrow 5_2$			110716.21		
110789.14 ± 0.55	$HCOOCH_3$	$10_{1,10} \rightarrow 9_{1,9}$ E	0.10 ± 0.01	20 ± 3	110788.72 ± 0.58 i	63 ± 2	
		$10_{1,10} \rightarrow 9_{1,9}$ A			110790.46 ± 0.10		
110822.4 ± 1.6	CH_3CN, ν_8	$6_1 \rightarrow 5_1$	0.03 ± 0.02	15 ± 7	110823.10 ± 0.06 h	64 ± 4	
110838.59 ± 0.96	CH_2CHCN	$12_{1,12} \rightarrow 11_{1,11}$	0.06 ± 0.02	16 ± 5	110839.98 ± 0.02 k	66 ± 3	

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110888.9 ± 1.1	$HCOOCH_3$	$9_{5,4} \rightarrow 8_{5,3}$ E	0.06 ± 0.02	12 ± 15	110873.81 ± 0.43	i		
		$9_{3,7} \rightarrow 8_{3,6}$ E			110879.79 ± 0.41			
		$9_{5,5} \rightarrow 8_{5,4}$ A			110880.40 ± 0.07			
		$9_{5,5} \rightarrow 8_{5,4}$ E			110882.93 ± 0.42			
		$9_{3,7} \rightarrow 8_{3,6}$ A			110887.04 ± 0.07			
		$9_{5,4} \rightarrow 8_{5,3}$ A			110890.20 ± 0.07			
	CH_2NH?	$6_{1,5} \rightarrow 6_{1,6}$			110897.78 ± 0.03	ll		
110940 → 111450	No data							
111747.2 ± 1.6	HCOOH?	$5_{0,5} \rightarrow 4_{0,4}$	0.10 ± 0.04	16 ± 15	111746.78 ± 0.01	cc		Low S/N
	SO_2?	$31_{3,29} \rightarrow 30_{4,26}$			111755.03 ± 0.08	e		
111783.4 ± 1.4	CH_3OCH_3	$7_{0,7} \rightarrow 6_{1,6}$	0.12 ± 0.04	19 ± 7	111782.73 ± 0.05	n		
111827.61 ± 0.82	HC_5N?	42 → 41	0.13 ± 0.06	8 ± 5	111823.03 ± 0.03	yy	50 ± 2	Low S/N
111885.95 ± 0.48	H	48β	0.16 ± 0.09	5 ± 3	111885.07 ± 0.03		60 ± 1	
112252.9 ± 1.1	CH_3CHO	$6_{1,6} \rightarrow 5_{1,5}$ A	0.19 ± 0.05	16 ± 6	112249.20 ± 0.95	j	58 ± 5	
		$6_{1,6} \rightarrow 5_{1,5}$ E			112253.58 ± 0.95			
112359.56 ± 0.50	$C^{17}O$	1 → 0	0.44 ± 0.05	18 ± 3	112359.27 ± 0.07	w	61 ± 1	
112464.6 ± 1.1	HCOOH	$5_{3,3} \rightarrow 4_{3,2}$	0.09 ± 0.01	30 ± 5	112459.61 ± 0.01	cc	59 ± 3	
		$5_{3,2} \rightarrow 4_{3,1}$			112467.00 ± 0.01			
112645.86 ± 0.54	CH_3CH_2CN	$13_{1,13} \rightarrow 12_{1,12}$	0.10 ± 0.03	7 ± 4	112646.24 ± 0.02	b	63 ± 1	
112806.59 ± 0.56	CH_3CH_2OH	$2_{2,1} \rightarrow 1_{1,0}$	0.16 ± 0.02	23 ± 3	112807.10 ± 0.11	b	63 ± 2	
112841.2 ± 1.0	CH_2CHCN	$12_{0,12} \rightarrow 11_{0,11}$	0.08 ± 0.02	16 ± 6	112840.65 ± 0.02	k	61 ± 3	
112892.0 ± 1.4	HCOOH	$5_{2,3} \rightarrow 4_{2,2}$	0.05 ± 0.02	15 ± 10	112891.43 ± 0.01	cc	60 ± 4	
113124.76 ± 0.59	CN N=1→0;J,F:	1/2,1/2 → 1/2,3/2	0.31 ± 0.02	35 ± 4	113144.34 ± 0.07	nn		Blending, velocity structure, self-absorption
113149.76 ± 0.41		1/2,3/2 → 1/2,1/2	0.21 ± 0.03	12 ± 2	113170.87 ± 0.07			
113174.55 ± 0.26		1/2,3/2 → 1/2,3/2	0.37 ± 0.03	12 ± 2	113191.33 ± 0.07			
113197.08 ± 0.62			0.13 ± 0.04	8 ± 3				
113450 → 114440	No data							
114484.7 ± 1.1	HC_5N?	43 → 42	0.11 ± 0.07	7 ± 5	114485.59 ± 0.38	s	64 ± 3	Low S/N
114616.4 ± 1.4	$H^{13}CCCN$	13 → 12	0.13 ± 0.04	18 ± 9	114615.02 ± 0.01	f		
	CH_2CHCN	$12_{2,10} \rightarrow 11_{2,9}$			114621.58 ± 0.02	k		
114939.9 ± 2.1	CH_3CHO	$6_{0,6} \rightarrow 5_{0,5}$ E	0.15 ± 0.04	25 ± 10	114939.4 ± 1.0	j	61 ± 6	
114960.8 ± 1.0	CH_3CHO	$6_{0,6} \rightarrow 5_{0,5}$ A	0.38 ± 0.07	22 ± 9	114960.6 ± 1.0	j	62 ± 4	

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115156.56 ± 0.54	NS	J,F:5/2,7/2 → 3/2,5/2 5/2,5/2 → 3/2,3/2 5/2,3/2 → 3/2,1/2	0.67 ± 0.07	21 ± 3	115153.84 ± 0.08 115156.80 ± 0.08 115162.96 ± 0.08	oo		
115185.1 ± 1.5	NS	J,F:5/2,3/2 → 3/2,3/2	0.26 ± 0.10	12 ± 6	115185.39 ± 0.06	oo	63 ± 4	
115259.0 ± 1.0	CO	1 → 0	30.8 ± 0.6	61 ± 4	115271.20 ± 0.01	w		Velocity structure between 213 and −120 km s^{-1}. The maximum intensity (30.8 K) occurs at 115259 MHz (v = 94 km s^{-1}). The FWHM of the central peak is 61 km s^{-1}.
115450 → 124250	No data							
124496.84 ± 0.62	$^{34}SO_2$	$12_{2,10} \rightarrow 12_{1,11}$	0.12 ± 0.03	10 ± 4	124496.45 ± 0.03	e	61 ± 1	Too strong?
124571.51 ± 0.28	CH_3OH	$6_0 \rightarrow 5_1$ E	0.44 ± 0.02	20 ± 1	124570.0 ± 0.1	v	58.3 ± 0.7	
124614.3 ± 1.4	$^{34}SO_2$	$10_{2,8} \rightarrow 10_{1,9}$	0.08 ± 0.03	14 ± 10	124614.08 ± 0.03	e	61 ± 3	
124726.95 ± 0.55	CH_3CH_2CN	$14_{2,13} \rightarrow 13_{2,12}$	0.10 ± 0.05	5 ± 4	124729.08 ± 0.02	b	67 ± 1	
124746.7 ± 1.5	H	37α	0.09 ± 0.02	20 ± 10	124746.73 ± 0.04		62 ± 4	
124791.4 ± 2.3	$^{13}CH_2NH$?	$2_{0,2} \rightarrow 1_{0,1}$	0.07 ± 0.02	33 ± 21	124789.84 ± 0.12	pp	58 ± 6	No other transitions in survey for comparison of intensity
124865.9 ± 1.0	SO_2	$11_{4,8} \rightarrow 12_{3,9}$	0.07 ± 0.02	14 ± 5	124864.74 ± 0.08	e	59 ± 2	
125039.5 ± 1.9	$^{13}CH_3CN$	$7_3 \rightarrow 6_3$ $7_2 \rightarrow 6_2$	0.04 ± 0.03	12 ± 11	125040.23 ± 0.03 125051.97 ± 0.03	h		
125060.4 ± 1.7	$^{13}CH_3CN$	$7_1 \rightarrow 6_1$ $7_0 \rightarrow 6_0$	0.05 ± 0.02	18 ± 10	125059.01 ± 0.03 125061.35 ± 0.03	h		
125133.7 ± 1.0	CH_3SH HC_5N	$5_1 \rightarrow 4_1$ A− 47 → 46	0.07 ± 0.02	5 ± 2	125133. 125133.50 ± 0.49	qq s		
125175.41 ± 0.67	CH_3CH_2OH	$8_{3,5} \rightarrow 8_{2,6}$	0.07 ± 0.03	6 ± 4	125173.15 ± 0.39	a	57 ± 2	
125248.75 ± 0.80	CH_3OCH_3	$2_{2,1} \rightarrow 1_{1,0}$	0.08 ± 0.02	9 ± 4	125246.88 ± 0.04	n		
125250 → 125450	No data							
125566.8 ± 1.8	CH_3CH_2CN	$14_{3,12} \rightarrow 13_{3,11}$	0.07 ± 0.02	20 ± 12	125564.50 ± 0.02	b	57 ± 4	
125848.6 ± 1.2	U		0.12 ± 0.03	21 ± 8				
125920.78 ± 0.85	CH_2CHCN	$13_{1,12} \rightarrow 12_{1,11}$	0.10 ± 0.03	12 ± 4	125921.67 ± 0.02	k	64 ± 2	
125947.14 ± 0.52	CH_3CH_2OH	$10_{1,9} \rightarrow 9_{2,8}$	0.13 ± 0.04	8 ± 3	125947.25 ± 0.10	b	62 ± 1	
125950 → 126950	No data							
126982.30 ± 0.90	SO_2	$35_{5,31} \rightarrow 34_{6,28}$	0.06 ± 0.02	12 ± 6	126980.70 ± 0.08	e	58 ± 2	

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TABLE 2—*Continued*

Astronomical Frequency (MHz)	Molecule or Atom	Transition	T_A^* (K)	Δv(FWHM) (km s^{-1})	Rest Frequency (MHz)		v_{LSR} (km s^{-1})	Comments
127076.25 ± 0.90	SiS	7 → 6	0.06 ± 0.02	12 ± 5	127076.12 ± 0.08	d	62 ± 2	
127114.61 ± 0.51	NH_2CHO ^{30}SiO	$6_{2,5} \rightarrow 5_{2,4}$ 3 → 2	0.16 ± 0.01	31 ± 3	127112.85 ± 0.13 127117.14 ± 0.32	c w		
127215.2 ± 1.3	CH_3CH_2OH	$7_{3,4} \rightarrow 7_{2,5}$	0.05 ± 0.02	14 ± 11	127215.15 ± 0.31	a	62 ± 3	
127288.1 ± 1.1	U		0.04 ± 0.02	6 ± 7				
127307.5 ± 1.2	U		0.03 ± 0.01	13 ± 5				
127328.7 ± 1.8	NH_2CHO	$6_5 \rightarrow 5_5$	0.03 ± 0.02	10 ± 8	127330.36 ± 0.43	c	66 ± 4	
127347.25 ± 0.78	NH_2CHO	$6_{4,3} \rightarrow 5_{4,2}$ $6_{4,2} \rightarrow 5_{4,1}$	0.08 ± 0.01	18 ± 4	127348.65 ± 0.22 127348.76 ± 0.22	c	65 ± 2	On shoulder of HC_3N
127368.30 ± 0.04	HC_3N	14 → 13	2.39 ± 0.01	20.4 ± 0.1	127367.658 ± 0.002	f	60.5 ± 0.1	
127393.48 ± 0.63	NH_2CHO	$6_{3,4} \rightarrow 5_{3,3}$	0.10 ± 0.02	16 ± 3	127393.78 ± 0.18	c	63 ± 2	
127411.20 ± 0.57	NH_2CHO	$6_{3,3} \rightarrow 5_{3,2}$	0.09 ± 0.02	11 ± 3	127412.36 ± 0.18	c	65 ± 1	
127430.3 ± 1.5	SO_2?	$28_{4,24} \rightarrow 27_{5,23}$	0.04 ± 0.02	11 ± 9	127428.23 ± 0.08	e	57 ± 4	Low S/N
127450 → 127950	No data							
128021.45 ± 0.40	HCS^+	3 → 2	0.28 ± 0.02	20 ± 2	128020.59 ± 0.52	rr	60 ± 2	
128102.61 ± 0.71	NH_2CHO	$6_{2,4} \rightarrow 5_{2,3}$	0.16 ± 0.02	20 ± 4	128102.97 ± 0.12	c	63 ± 2	
128294.00 ± 0.53	HCO_2^+	$6_{0,6} \rightarrow 5_{0,5}$	0.27 ± 0.02	27 ± 3	128294.43 ± 0.41	aaa	63 ± 1	
128605.58 ± 0.44	SO_2	$12_{2,10} \rightarrow 12_{1,11}$	0.22 ± 0.02	19 ± 2	128605.13 ± 0.08	e	61 ± 1	
128640.90 ± 0.74	^{29}SiO	3 → 2	0.11 ± 0.01	25 ± 4	128636.74 ± 0.32	w	52 ± 2	
128671.5 ± 1.8	$^{34}SO_2$	$8_{2,6} \rightarrow 8_{1,7}$	0.04 ± 0.02	18 ± 8	128668.79 ± 0.03	e	56 ± 4	
128691.69 ± 0.77	CH_3CH_2OH CH_3CN	$6_{3,3} \rightarrow 6_{2,4}$ $7_6 \rightarrow 6_6$	0.09 ± 0.01	14 ± 4	128689.67 ± 0.24 128690.112 ± 0.002	a h		
128715.86 ± 0.76	$CH_3{}^{13}CN$ CH_3CN	$7_1 \rightarrow 6_1$ $7_0 \rightarrow 6_0$ $7_5 \rightarrow 6_5$	0.11 ± 0.01	25 ± 4	128713.18 ± 0.03 128715.65 ± 0.03 128717.362 ± 0.002	h		
128740.22 ± 0.72	CH_3CN	$7_4 \rightarrow 6_4$	0.17 ± 0.02	22 ± 4	128739.672 ± 0.002	h		
128758.31 ± 0.19	CH_3CN	$7_3 \rightarrow 6_3$	0.48 ± 0.01	29 ± 1	128757.034 ± 0.002	h		
128777.14 ± 0.10	CH_3CN	$7_2 \rightarrow 6_2$ $7_1 \rightarrow 6_1$ $7_0 \rightarrow 6_0$	1.04 ± 0.01	33.4 ± 0.4	128769.44 ± 0.06 128776.89 ± 0.04 128779.37 ± 0.04	h		
128815.1 ± 1.0	HCO?	$2_{0,2} \rightarrow 1_{0,1}$	0.05 ± 0.02	10 ± 6	128812.74 ± 0.03	ss	57 ± 2	No other transitions in survey for comparison of intensity

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TABLE 2—*Continued*

Astronomical Frequency (MHz)	Molecule or Atom	Transition	T_A^* (K)	Δv(FWHM) (km s^{-1})	Rest Frequency (MHz)		v_{LSR} (km s^{-1})	Comments
129012.4 ± 2.0	HNCS	$11_{0,11} \rightarrow 10_{0,10}$	0.06 ± 0.02	23 ± 15	129013.21	± 0.71 r	64 ± 5	
129078.03 ± 0.73	CH_3CH_2OH	$3_{2,2} \rightarrow 2_{1,1}$	0.13 ± 0.02	19 ± 4	129077.58	± 0.12 b	61 ± 2	
129107.06 ± 0.42	SO_2	$12_{1,11} \rightarrow 11_{2,10}$	0.20 ± 0.02	18 ± 2	129105.83	± 0.08 e	59 ± 1	
129139.84 ± 0.09	SO	J,K: 3,3 → 2,2	1.09 ± 0.02	19.5 ± 0.4	129138.86	± 0.05 u	59.7 ± 0.2	
129219.7 ± 1.4	CH_2CHCN	$14_{1,14} \rightarrow 13_{1,13}$	0.05 ± 0.02	17 ± 7	129219.22	± 0.02 k	61 ± 3	
129296.1 ± 4.5	$HCOOCH_3$	$10_{2,8} \rightarrow 9_{2,7}$ E	0.03 ± 0.01	29 ± 55	129296.41	± 0.58 i	63 ± 11	
129309.8 ± 1.6	$HCOOCH_3$	$10_{2,8} \rightarrow 9_{2,7}$ A	0.05 ± 0.02	17 ± 11	129310.08	± 0.10 i	63 ± 4	
129433.48 ± 0.95	CH_3OH	$12_1 \rightarrow 11_2$ A−	0.07 ± 0.02	11 ± 5	129433.41	kk	62	
129450 → 129950	No data							
130012.5 ± 1.6	$HCOOCH_3$	$11_{2,10} \rightarrow 10_{2,9}$ E $11_{2,10} \rightarrow 10_{2,9}$ A	0.04 ± 0.02	15 ± 8	130010.11 130016.66	± 0.79 i ± 0.13	64 ± 4	
130170.3 ± 1.4	$H_2{}^{13}CS$?	$4_{1,4} \rightarrow 3_{1,3}$	0.04 ± 0.02	14 ± 8	130171.47	± 0.02 yy	65 ± 3	Low S/N. Identification tentative.
130271.00 ± 0.18	SiO	3 → 2	0.93 ± 0.02 0.41 ± 0.02	41 ± 1	130268.49	± 0.32 w	56.2 ± 0.8	Two peaks, at 130264 and 130274 MHz.
130450 → 130930	No data							
131015.33 ± 0.25	SO_2	$12_{1,11} \rightarrow 12_{0,12}$	0.25 ± 0.01	21 ± 1	131014.86	± 0.08 e	60.9 ± 0.6	
131105.1 ± 1.3	CH_3CH_2OH	$5_{3,3} \rightarrow 5_{2,4}$	0.04 ± 0.01	14 ± 7	131103.07	± 0.24 a	57 ± 3	
131134.00 ± 0.68	U		0.06 ± 0.02	9 ± 3				
131272.53 ± 0.84	CH_2CHCN SO_2	$14_{0,14} \rightarrow 13_{0,13}$ $16_{5,11} \rightarrow 17_{4,14}$	0.09 ± 0.01	29 ± 4	131267.48 131274.93	± 0.02 k ± 0.08 e		
131394.50 ± 0.25	HNCO	$6_{1,6} \rightarrow 5_{1,5}$	0.23 ± 0.01	18 ± 1	131394.24	± 0.01 hh	61.4 ± 0.6	
131405.53 ± 0.52	CH_3OCH_3	$6_{1,6} \rightarrow 5_{0,5}$	0.14 ± 0.01	19 ± 3	131405.84	± 0.02 n		On shoulder of HNCO
131501.50 ± 0.74	CH_3CH_2OH	$6_{3,4} \rightarrow 6_{2,5}$	0.05 ± 0.02	8 ± 4	131502.66	± 0.10 b	65 ± 2	
131552.3 ± 1.4	U		0.09 ± 0.03	14 ± 8				
131617.94 ± 0.65	NH_2CHO	$6_{1,5} \rightarrow 5_{1,4}$	0.23 ± 0.03	18 ± 3	131618.03	± 0.08 c	62 ± 1	
131799.9 ± 1.2	HNCO?	$6_3 \rightarrow 5_3$	0.05 ± 0.01	13 ± 10	131799.29	± 0.01 hh	61 ± 3	+ CH_2CHNC?
131845.40 ± 0.96	HNCO	$6_{2,5} \rightarrow 5_{2,4}$ $6_{2,4} \rightarrow 5_{2,3}$	0.06 ± 0.02	14 ± 6	131845.88 131846.59	± 0.01 hh ± 0.01	64 ± 2	
131885.78 ± 0.06	HNCO	$6_{0,6} \rightarrow 5_{0,5}$	3.41 ± 0.03	23.0 ± 0.2	131885.74	± 0.01 hh	61.9 ± 0.1	
132086.2 ± 1.1	$H_2{}^{13}CS$?	$4_{0,4} \rightarrow 3_{0,3}$	0.08 ± 0.04	7 ± 5	132089.8	± 1.0 jj	70 ± 3	Low S/N. Identification tentative

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TABLE 2—*Continued*

Astronomical Frequency (MHz)	Molecule or Atom	Transition	T_A^* (K)	Δv(FWHM) (km s^{-1})	Rest Frequency (MHz)	v_{LSR} (km s^{-1})	Comments
132106.19 ± 0.85	$HCOOCH_3$	$12_{1,12} \rightarrow 11_{1,11}$ E	0.10 ± 0.04	8 ± 5	132105.6 ± 1.1 i		
		$12_{1,12} \rightarrow 11_{1,11}$ A			132107.03 ± 0.19		
	$^{34}SO_2$?	$12_{1,11} \rightarrow 12_{0,12}$			132114.04 ± 0.10 e		
132247.44 ± 0.74	$HCOOCH_3$	$12_{0,12} \rightarrow 11_{0,11}$ E	0.18 ± 0.03	18 ± 3	132245.2 ± 1.1 i		
	$H^{13}CCCN$	$15 \rightarrow 14$			132246.39 ± 0.01 f		
	$HCOOCH_3$	$12_{0,12} \rightarrow 11_{0,11}$ A			132246.56 ± 0.19 i		
132357.47 ± 0.80	HNCO	$6_{1,5} \rightarrow 5_{1,4}$	0.19 ± 0.02	22 ± 3	132356.71 ± 0.01 hh	60 ± 2	
132524.22 ± 0.77	CH_2CHCN	$14_{2,13} \rightarrow 13_{2,12}$	0.15 ± 0.02	22 ± 4	132524.59 ± 0.02 k		
	CH_3OCH_3	$8_{0,8} \rightarrow 7_{1,7}$			132525.39 ± 0.03 n		
132621.56 ± 0.88	CH_3OH	$6_2 \rightarrow 7_1$ A-	0.12 ± 0.02	16 ± 5	132621.9 ± 0.1 v	63 ± 2	
132745.28 ± 0.60	SO_2	$14_{2,12} \rightarrow 14_{1,13}$	0.20 ± 0.02	22 ± 3	132744.86 ± 0.08 e	61 ± 1	
132891.03 ± 0.06	CH_3OH	$6_{-1} \rightarrow 5_0$ E	2.07 ± 0.02	21.6 ± 0.3	132890.8 ± 0.1 v	61.5 ± 0.3	
132931.9 ± 1.2	CH_2CHCN	$14_{4,11} \rightarrow 13_{4,10}$	0.11 ± 0.01	39 ± 8	132917.76 ± 0.01 k		
		$14_{4,10} \rightarrow 13_{4,9}$			132919.02 ± 0.01		
	$HCOOCH_3$	$11_{1,10} \rightarrow 10_{1,9}$ E			132921.92 ± 0.80 i		
		$11_{1,10} \rightarrow 10_{1,9}$ A			132928.60 ± 0.14		
	CH_3CH_2OH	$3_{2,1} \rightarrow 2_{1,2}$			132935.14 ± 0.11 a		
132950 → 133510	No data						
133606.25 ± 0.74	CH_3OH	$5_{-2} \rightarrow 6_{-1}$ E	0.19 ± 0.07	7 ± 5	133605.5 ± 0.1 v	60 ± 2	
133786.15 ± 0.27	OCS	$11 \rightarrow 10$	0.85 ± 0.04	19 ± 1	133785.90 ± 0.01 g	61 ± 1	
133829.7 ± 1.3	CH_3CHO	$7_{0,7} \rightarrow 6_{0,6}$ E	0.16 ± 0.05	14 ± 8	133829.5 ± 1.1 j	62 ± 4	
133855.1 ± 1.6	CH_3CHO	$7_{0,7} \rightarrow 6_{0,6}$ A	0.15 ± 0.04	20 ± 9	133854.9 ± 1.1 j	62 ± 4	
134005.94 ± 0.52	SO_2	$8_{2,6} \rightarrow 8_{1,7}$	0.38 ± 0.05	12 ± 3	134004.86 ± 0.08 e	60 ± 1	
134030 → 135950	No data						
136250.7 ± 1.1	U		0.04 ± 0.03	7 ± 5			
136281.81 ± 0.29	$HCOOCH_3$	$11_{4,8} \rightarrow 10_{4,7}$ E	0.12 ± 0.01	10 ± 1	136280.00 ± 0.80 i	61 ± 2	
		$11_{4,8} \rightarrow 10_{4,7}$ A			136282.46 ± 0.13		
136387.8 ± 1.5	U		0.05 ± 0.02	16 ± 7			
136465.65 ± 0.09	HC_3N	$15 \rightarrow 14$	2.00 ± 0.03	19.5 ± 0.4	136464.400 ± 0.002 f	59.3 ± 0.2	
136543.31 ± 0.36	CH_3CH_2CN	$15_{1,14} \rightarrow 14_{1,13}$	0.10 ± 0.01	12 ± 2	136541.29 ± 0.01 xx	57.6 ± 0.8	
136635.3 ± 1.2	SO	J,K: 5,6 → 5,5	0.16 ± 0.03	23 ± 8	136634.90 ± 0.21 u	61 ± 3	Too strong?
136715.56 ± 0.58	CH_3OH?	unassigned	0.25 ± 0.04	11 ± 3	136703.40 kk		
	CH_3CCH	$8_3 \rightarrow 7_3$			136704.501 ± 0.001 y		
	CH_3OH?	unassigned			136704.76 kk		
	CH_3CCH	$8_2 \rightarrow 7_2$			136717.560 ± 0.001 y		

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TABLE 2—*Continued*

Astronomical Frequency (MHz)	Molecule or Atom	Transition	T_A^* (K)	Δv(FWHM) (km s^{-1})	Rest Frequency (MHz)		v_{LSR} (km s^{-1})	Comments
136726.65 ± 0.27	CH_3CCH	$8_1 \rightarrow 7_1$ $8_0 \rightarrow 7_0$	0.72 ± 0.02	28 ± 1	136725.397 ± 0.001 136728.010 ± 0.001	y		
136798.5 ± 2.2	HC_3N, v_7, le	15 → 14	0.09 ± 0.03	26 ± 11	136799.70 ± 0.03	f	65 ± 5	
137371.97 ± 0.28	H_2CS	$4_{0,4} \rightarrow 3_{0,3}$	0.47 ± 0.02	22 ± 1	137371.04 ± 0.08	c	60.0 ± 0.6	
137382.84 ± 0.86	H_2CS	$4_{2,3} \rightarrow 3_{2,2}$	0.13 ± 0.03	13 ± 5	137381.96 ± 0.06	c	60 ± 2	On shoulder of 137372 MHz
137412.1 ± 1.4	H_2CS	$4_{2,2} \rightarrow 3_{2,1}$	0.09 ± 0.02	19 ± 8	137411.80 ± 0.06	c	61 ± 3	
137453.12 ± 0.59	$H_2{}^{13}CO$?	$2_{1,2} \rightarrow 1_{1,1}$	0.19 ± 0.03	11 ± 4	137449.97 ± 0.02	c	55 ± 1	Identification tentative
137455 → 137950	No data							
138180.44 ± 0.12	SO	J,K: 4,3 → 3,2	1.66 ± 0.03	24 ± 1	138178.55 ± 0.10	u	57.9 ± 0.3	
138285.62 ± 0.93	CH_3CHO	$7_{1,6} \rightarrow 6_{1,5}$ E	0.15 ± 0.03	15 ± 4	138284.2 ± 1.1	j	59 ± 3	
138319.8 ± 1.3	CH_3CHO	$7_{1,6} \rightarrow 6_{1,5}$ A	0.14 ± 0.03	21 ± 7	138319.7 ± 1.1	j	62 ± 4	
138351.22 ± 0.60	CH_3CH_2CN?	$16_{1,16} \rightarrow 15_{1,15}$	0.15 ± 0.08	5 ± 3	138351.06 ± 0.01	xx	62 ± 1	Low S/N
138450 → 139450	No data							
139484.84 ± 0.24	H_2CS	$4_{1,3} \rightarrow 3_{1,2}$	0.44 ± 0.02	23 ± 1	139483.47 ± 0.07	c	59.0 ± 0.5	
139954.12 ± 0.65	NH_2CN	$7_{0,7} \rightarrow 6_{0,6}$	0.08 ± 0.01	15 ± 3	139953.60 ± 0.94	tt	61 ± 2	
140033.7 ± 1.3	CH_3OH?	unassigned	0.03 ± 0.02	8 ± 5	140033.50	kk	62	
140127.31 ± 0.57	H_2CCO	$7_{1,7} \rightarrow 6_{1,6}$	0.15 ± 0.02	19 ± 3	140127.41 ± 0.03	p	62 ± 1	
140148.59 ± 0.90	CH_3OH	$18_0 \rightarrow 18_{-1}$ E	0.05 ± 0.01	12 ± 4	140151.08	kk	67	
140307.12 ± 0.37	SO_2	$6_{2,4} \rightarrow 6_{1,5}$	0.23 ± 0.01	21 ± 2	140306.17 ± 0.08	e	60.0 ± 0.8	
140428.59 ± 0.75	$^{13}CH_3OH$? CH_2CHCN	$3_1 \rightarrow 2_1$ A+ $15_{0,15} \rightarrow 14_{0,14}$	0.05 ± 0.02	8 ± 3	140423.83 ± 0.04 140429.44 ± 0.02	uu k		
140450 → 140600	No data							
140687.3 ± 1.6	U		0.07 ± 0.01	27 ± 9				
140849 ± 1	H_2CO	$2_{1,2} \rightarrow 1_{1,1}$	0.61 ± 0.03	29 ± 4	140839.53 ± 0.03	c	42 ± 2	Frequency anomalously high
140876.0 ± 1.8	NH_2CN	$7_{1,6} \rightarrow 6_{1,5}$	0.05 ± 0.02	21 ± 10	140877.40 ± 0.99	tt	65 ± 4	
140902.2 ± 1.4	U		0.07 ± 0.02	20 ± 6				
141060.44 ± 0.55	$H^{13}CCCN$	16 → 15	0.07 ± 0.04	3 ± 5	141061.80 ± 0.02	f	65 ± 1	
141100 → 141450	No data							

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TABLE 2—*Continued*

Astronomical Frequency (MHz)	Molecule or Atom	Transition	T_A^* (K)	Δv(FWHM) (km s^{-1})	Rest Frequency (MHz)		v_{LSR} (km s^{-1})	Comments
141599.94 ± 0.39	$^{13}CH_3OH$	$3_0 \rightarrow 2_0$ E	0.44 ± 0.02	29 ± 2	141595.48	± 0.05 uu		
		$3_{-1} \rightarrow 2_{-1}$ E			141597.06	± 0.05		
		$3_0 \rightarrow 2_0$ A+			141602.53	± 0.04		
141985.28 ± 0.82	$H_2{}^{13}CO$?	$2_{0,2} \rightarrow 1_{0,1}$	0.10 ± 0.02	18 ± 3	141983.76	± 0.02 c	59 ± 2	Identification tentative
142285.15 ± 0.66	CH_3CH_2OH	$9_{0,9} \rightarrow 8_{1,8}$	0.14 ± 0.01	23 ± 3	142284.92	± 0.44 a	62 ± 2	
142346.3 ± 1.5	CH_3CH_2CN	$16_{2,15} \rightarrow 15_{2,14}$	0.07 ± 0.01	22 ± 10	142346.31	± 0.01 xx	62 ± 3	
142380.8 ± 1.0	$OC^{34}S$	$12 \rightarrow 11$	0.08 ± 0.02	15 ± 5	142379.34	± 0.20 g	59 ± 2	
142398.6 ± 1.1	CH_2CHCN	$15_{5,11} \rightarrow 14_{5,10}$	0.07 ± 0.02	16 ± 4	142399.49	± 0.01 k		
		$15_{5,10} \rightarrow 14_{5,9}$			142399.51	± 0.01		
		$15_6 \rightarrow 14_6$			142401.87	± 0.02		
142422.9 ± 1.2	CH_2CHCN	$15_7 \rightarrow 14_7$	0.06 ± 0.02	11 ± 5	142419.70	± 0.02 k		
		$15_{4,12} \rightarrow 14_{4,11}$			142424.45	± 0.01		
		$15_{4,11} \rightarrow 14_{4,10}$			142426.51	± 0.01		
142447.19 ± 0.56	CH_2CHCN?	$15_8 \rightarrow 14_8$	0.07 ± 0.03	4 ± 3	142447.94	± 0.02 k	64 ± 1	Too strong?
142701.62 ± 0.51	NH_2CHO	$7_{1,7} \rightarrow 6_{1,6}$	0.11 ± 0.01	18 ± 3	142701.50	± 0.13 c	62 ± 1	
142737.65 ± 0.87	$HCOOCH_3$	$13_{1,13} \rightarrow 12_{1,12}$ E	0.05 ± 0.02	8 ± 5	142733.68	vv	55	
		$13_{1,13} \rightarrow 12_{1,12}$ A			142734.90			
142770.06 ± 0.70	H_2CCO	$7_{1,6} \rightarrow 6_{1,5}$	0.11 ± 0.01	20 ± 3	142768.88	± 0.03 p	60 ± 1	
142814.5 ± 2.9	$^{13}CH_3OH$?	$3_1 \rightarrow 2_1$ A−	0.04 ± 0.01	34 ± 18	142807.66	± 0.04 uu		
	$HCOOCH_3$	$13_{0,13} \rightarrow 12_{0,12}$ E			142815.63	vv		
		$13_{0,13} \rightarrow 12_{0,12}$ A			142816.78			
143603.4 ± 1.1	CH_3OCH_3	$7_{3,4} \rightarrow 7_{2,5}$	0.08 ± 0.03	10 ± 4	143603.06	± 0.07 n		
143768.4 ± 1.5	HC_5N	$54 \rightarrow 53$	0.07 ± 0.03	13 ± 6	143766.0	± 0.7 s	57 ± 3	
143866.94 ± 0.11	CH_3OH	$3_1 \rightarrow 2_1$ A+	1.27 ± 0.02	20.5 ± 0.4	143865.8	± 0.1 v	59.6 ± 0.3	

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NOTES TO TABLE 2

[a] Calculated from parameters provided by F. J. Lovas 1976, private communication.
[b] From F. J. Lovas 1980, private communication.
[c] Calculated by Johnson, Lovas, and Kirchhoff 1972.
[d] Calculated by Tiemann 1976.
[e] From Lovas 1978.
[f] Calculated by Lafferty and Lovas 1978.
[g] Calculated from parameters from Lovas 1978.
[h] Calculated by Boucher *et al.* 1980.
[i] Calculated by Bauder 1979.
[j] Calculated by Bauder, Lovas, and Johnson 1976.
[k] Calculated by Gerry, Yamada, and Winnewisser 1979.
[l] Observed by Lees and Mohammadi 1980.
[m] Observed by Sastry, Lees, and De Lucia 1984.
[n] Calculated by Lovas, Lutz, and Dreizler 1979.
[o] Observed by Johnson, Suenram, and Lafferty 1976.
[p] Calculated by Johns, Stone, and Winnewisser 1972.
[q] Observed by Saito and Takagi 1973.
[r] Calculated from parameters from Kewley, Sastry, and Winnewisser 1963.
[s] Calculated from parameters from Winnewisser, Creswell, and Winnewisser 1978.
[t] Observed by Takagi and Kojima 1973.
[u] Calculated by Tiemann 1974.
[v] Observed by Lees, *et al.* 1973.
[w] Calculated by Lovas and Krupenie 1974.
[x] Observed by Gudeman *et al.* 1981.
[y] Calculated by Bauer *et al.* 1979.
[z] Calculated by Gottlieb *et al.* 1983.
[aa] From De Lucia and Helminger 1975.
[bb] Observed by Pearson *et al.* 1976.
[cc] Calculated by Willemot *et al.* 1980.
[dd] Observed by Saito 1972.
[ee] Calculated by Guélin, Cernicharo, and Linke 1982.
[ff] Observed by Creswell *et al.* 1976.
[gg] Calculated by Gottlieb, Gottlieb, and Thaddeus 1983.
[hh] Calculated by Winnewisser, Hocking, and Gerry 1976.
[ii] Observed by De Lucia and Gordy 1969.
[jj] From Poynter and Pickett 1980.
[kk] Observed by Lees and Baker 1968.
[ll] Calculated by Kirchhoff, Johnson, and Lovas 1973.
[mm] Observed by Helminger, De Lucia, and Kirchhoff 1973.
[nn] From Turner and Gammon 1975.
[oo] Measured by Lovas and Suenram 1982.
[pp] Observed by Pearson and Lovas 1977.
[qq] Calculated from data provided by R. M. Lees 1979, private communication.
[rr] Calculated from parameters from Thaddeus, Guélin, and Linke 1981.
[ss] Calculated by Dangoisse, Willemot, and Bellet 1978.
[tt] Calculated from parameters from Johnson, Suenram, and Lafferty 1976.
[uu] Observed by Haque *et al.* 1974.
[vv] Calculated by Bauder 1981.
[ww] Observed by Thaddeus *et al.* 1985 in IRC +10216.
[xx] Calculated from parameters from Burie *et al.* 1978.
[yy] Calculated by F. J. Lovas 1984, private communication.
[zz] From Gerin *et al.* 1984.
[aaa] Calculated by Bogey, Demuynck, and Destombes 1984.
[bbb] Calculated by Thaddeus, Vrtilek, and Gottlieb 1985.

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TABLE 3

TRANSITIONS USED FOR FITTING T_{rot} AND N

Rest Frequency (MHz)	Transition	T_R (K)	E_u/k (K)	S
NH_2CN				
79449.73 ± 0.05	$4_{1,4} \rightarrow 3_{1,3}$	0.26 ± 0.02	24	3.75
79979.60 ± 0.05	$4_{0,4} \rightarrow 3_{0,3}$	0.15 ± 0.06	10	4.00
80504.60 ± 0.05	$4_{1,3} \rightarrow 3_{1,2}$	0.27 ± 0.04	24	3.75
99953.27 ± 0.06 99956.60 ± 0.04	$5_{2,4} \rightarrow 4_{2,3}$ $5_{2,3} \rightarrow 4_{2,2}$	0.10 ± 0.03	72	4.20
99972.66 ± 0.08	$5_{0,5} \rightarrow 4_{0,4}$	0.14 ± 0.02	14	5.00
100629.50 ± 0.06	$5_{1,4} \rightarrow 4_{1,3}$	0.46 ± 0.04	29	4.80
139953.60 ± 0.94	$7_{0,7} \rightarrow 6_{0,6}$	0.12 ± 0.02	27	7.00
140877.40 ± 0.99	$7_{1,6} \rightarrow 6_{1,5}$	0.08 ± 0.02	41	6.86
CH_2CHCN				
75585.70 ± 0.02	$8_{0,8} \rightarrow 7_{0,7}$	0.11 ± 0.04	16	8.00
84946.00 ± 0.02	$9_{0,9} \rightarrow 8_{0,8}$	0.09 ± 0.01	20	9.00
85302.65 ± 0.02	$9_{2,8} \rightarrow 8_{2,7}$	0.13 ± 0.02	29	8.56
85715.43 ± 0.02	$9_{2,7} \rightarrow 8_{2,6}$	0.06 ± 0.01	29	8.56
103575.40 ± 0.02	$11_{0,11} \rightarrow 10_{0,10}$	0.08 ± 0.01	30	10.99
104212.65 ± 0.02	$11_{2,10} \rightarrow 10_{2,9}$	0.07 ± 0.02	39	10.64
104453.93 ± 0.02	$11_{3,8} \rightarrow 10_{3,7}$	0.07 ± 0.03	50	10.18
106641.39 ± 0.02	$11_{1,10} \rightarrow 10_{1,9}$	0.06 ± 0.01	33	10.91
110839.98 ± 0.02	$12_{1,12} \rightarrow 11_{1,11}$	0.08 ± 0.03	37	11.91
112840.65 ± 0.02	$12_{0,12} \rightarrow 11_{0,11}$	0.10 ± 0.03	35	11.99
125921.67 ± 0.02	$13_{1,12} \rightarrow 12_{1,11}$	0.14 ± 0.04	45	12.92
129219.22 ± 0.02	$14_{1,14} \rightarrow 13_{1,13}$	0.07 ± 0.03	49	13.93
CH_3CH_2CN				
72108.62 ± 0.02	$8_{2,6} \rightarrow 7_{2,5}$	0.07 ± 0.02	20	7.50
86819.86 ± 0.02	$10_{1,10} \rightarrow 9_{1,9}$	0.07 ± 0.01	24	9.90
98177.58 ± 0.01	$11_{2,10} \rightarrow 10_{2,9}$	0.06 ± 0.01	33	10.63
98564.83 ± 0.01 98566.80 ± 0.01	$11_{4,8} \rightarrow 10_{4,7}$ $11_{4,7} \rightarrow 10_{4,6}$	0.05 ± 0.02	46	9.55
98701.11 ± 0.01	$11_{3,8} \rightarrow 10_{3,7}$	0.05 ± 0.02	38	10.18
99681.51 ± 0.01	$11_{2,9} \rightarrow 10_{2,8}$	0.06 ± 0.01	33	10.64
100614.31 ± 0.02	$11_{1,10} \rightarrow 10_{1,9}$	0.17 ± 0.03	30	10.90
107043.52 ± 0.01	$12_{2,11} \rightarrow 11_{2,10}$	0.06 ± 0.02	38	11.66
107502.44 ± 0.02 107502.49 ± 0.02	$12_{5,8} \rightarrow 11_{5,7}$ $12_{5,7} \rightarrow 11_{5,6}$	0.06 ± 0.01	61	9.92
107594.06 ± 0.02	$12_{3,10} \rightarrow 11_{3,9}$	0.08 ± 0.03	44	11.25
107734.75 ± 0.02	$12_{3,9} \rightarrow 11_{3,8}$	0.05 ± 0.01	44	11.25
109650.32 ± 0.02	$12_{1,11} \rightarrow 11_{1,10}$	0.14 ± 0.04	35	11.91
112646.24 ± 0.02	$13_{1,13} \rightarrow 12_{1,12}$	0.13 ± 0.04	39	12.92
124729.08 ± 0.02	$14_{2,13} \rightarrow 13_{2,12}$	0.13 ± 0.07	49	13.71
125564.50 ± 0.02	$14_{3,12} \rightarrow 13_{3,11}$	0.10 ± 0.03	55	13.36
136541.29 ± 0.01	$15_{1,14} \rightarrow 14_{1,13}$	0.14 ± 0.01	54	14.91
142346.31 ± 0.01	$16_{2,15} \rightarrow 15_{2,14}$	0.11 ± 0.02	63	15.74
HC_5N				
85201.83 ± 0.33	32 → 31	0.06 ± 0.02	68	32.00
87864.17 ± 0.35	33 → 32	0.11 ± 0.02	72	33.00
90526.49 ± 0.38	34 → 33	0.10 ± 0.03	76	34.00
98513.31 ± 0.48	37 → 36	0.07 ± 0.02	90	37.00
103837.74 ± 0.55	39 → 38	0.06 ± 0.03	100	39.00
106499.92 ± 0.59	40 → 39	0.05 ± 0.02	105	40.00
143767.6 ± 1.4	54 → 53	0.11 ± 0.04	190	54.00
NH_2CHO				
81693.50 ± 0.04	$4_{1,4} \rightarrow 3_{1,3}$	0.19 ± 0.02	13	3.75
84542.37 ± 0.04	$4_{0,4} \rightarrow 3_{0,3}$	0.22 ± 0.04	10	4.00

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TABLE 3—*Continued*

Rest Frequency (MHz)	Transition	T_R (K)	E_u/k (K)	S
84807.88 ± 0.05	$4_{2,3} \rightarrow 3_{2,2}$	0.19 ± 0.02	22	3.00
84889.14 ± 0.08	$4_{3,2} \rightarrow 3_{3,1}$	0.11 ± 0.01	37	1.75
84891.13 ± 0.08	$4_{3,1} \rightarrow 3_{3,0}$			
85093.36 ± 0.05	$4_{2,2} \rightarrow 3_{2,1}$	0.13 ± 0.02	22	3.00
87848.93 ± 0.04	$4_{1,3} \rightarrow 3_{1,2}$	0.33 ± 0.02	14	3.75
102064.35 ± 0.06	$5_{1,5} \rightarrow 4_{1,4}$	0.32 ± 0.01	18	4.80
105972.73 ± 0.08	$5_{2,4} \rightarrow 4_{2,3}$	0.17 ± 0.02	27	4.20
106134.62 ± 0.12	$5_{3,3} \rightarrow 4_{3,2}$	0.12 ± 0.02	42	3.20
106141.59 ± 0.12	$5_{3,2} \rightarrow 4_{3,1}$			
106541.81 ± 0.08	$5_{2,3} \rightarrow 4_{2,2}$	0.19 ± 0.01	27	4.20
109753.59 ± 0.06	$5_{1,4} \rightarrow 4_{1,3}$	0.50 ± 0.02	18	4.80
127393.78 ± 0.18	$6_{3,4} \rightarrow 5_{3,3}$	0.14 ± 0.02	48	4.50
127412.36 ± 0.18	$6_{3,3} \rightarrow 5_{3,2}$	0.13 ± 0.02	48	4.50
128102.97 ± 0.12	$6_{2,4} \rightarrow 5_{2,3}$	0.22 ± 0.03	33	5.33
131618.03 ± 0.08	$6_{1,5} \rightarrow 5_{1,4}$	0.32 ± 0.04	25	5.83
142701.50 ± 0.13	$7_{1,7} \rightarrow 6_{1,6}$	0.16 ± 0.01	30	6.85
CH_3CN				
73577.453± 0.001	$4_3 \rightarrow 3_3$	0.15 ± 0.05	73	1.75
73584.545± 0.001	$4_2 \rightarrow 3_2$	0.45 ± 0.05	38	3.00
73588.801± 0.001	$4_1 \rightarrow 3_1$	0.42 ± 0.03	16	3.75
73590.220± 0.001	$4_0 \rightarrow 3_0$	0.48 ± 0.03	9	4.00
110349.473± 0.002	$6_4 \rightarrow 5_4$	0.30 ± 0.02	133	3.33
110364.357± 0.001	$6_3 \rightarrow 5_3$	0.90 ± 0.02	83	4.50
110374.992± 0.001	$6_2 \rightarrow 5_2$	0.94 ± 0.02	47	5.33
110381.376± 0.001	$6_1 \rightarrow 5_1$	0.86 ± 0.01	26	5.83
110383.504± 0.001	$6_0 \rightarrow 5_0$	0.96 ± 0.01	19	6.00
128739.672± 0.002	$7_4 \rightarrow 6_4$	0.25 ± 0.01	139	4.71
128757.034± 0.002	$7_3 \rightarrow 6_3$	0.69 ± 0.01	89	5.71
128769.44 ± 0.06	$7_2 \rightarrow 6_2$	0.68 ± 0.01	53	6.43
128776.89 ± 0.04	$7_1 \rightarrow 6_1$	0.749± 0.004	32	6.86
128779.37 ± 0.04	$7_0 \rightarrow 6_0$	0.834± 0.004	25	7.00
CH_3SH				
75862.87 ± 0.07	$3_0 \rightarrow 2_0$ A+	0.20 ± 0.03	8	3.00
75864.43 ± 0.07	$3_0 \rightarrow 2_0$ E			
100110.2 ± 0.1	$4_1 \rightarrow 3_1$ A+	0.07 ± 0.02	17	3.75
101139.4 ± 0.1	$4_0 \rightarrow 3_0$ A+	0.27 ± 0.02	13	4.00
101139.6 ± 0.1	$4_0 \rightarrow 3_0$ E			
101159.5 ± 0.1	$4_2 \rightarrow 3_2$ A−	0.04 ± 0.01	31	3.00
101284.3 ± 0.1	$4_1 \rightarrow 3_1$ E	0.11 ± 0.02	18	3.75
102202.4 ± 0.1	$4_1 \rightarrow 3_1$ A−	0.08 ± 0.04	17	3.75
107316.5 ± 0.1	$3_{-1} \rightarrow 3_0$ A	0.05 ± 0.02	12	3.40[a]
H_2CCO				
80076.61 ± 0.03	$4_{1,4} \rightarrow 3_{1,3}$	0.16 ± 0.05	23	3.75
81586.19 ± 0.03	$4_{1,3} \rightarrow 3_{1,2}$	0.14 ± 0.02	23	3.75
100094.47 ± 0.03	$5_{1,5} \rightarrow 4_{1,4}$	0.20 ± 0.02	27	4.80
101981.39 ± 0.03	$5_{1,4} \rightarrow 4_{1,3}$	0.14 ± 0.01	28	4.80
140127.41 ± 0.03	$7_{1,7} \rightarrow 6_{1,6}$	0.22 ± 0.02	40	6.86
142768.88 ± 0.03	$7_{1,6} \rightarrow 6_{1,5}$	0.17 ± 0.02	40	6.86
CH_3CHO				
79098.65 ± 0.96	$4_{1,3} \rightarrow 3_{1,2}$ E	0.16 ± 0.02	12	3.74
79150.26 ± 0.94	$4_{1,3} \rightarrow 3_{1,2}$ A	0.25 ± 0.03	12	3.75
84221.9 ± 1.4	$2_{1,2} \rightarrow 1_{0,1}$ A	0.05 ± 0.02	5	1.50
93581.35 ± 0.95	$5_{1,5} \rightarrow 4_{1,4}$ A	0.19 ± 0.01	16	4.80
93594.55 ± 0.95	$5_{1,5} \rightarrow 4_{1,4}$ E	0.19 ± 0.01	16	4.80

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TABLE 3—*Continued*

Rest Frequency (MHz)	Transition		T_R (K)	E_u/k (K)	S
98862.65 ± 0.98	$5_{1,4} \rightarrow 4_{1,3}$	E	0.27 ± 0.02	17	4.80
98901.05 ± 0.97	$5_{1,4} \rightarrow 4_{1,3}$	A	0.21 ± 0.01	17	4.80
101341.0 ± 1.5	$3_{1,3} \rightarrow 2_{0,2}$	E	0.09 ± 0.02	8	1.98
112249.20 ± 0.95	$6_{1,6} \rightarrow 5_{1,5}$	A	0.25 ± 0.07	21	2.26
112253.58 ± 0.95	$6_{1,6} \rightarrow 5_{1,5}$	E			
114939.4 ± 1.0	$6_{0,6} \rightarrow 5_{0,5}$	E	0.19 ± 0.05	19	5.99
133854.9 ± 1.1	$7_{0,7} \rightarrow 6_{0,6}$	A	0.21 ± 0.06	26	6.99
138284.2 ± 1.1	$7_{1,6} \rightarrow 6_{1,5}$	E	0.22 ± 0.05	29	6.85
138319.7 ± 1.1	$7_{1,6} \rightarrow 6_{1,5}$	A	0.20 ± 0.04	29	6.85
$HCOOCH_3$					
84449.19 ± 0.16	$7_{2,6} \rightarrow 6_{2,5}$	E	0.06 ± 0.01	19	6.40
84454.76 ± 0.03	$7_{2,6} \rightarrow 6_{2,5}$	A			
86265.80 ± 0.03	$7_{3,5} \rightarrow 6_{3,4}$	A	0.10 ± 0.02	23	5.69
86268.73 ± 0.17	$7_{3,5} \rightarrow 6_{3,4}$	E			
87143.40 ± 0.17	$7_{3,4} \rightarrow 6_{3,3}$	E	0.05 ± 0.02	23	5.67
98279.65 ± 0.31	$8_{6,3} \rightarrow 7_{6,2}$	E	0.04 ± 0.02	45	3.50
98279.70 ± 0.05	$8_{6,3} \rightarrow 7_{6,2}$	A			
98279.74 ± 0.05	$8_{6,2} \rightarrow 7_{6,1}$	A			
98432.36 ± 0.29	$8_{5,4} \rightarrow 7_{5,3}$	E	0.05 ± 0.01	38	4.88
98432.73 ± 0.05	$8_{5,4} \rightarrow 7_{5,3}$	A			
98435.78 ± 0.05	$8_{5,3} \rightarrow 7_{5,2}$	A			
98712.28 ± 0.28	$8_{4,5} \rightarrow 7_{4,4}$	E	0.04 ± 0.02	32	5.80
100482.27 ± 0.27	$8_{1,7} \rightarrow 7_{1,6}$	E	0.07 ± 0.02	23	7.76
100490.66 ± 0.05	$8_{1,7} \rightarrow 7_{1,6}$	A	0.12 ± 0.04	23	7.76
100681.58 ± 0.40	$9_{0,9} \rightarrow 8_{0,8}$	E	0.11 ± 0.02	25	8.85
100683.33 ± 0.07	$9_{0,9} \rightarrow 8_{0,8}$	A			
103466.60 ± 0.26	$8_{2,6} \rightarrow 7_{2,5}$	E	0.09 ± 0.02	25	7.52
103478.64 ± 0.04	$8_{2,6} \rightarrow 7_{2,5}$	A	0.05 ± 0.02	25	7.52
110535.11 ± 0.08	$9_7 \rightarrow 8_7$	A	0.04 ± 0.02	59	3.56
110536.99 ± 0.48	$9_{7,3} \rightarrow 8_{7,2}$	E			
110788.72 ± 0.58	$10_{1,10} \rightarrow 9_{1,9}$	E	0.13 ± 0.01	30	9.84
110790.46 ± 0.10	$10_{1,10} \rightarrow 9_{1,9}$	A			
129310.08 ± 0.10	$10_{2,8} \rightarrow 9_{2,7}$	A	0.07 ± 0.03	36	9.60
130010.11 ± 0.79	$11_{2,10} \rightarrow 10_{2,9}$	E	0.05 ± 0.02	41	10.55
130016.66 ± 0.13	$11_{2,10} \rightarrow 10_{2,9}$	A			
136280.00 ± 0.80	$11_{4,8} \rightarrow 10_{4,7}$	E	0.18 ± 0.02	50	9.55
136282.46 ± 0.13	$11_{4,8} \rightarrow 10_{4,7}$	A			
142733.68	$13_{1,13} \rightarrow 12_{1,12}$	E	0.08 ± 0.03	49	12.84
142734.90	$13_{1,13} \rightarrow 12_{1,12}$	A			
HC_3N					
72783.824± 0.002	8 → 7		2.71 ± 0.08	16	8.00
81881.468± 0.002	9 → 8		2.80 ± 0.03	20	9.00
90978.993± 0.002	10 → 9		3.04 ± 0.04	24	10.00
100076.388± 0.002	11 → 10		3.84 ± 0.02	29	11.00
109173.639± 0.002	12 → 11		3.61 ± 0.03	34	12.00
127367.658± 0.002	14 → 13		3.30 ± 0.02	46	14.00
136464.400± 0.002	15 → 14		2.88 ± 0.04	52	15.00
SO					
86093.94 ± 0.03	J,K: 2,2 → 1,1		0.53 ± 0.06	19	1.50
99299.88 ± 0.06	3,2 → 2,1		1.60 ± 0.01	9	2.93
100029.63 ± 0.10	4,5 → 4,4		0.15 ± 0.02	39	0.36
109252.13 ± 0.04	2,3 → 1,2		0.91 ± 0.03	21	1.51
129138.86 ± 0.05	3,3 → 2,2		1.52 ± 0.03	26	2.67
136634.90 ± 0.21	5,6 → 5,5		0.23 ± 0.04	51	0.27
138178.55 ± 0.10	4,3 → 3,2		2.42 ± 0.04	16	3.94
CH_3CH_2OH					
71971.7 ± 1.0	$10_{1,9} \rightarrow 10_{0,10}$		0.05 ± 0.01	49	5.36
85265.47 ± 0.07	$6_{0,6} \rightarrow 5_{1,5}$		0.19 ± 0.02	17	3.28

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TABLE 3—*Continued*

Rest Frequency (MHz)	Transition	T_R (K)	E_u/k (K)	S
87715.98 ± 0.07	$5_{2,4} \rightarrow 5_{1,5}$	0.06 ± 0.02	18	2.40
90117.61 ± 0.10	$4_{1,4} \rightarrow 3_{0,3}$	0.17 ± 0.05	9	2.59
100989.95 ± 0.10	$8_{2,7} \rightarrow 8_{1,8}$	0.03 ± 0.01	35	3.45
104487.22 ± 0.07	$7_{0,7} \rightarrow 6_{1,6}$	0.24 ± 0.04	23	4.16
104808.63 ± 0.09	$5_{1,5} \rightarrow 4_{0,4}$	0.23 ± 0.02	13	3.20
106723.41 ± 0.12	$9_{2,8} \rightarrow 9_{1,9}$	0.07 ± 0.02	43	3.71
112807.10 ± 0.11	$2_{2,1} \rightarrow 1_{1,0}$	0.21 ± 0.03	8	1.50
125173.15 ± 0.39	$8_{3,5} \rightarrow 8_{2,6}$	0.10 ± 0.05	42	4.31
125947.25 ± 0.10	$10_{1,9} \rightarrow 9_{2,8}$	0.18 ± 0.05	49	2.82
127215.1 ± 1.3	$7_{3,4} \rightarrow 7_{2,5}$	0.07 ± 0.02	35	3.62
129077.58 ± 0.12	$3_{2,2} \rightarrow 2_{1,1}$	0.18 ± 0.03	10	1.67
131103.07 ± 0.24	$5_{3,3} \rightarrow 5_{2,4}$	0.06 ± 0.02	24	2.29
131502.66 ± 0.10	$6_{3,4} \rightarrow 6_{2,5}$	0.07 ± 0.03	29	2.92
142284.92 ± 0.44	$9_{0,9} \rightarrow 8_{1,8}$	0.21 ± 0.02	37	6.10
CH_3OCH_3				
76364.26 ± 0.06	$7_{2,5} \rightarrow 7_{1,6}$	0.11 ± 0.05	31	5.05
84634.39 ± 0.04	$3_{2,1} \rightarrow 3_{1,2}$	0.03 ± 0.01	11	1.61
90938.24 ± 0.03	$6_{0,6} \rightarrow 5_{1,5}$	0.13 ± 0.04	19	3.18
93666.65 ± 0.12	$12_{1,11} \rightarrow 12_{0,12}$	0.06 ± 0.02	74	5.53
99325.24 ± 0.04	$4_{1,4} \rightarrow 3_{0,3}$	0.14 ± 0.01	10	2.57
111782.73 ± 0.05	$7_{0,7} \rightarrow 6_{1,6}$	0.15 ± 0.05	25	4.01
125246.88 ± 0.04	$2_{2,1} \rightarrow 1_{1,0}$	0.11 ± 0.03	8	1.50
143603.06 ± 0.07	$7_{3,4} \rightarrow 7_{2,5}$	0.11 ± 0.05	38	3.58
H_2CS				
101477.75 ± 0.05	$3_{1,3} \rightarrow 2_{1,2}$	0.72 ± 0.03	23	2.67
103040.40 ± 0.05	$3_{0,3} \rightarrow 2_{0,2}$	0.61 ± 0.01	10	3.00
103051.79 ± 0.05	$3_{2,1} \rightarrow 2_{2,0}$	0.16 ± 0.01	63	1.67
104616.98 ± 0.05	$3_{1,2} \rightarrow 2_{1,1}$	0.89 ± 0.03	23	2.67
137371.04 ± 0.08	$4_{0,4} \rightarrow 3_{0,3}$	0.68 ± 0.03	16	4.00
137381.96 ± 0.06	$4_{2,3} \rightarrow 3_{2,2}$	0.18 ± 0.04	69	3.00
137411.80 ± 0.06	$4_{2,2} \rightarrow 3_{2,1}$	0.13 ± 0.03	69	3.00
139483.47 ± 0.07	$4_{1,3} \rightarrow 3_{1,2}$	0.64 ± 0.02	30	3.75
HNCO				
87597.333± 0.003	$4_{1,4} \rightarrow 3_{1,3}$	0.15 ± 0.02	54	3.75
87898.416± 0.004 87898.620± 0.004	$4_{2,3} \rightarrow 3_{2,2}$ $4_{2,2} \rightarrow 3_{2,1}$	0.06 ± 0.02	181	3.00
87925.238± 0.004	$4_{0,4} \rightarrow 3_{0,3}$	4.20 ± 0.01	11	4.00
109496.007± 0.004	$5_{1,5} \rightarrow 4_{1,4}$	0.30 ± 0.06	59	4.80
109905.753± 0.005	$5_{0,5} \rightarrow 4_{0,4}$	5.30 ± 0.03	16	5.00
110298.098± 0.004	$5_{1,4} \rightarrow 4_{1,3}$	0.29 ± 0.02	59	4.80
131799.29 ± 0.01	$6_3 \rightarrow 5_3$	0.07 ± 0.02	398	4.50
131845.880± 0.005 131846.59 ± 0.01	$6_{2,5} \rightarrow 5_{2,4}$ $6_{2,4} \rightarrow 5_{2,3}$	0.09 ± 0.02	193	5.33
131885.74 ± 0.01	$6_{0,6} \rightarrow 5_{0,5}$	4.82 ± 0.04	22	6.00
132356.711± 0.005	$6_{1,5} \rightarrow 5_{1,4}$	0.27 ± 0.03	66	5.83
OCS				
72976.80 ± 0.02	6 → 5	0.72 ± 0.03	12	6.00
85139.12 ± 0.01	7 → 6	0.86 ± 0.01	16	7.00
97301.21 ± 0.02	8 → 7	1.02 ± 0.07	21	8.00
109463.06 ± 0.01	9 → 8	1.24 ± 0.06	26	9.00
133785.90 ± 0.01	11 → 10	1.21 ± 0.06	39	11.00

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TABLE 3—*Continued*

Rest Frequency (MHz)	Transition	T_R (K)	E_u/k (K)	S
SO_2				
72758.24 ± 0.05	$6_{0,6} \rightarrow 5_{1,5}$	0.50 ± 0.07	19	3.01[b]
82952.02 ± 0.01	$13_{4,10} \rightarrow 14_{3,11}$	0.06 ± 0.01	123	1.93
84320.92 ± 0.02	$32_{5,27} \rightarrow 31_{6,26}$	0.09 ± 0.03	549	5.05
86639.14 ± 0.01	$8_{3,5} \rightarrow 9_{2,8}$	0.03 ± 0.02	55	1.13
97702.39 ± 0.01	$7_{3,5} \rightarrow 8_{2,6}$	0.10 ± 0.01	48	0.94
99392.61 ± 0.02	$29_{4,26} \rightarrow 28_{5,23}$	0.09 ± 0.03	441	4.38
100878.09 ± 0.08	$2_{2,0} \rightarrow 3_{1,3}$	0.09 ± 0.02	13	0.16
104029.42 ± 0.08	$3_{1,3} \rightarrow 2_{0,2}$	0.40 ± 0.01	8	2.01
104239.28 ± 0.08	$10_{1,9} \rightarrow 10_{0,10}$	0.35 ± 0.02	55	6.73
107060.19 ± 0.08	$27_{3,25} \rightarrow 26_{4,22}$	0.09 ± 0.02	369	3.10
107843.46 ± 0.08	$12_{4,8} \rightarrow 13_{3,11}$	0.07 ± 0.01	111	1.70
124864.74 ± 0.08	$11_{4,8} \rightarrow 12_{3,9}$	0.10 ± 0.03	100	1.49
126980.70 ± 0.08	$35_{5,31} \rightarrow 34_{6,28}$	0.08 ± 0.02	643	5.43
128605.13 ± 0.08	$12_{2,10} \rightarrow 12_{1,11}$	0.31 ± 0.03	83	9.92
129105.83 ± 0.08	$12_{1,11} \rightarrow 11_{2,10}$	0.28 ± 0.03	76	3.38
131014.86 ± 0.08	$12_{1,11} \rightarrow 12_{0,12}$	0.35 ± 0.02	76	6.73
132744.86 ± 0.08	$14_{2,12} \rightarrow 14_{1,13}$	0.28 ± 0.03	108	11.77
134004.86 ± 0.08	$8_{2,6} \rightarrow 8_{1,7}$	0.54 ± 0.08	43	5.69
140306.17 ± 0.08	$6_{2,4} \rightarrow 6_{1,5}$	0.34 ± 0.02	29	3.83

Rest Frequency (MHz)	Transition		T_R (K)	E_u/k (K)	S
CH_3OH					
76509.7 ± 0.1	$5_0 \rightarrow 4_1$	E	0.30 ± 0.04	48	0.86[c]
84423.8 ± 0.1	$13_{-3} \rightarrow 14_{-2}$	E	0.04 ± 0.02	274	2.11
84521.2 ± 0.1	$5_{-1} \rightarrow 4_0$	E	4.03 ± 0.05	40	1.41
85568.0 ± 0.1	$6_{-2} \rightarrow 7_{-1}$	E	0.07 ± 0.02	75	1.03
86615.8 ± 0.1	$7_2 \rightarrow 6_3$	A−	0.06 ± 0.02	103	0.64
86903.0 ± 0.1	$7_2 \rightarrow 6_3$	A+	0.07 ± 0.03	103	0.64
97582.8 ± 0.1	$2_1 \rightarrow 1_1$	A−	1.38 ± 0.01	22	1.50
104300.5 ± 0.1	$11_{-1} \rightarrow 10_{-2}$	E	0.15 ± 0.02	159	1.97
104354.85	$10_4 \rightarrow 11_3$	A−	0.07 ± 0.03	208	1.22
105063.70	$13_1 \rightarrow 12_2$	A+	0.13 ± 0.04	224	2.22
107013.9 ± 0.1	$3_1 \rightarrow 4_0$	A+	0.40 ± 0.02	28	1.43
108893.9 ± 0.1	$0_0 \rightarrow 1_{-1}$	E	1.23 ± 0.04	13	0.47
124570.0 ± 0.1	$6_0 \rightarrow 5_1$	E	0.60 ± 0.03	62	1.08
129433.41	$12_1 \rightarrow 11_2$	A−	0.10 ± 0.03	197	2.01
132621.9 ± 0.1	$6_2 \rightarrow 7_1$	A−	0.17 ± 0.03	86	0.94
132890.8 ± 0.1	$6_{-1} \rightarrow 5_0$	E	2.94 ± 0.03	54	1.65
140151.08	$18_0 \rightarrow 18_{-1}$	E	0.08 ± 0.02	408	8.70
143865.8 ± 0.1	$3_1 \rightarrow 2_1$	A+	1.89 ± 0.03	28	2.67

[a] Calculated with torsional overlap matrix elements provided by R. M. Lees 1979, private communication.
[b] Energies and line strengths were calculated from parameters given in Steenbeckeliers 1968.
[c] Where possible, energies and line strengths were taken from Lees *et al.* 1973; to use the same zero of energy for both E and A states, 7.899 K was added to the E-state energies listed by Lees *et al.* Other line strengths were calculated with torsional matrix elements provided by R. M. Lees 1980, private communication, and other energies were provided by Lees 1980–1985, private communications.

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diagrams from which column densities and rotational temperatures were estimated; the exception was CH_3CCH, for which the column density was estimated by comparison of its intensity and that of CH_3CN. When some of the gaps in the survey are filled in, estimation of column densities for a number of other species, such as CH_2NH and HCOOH, will be possible.

The range of the rotational temperatures computed is 10–30 K, which is cooler than the kinetic temperature of Sgr B2 is believed to be. The low values of rotational temperature indicate insufficient H_2 to thermalize the molecules. No correlation was found between T_{rot} and the molecule's dipole moment. A better understanding of the consistency of the rotational temperatures awaits statistical equilibrium analyses of individual molecules.

Although the consistently low values of T_{rot} are interesting in themselves, the exceptions to the pattern are even more interesting, giving evidence of hot spots within the source, possibly sites of star formation. The exceptions are transitions of CH_3OH, HNCO, and SO_2 that come from high-energy states and transitions in vibrationally excited states: CH_3CN, ν_8 and HC_3N, ν_7 and $2\nu_7$, all of high energy.

The average line width and v_{LSR} were calculated for 19 of the species considered here, but no apparent correlation was found between these parameters or between these and T_{rot}. A detailed mapping of the source should reveal whether the relative abundance of the species varies significantly from place to place.

The basic contribution of the present survey toward understanding molecular formation in Sgr B2 is a quantitative analysis that now makes available a large set of column densities based on well-calibrated observations with one telescope which well sample the rotational partition function. Relative abundances predicted by proposed schemes of molecular formation can be tested against these observed relative abundances. The unidentified lines remain a challenge.

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APPENDIX

INTENSITY OF THE MOLECULAR EMISSION LINES IN ROTATIONAL EQUILIBRIUM

For an optically thin transition with spontaneous radiative decay rate A, the intensity of radiation I_ν integrated in frequency over the transition line width is

$$\int I_\nu \, d\nu = \frac{NfAh\nu}{4\pi}, \tag{A1}$$

where f is the fractional population of the upper state of the transition and N the column density. In the Rayleigh-Jeans approximation, $I_\nu = 2kT_R\nu^2/c^2$ (which defines the radiation temperature T_R), and equation (A1) becomes

$$W \equiv \int T_R \, dv = \frac{NfAhc^3}{8\pi k\nu^2}, \tag{A2}$$

where the integration is now over radial velocity, $dv = cd\nu/\nu$, as customary in radio astronomy. The radiative decay rate is a function of the rotational line strength, S, a component μ_x of the permanent electric dipole moment along a principal axis of inertia, and the frequency (see, e.g., Condon and Shortley 1959, p. 98):

$$A = \frac{1}{2J+1} \frac{64\pi^4\nu^3\mu_x^2 S}{3hc^3}, \tag{A3}$$

where J is the angular-momentum quantum number of the upper state of the transition. Substituting equation (A3) in equation (A2), and assuming rotational equilibrium at a temperature T_{rot} so that $f = (2J+1)\exp(-E_u/kT_{rot})/Z$, where E_u is the energy of the upper state and Z is the rotational partition function, yields

$$\frac{3kW}{8\pi^3\nu S\mu_x^2} = \frac{Ne^{-E_u/kT_{rot}}}{Z}, \tag{A4}$$

and, taking the logarithm,

$$\log\left(\frac{3kW}{8\pi^3\nu S\mu_x^2}\right) = \log\left(\frac{N}{Z}\right) - \frac{E_u \log e}{kT_{rot}}. \tag{A5}$$

The term on the left-hand side is denoted by L and is the ordinate in Figure 4. This derivation neglects the effects on the apparent emission intensity of line absorption of continuum radiation that results from either the cosmic background or localized sources such as H I regions in Sgr B2. At millimeter wavelengths such effects are generally negligible toward Sgr B2 when $T_{rot} > 5$ K, which holds for all molecules analyzed in this paper.

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