1977

Report on Current Data and uses of Interstellar Molecules

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REPORT ON CURRENT DATA AND USES

OF INTERSTELLAR MOLECULES

by

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INTRODUCTION

The problem presented by polyatomic molecules in interstellar space were first suggested by the detection of CN, CH, and CH^+ just before 1940; but it was not until the discovery of radio emission from NH_3 in 1968 that radio observatories began to devote considerable time to searches for such molecules. The quest has been an extremely successful one, with well over thirty molecules listed to date and more being added to the collection every month. (The list in the appendix gives some idea of the discoveries, but makes no boast as to its completeness.)

The search for different types of polyatomic molecules has been valuable, in that it gives researchers some idea as to the complexity of the problems presented by their presence. But in order for these questions to be answered, it will be necessary to study the distribution and densities of a select number of these molecules, keeping a close eye on laboratory data concerning their formation. The purpose of this paper is to bring together data from a wide number of sources on a specific set of molecules: H_2CO CO H_2O. NH_3, OH, and HCN are also considered in light of their co-habitation of areas in space with the foresaid molecules. Data is provided on the first three molecules concerning the source temperature, line parameter (where provided by researchers) continuum source type, and distance. H_2 emission velocity and velocity of other molecules in the area studied are also included, as determined by researchers.

The data must not be considered as consistent as the observations were made with a variety of equipment. Some effort has been made on the part of researchers to determine the densities of CO (1) but must, once again, not be considered conclusive as an assumption has been made concerning the relative abundances of C^{12} to C^{13} as being the same in interstellar space as upon earth.

Because of the qualifications put upon the data, some readers may consider it to be less than indicative of certain theories that it is used to support. I shall try to argue against this in my report.

Before delineating any data upon specific molecules, it is necessary to have a general knowledge of research methods used in order that the said data may be understood. As has been stated, the vast majority of useful material on interstellar molecules has been gained through observation of the radio spectrum. There are specific reasons for this. Various molecular transitions occur in certain regions of the electromagnetic spectrum. Electronic transitions in the visible and ultraviolet, pure vibrational in the infrared, and pure rotational transitions in far infrared and short microwave. Because of extinction of starlight by dust, very little usable data can be gained in these wavelengths. Infrared and radio waves are not so affected by dust, thus allowing the study of more distant parts of the galaxy. However, the longer wavelengths provide poor angular resolution giving rather unaccurate pictures of spatial distribution. (It should be noted that sources between 1 cm and 1 mm wavelengths require a high degree of excitation to be detected because there are few sources with enough intensity at these wavelengths to be used as background sources for absorption observations.) In spite of these seeming difficulties, it is still possible to gain much information upon the molecules observed. This is the result of improvements in both the sensitivity and selectivity of receivers and of antenna designs. Also, a large catalogue of spectra lines has been compiled through laboratory experimentation over the past thirty years. In general, detection of a single line, well above the noise level, which agrees with a spectrum from this "catalogue" has been considered solid proof of the molecular existence.

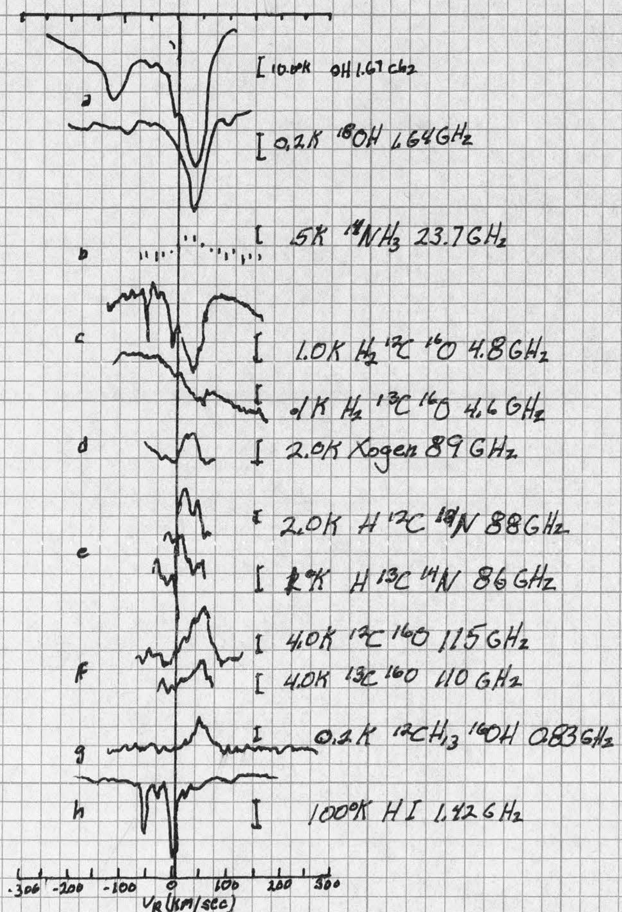
INTERPRETATION OF DATA: A SPECIFIC EXAMPLE

It would be best, before plunging into the data to see how findings have been interpreted and what meanings are assigned to data. An example might best clarify this. We shall, for the present limit ourselves to information gained from the frequency of the line.

Line frequencies, even at interstellar distances, can be measured with great accuracy. Thus small shifts in the frequency, due to Doppler effect, are easily detected. Because of small line widths, compared to frequencies, Doppler shifts of 10^{-5} of the velocity of light (1^{KM}/SEC) are easily detected. This gives the observer very accurate, and interesting data on the velocity, relative to the sun, of molecular gas clouds. Along with this general motion of the cloud, it is possible to determine velocities within specific portions of a cloud, because of the extremely narrow "window" of the radio telescopes used.

Figure 1 shows the spectra of a number of molecules that are detected in the direction of the galactic center. Figure 1h is the spectrum of neutral hydrogen 21 cm absorption against the strong radio source Sagittarius A, located at the galactic center. The central core of the galaxy may be responsible for absorptions at OKM?SEC (no radial velocity), or they may be due simply to very local gas. The feature at -55 Km/SEC and possibly -30 Km/SEC are produced by the intersection of two spiral arms (of the galaxy) with one line of sight to the galactic center. Right away we see that the strongest features of the molecular spectra in Sagittarius A do not correspond to those

Figure One



Microwave spectra taken from the galactic center

V_R = radial velocity with respect to sun.

taken from Rank, Townes & Welch "Interstellar Molecules and Dense Clouds" Science Vol. 174. page 1084.

in the atomic hydrogen spectrum. For example, the strongest features of OH and H_2CO are in the 25 to 75 KM/SEC range where there is not much of an atomic hydrogen feature. This suggests the presence of two quite different gas clouds. The one represented by sharp features which follow the atomic hydrogen closely; the other is represented by the lack of atomic hydrogen intensity compared to the activity of the molecular lines. If the ratio of hydrogen to other elements is the same for both clouds, then molecular formation would be favored in the cloud where atomic hydrogen has been replaced by molecular hydrogen. The densities of clouds for the formation of the latter is usually much greater than those of the former, hence the greater molecular formation and excitation. A close look at Figure 1 shows that the maxima of the different molecular lines do not coincide. This may result from the possibility that the formation and excitation of the different molecules is at an optimum in different parts of the cloud, which may have slightly different velocities.

MASER ACTION

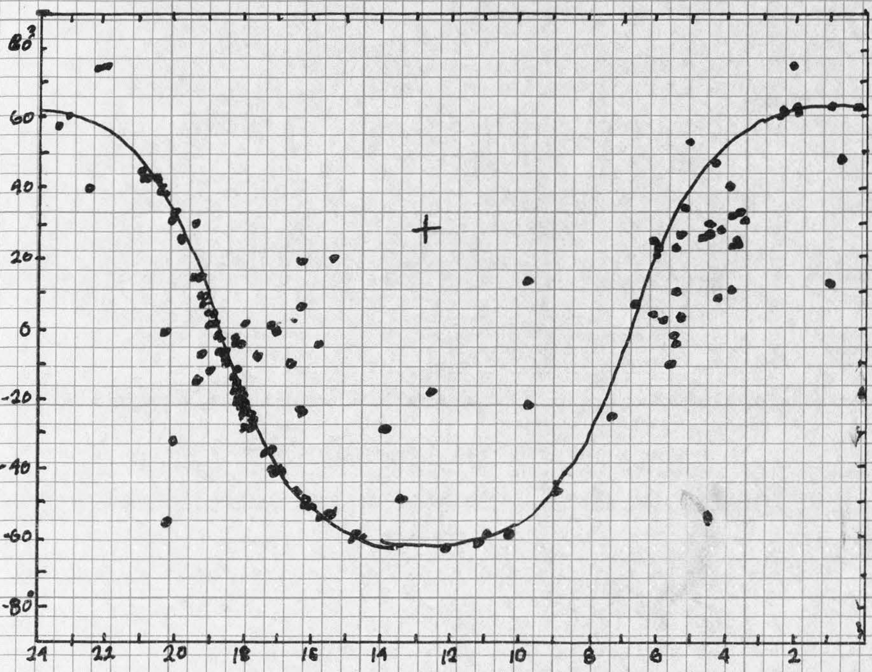
It might be interesting at this point to give the reader some information about interstellar maser action, as it is the action to which most sightings of OH and H_2O can be attributed.

Basically, a maser may be considered as an energy pump or a heat engine that require a high temperature source and a low temperature sink in order to continuously produce radiation at a very high temperature. In OH and H_2O maser action a large amount of infrared is absorbed and released in correspondence to the production of microwave quanta. Since it is impossible for the system to get rid of such a great amount of infrared quanta at a reasonable temperature, it is possible to assume that the source and the sink for the maser pump are within the object. Perhaps such a maser might be a dense cloud of gas and dust, about the size of a large star, with temperatures ranging from a few hundred to a few thousand degrees (so as not to desperse the cloud via radiation press). In conclusion, it is interesting to note that maser action is association with three types of objects: (1) H II regions, (2) supernova remnants, and (3) certain infrared stars. Any of these objects could be associated with the model described above.

OTHER AVAILABLE DATA

There are many other facts and insights to be gained through a careful study of molecular emission and absorption lines besides cloud velocities. A careful and precise study of the mechanisms of excitation and relaxation of molecules allows one to gain some idea of temperatures and densities of the medium in which the molecules are found. Because molecular excitation in interstellar space rarely corresponds to thermal equilibrium, each measurement can yield independent and useful information. Thus, for example, minimum densities of H_2 molecules in a region (at least lower limits) can be determined. Molecular densities may be determined from the colums densities, obtained from the absorption coefficient of the cloud and its temperature, if an accurate estimate of cloud size can be made.

Figure Two



Map of celestial sphere with distribution of galactic sources that show molecular lines.

Solid line is the galactic plane.

Source. Bank, Townes + Welch Ibid page 1089.

DISTRIBUTION OF MOLECULES

A few general comments concerning the distribution of molecules, later to be added to in the sections on individual molecules should be made. First, the distribution is clearly not of a random nature of all molecules that have been detected to date, the vast majority tend to be concentrated towards the galactic plane. Figure 2 is a map of the celestial sphere showing the positions of the majority of concentrations of interstellar molecules. The inverted bell curve represents the intersection between the celestial sphere and the galactic plane. The high density of molecules in the galactic plane should be quite evident especially towards the galactic center, where the majority of the galactic mass is located. If the molecules were a local phenomenon, that is, concentrated in the area of the galaxy near the sun, their distribution would tend to exhibit a much greater degree of uniformity. Since the sun lies close to the galactic plane, Figure 2 gives a rough measure of the distance from the sun to the molecular clouds. The greater the distance of the cloud from the sun, the higher the probability that the cloud lies in the galactic plane. A more accurate measure can be made by comparing the Doppler shifts of the molecular spectrum with the shifts of known hydrogen lines in the same direction.

MOLECULES AS INDICATORS OF ISOTOPIC ABUNDANCES

Molecular spectra offer an excellent chance to determine the relative abundances of common elements in different parts of interstellar space. The slight variation in mass between an element and its isotope is usually enough to effect the rotational frequencies, yet not enough so as to prevent the lines from being measured with the same apparatus. For example, the difference between $^{12}C^{16}O$ and $^{13}C^{16}O$ amounts to a 5% difference in moments of inertia. When a cloud is optically thin at the point of molecular resonance, a comparison of intensities, with minor corrections, gives the isotopic abundance ratios directly. If the cloud is optically thick, an accurate determination of the ratio is usually not possible, but limiting values can be obtained. The determination of these ratios is of interest because it allows the astrophysicist to verify his theories on the nuclear processes in stars based upon a general knowledge of the products of reactions. Most interesting is the ratio of ^{12}C to ^{13}C because of its association with the CNO cycle in H burning stars. In equilibrium the ratio should be 4 (2). He burning would essentially eleminate ^{13}C and produce a ratio approaching infinity. The $^{12}C : {}^{13}C$ ratio in Alpha Bootis appears to be about 3.5 (3). The ratio of 89 on earth appears to be a quirck. However, ratios as high as 105 and as low as 2 (in Zeta Ophirechi and Sgr. A, B2 respectively) have been determined. More microwave measurements are necessary in order to give a clearer picture as to isotopic ratios and the history of interstellar materials.

MOLECULES AS PROBES OF THE RADIATION FIELD

It is a well-known fact that the universe is apparently blanketed by an isotropic radiation of 2.7° K. This radiation has been assumed to be the remains of the "big bang" in which the universe was created, and has a strong effect on molecular excitation. White the radiation intensity is fairly well-known at wavelengths down to 3 mm, there is relatively little information at still shorter wavelengths. This information is of great importance to the verification of the "Big Bang" theory, for if the theory is to be correct, then it should agree with a blackbody curve for these higher frequencies. Anything short of a drastic deviation from this curve could still give us considerable insight as to the early history of the universe.

The best data available about the intensity of the isotropic field in these shorter wavelengths comes from measurements of molecular excitation. So far only upper limits for this field have been set with the measurements of molecular excitation. These are substantially greater than expected with blackbody radiation (4). Again, further measurements are needed before any specific conclusions can be reached.

FORMATION AND DISAPPEARANCE OF MOLECULES

The fact that complex molecules have been discovered in such great abundance in interstellar space has come as quite a surprise to astronomers, for there is no known mechanism to account for their production and maintainence. Many theories have been put forth but none are completely satisfactory. There are several theories which attempt to explain these mechanisms: (1) Building up of molecules by binary collisions in the gaseous medium of interstellar space, (2) Formation of molecules on surfaces of dust grains from atoms or simpler molecules impinging on the surfaces, (3) Formation of molecules in the dense atmospheres of stars, perhaps largely by many-body collisions, and their subsequent expulsion into the interstellar medium, (4) Evaporation or decomposition of dust grains.

Any theory dealing with the formation of molecules must provide a mechanism that allows for the production of enough molecules to result in an equilibrium (or close to it), otherwise the clouds would have a very short life as the various molecules became dissociated. Thus an understanding of the molecules dissappearance is of as much importance as that of their formation. Indeed, this is perhaps the best way to approach the problem.

One of the main mechanisms for the elimination of molecules is photo decomposition (5). It has been estimated that most molecules left protected from U. V. radiation would have a life of less than 100 years (6). This severely restricts the possible mechanisms of formation, since said formation would, of necessity, have to take place within the shielding of dust clouds. Further research has shown that the Albedo of grains is very high in the far U. V. which dominates in the photo-dissociation process (7). Optimum lifetimes in dense clouds are assumed to be 200-1000 years. Such a short lifetime requires the presence of efficient formation processes. This tends to rule out two theories of formation: (1) Binary collisions, and (2) formation in stellar atmospheres.

Binary collisions in the gas phase can in principle build up molecules, but the probability of collisions between atoms resulting in the formation of molecules is much too small to account for the observed densities of molecules. The formation of molecules in stellar atmospheres is also unlikely because of the problems in shielding the molecules from the stellar radiation. Even if one assumes the formation of dust grains, along with the molecules, as a shield, one is still faced with the problem of the grains high Albedo, extremely important in the close proximity of a stellar environment. Similar arguments can be brought against theories proposing the decomposition of dust grains as a probable mechanism. Grain surfaces may be used for molecule formation. An important parameter to consider in this theory is the ratio of gas density $N(CM^{-3})$ to the shielding against U. V. photons: e^{-Cuv}

$$\mathcal{R} = \frac{N}{100\ cm^{-3}} \cdot e^{Cuv}$$

For molecules to stick to the grain surface $\mathcal{R}$ must be greater than 10^4 (8).

APPENDIXES

OBSERVATION OF GALACTIC CARBON MONOXIDE

Interstellar CO was discovered through microwave emission at 115, 271.2 MH_2 (2.6mm) from the J = 1-0 rotational transition in 1970 (Wilson Jefferts and Penzias, 1970). Subsequent studies have suggested that CO was widespread (Penzias, Jefferts, and Wilson, 1971). Theoretical considerations also predict large abundance of CO since it is relatively easy to form in regions of moderate densities ($N_{H_2} > 10^2 cm^{-3}$) (Watson and Saldpeter, 1972). In dense clouds it has been found to be the most abundant molecule. CO would also be expected to be widely distributed since it is very stable, having a lifetime greater than 10^4 years in regions where the visual extinction is at least 1 mag. (Stief et. al. 1972).

A wide survey of the nature and extent of galactic CO has been made by several observers, most important of which are W. J. Wilson, P. R. Schwartz, E. E. Epstein. Also prominant is R. D. Eleheverry. Table 1 gives a listing of their data. Because of overlapping sightings, no attempt has been made to indicate the individual responsible in this paper for each specific detection. The latest sighting is the one given: (usually Wilson, Schwartz and Epstein et. al, 1974).

Table 1.

Galactic Source No.	R.A. H.M.S.	DEC D.M.	Vel.Range Searched (Km/s)	Ant. Temp.	Radial Vel. (Km/s)	Half Power Linewidth	Remarks
133.5 + 1.1	02 20 21	61 52.3	(-77,7)	1.5	-42	6	W3 cont
133.7 + 1.2	02 21 44	61 52 8	(-94,-7)	9.7	-41	9	
133.8 + 1.0	02 21 51	61 40.6	(-99,-7)	1.0	-44	5	
133.7 + 1.3	02 21 51	61 56.3	(-94,-7)	4.0	-40	6	
133.6 + 1.4	02 21 51	62 04.6	(-155,70)	≤0.7	---	---	
133.7 + 1.2	02 21 52	61 52.3	(-94,-7)	10.4	-41	9	(IR,420)
133.7 + 1.2	02 21 57	61 52.8	(-94,-7)	7.8	-40	9	
133.8 + 1.2	02 22 40	61 50.0	(-99,-5)	3.0	-40	7	
133.9 + 1.3	02 23 15	61 51.0	(-99,-5)	1.6	-44	8	
134.0 + 1.3	02 24 00	61 51.0	(-76,-5)	≤0.7	---	---	
133.7 + 1.4	02 22 20	62 01.0	(-100,-7)	1.5	-40	6	W 3 N
133.8 + 1.4	02 23 07	62 01.0	(-100,-7)	2.5	-41	5	
133.9 + 1.1	02 23 17	61 38.9	(-98,-10)	6.6	-47	8	
134.0 + 1.1	02 24 20	61 38.9	(-56,70)	≤1.3	---	---	W 3 (OH)
165.4 - 9.0	04 26 57	35 10.0	(-50,40)	1.8	-2	6	
209.0 -19.4	05 32 47	-05 24.3	(-42,53)	31.0	9	7	
206.5-16.3	05 39 13	-01 55.8	(-50,52)	11.8	11	8	
196.4-1.7	06 11 44	13 50.2	(-90,35)	4.8	17	6	
201.5 + 0.7	06 30 00	10 30.0	(-50,37)	(1.9,2.2)	(-13,5)	(5,6)	
202.6 + 0.7	06 32 25	09 32.5	(-34,37)	(1.0,1.2)	(-17,-6)	(6,5)	

Galactic Source No.	R.A. H.M.S.	DEC D.M.	Vel.Range Searched (Km/s)	Ant. Temp.	Radial Vel. (Km/s)	Half Power Linewidth	Remarks
201.6+1.7	06 33 50	10 51.0	(-34,37)	1.8	-13	5	
203.6+1.7	06 37 52	09 05.5	(-34,27)	2.2	6	9	
202.4+2.4	06 38 00	10 30.0	(-40,37)	2.4	8	9	
203.0+2.1	06 38 04	09 51.1	(-40,37)	2.7	8	9	
203.4+2.0	06 38 22	09 25.7	(-50,31)	5.1	5	6	
203.3+2.1	06 38 25	09 32.5	(-50,37)	11.0	7	6	
203.4+2.1	06 38 34	09 27.7	(-50,37)	7.0	7	6	
203.7+2.1	06 39 22	09 15.8	(-34,37)	1.8	8	7	
345.4-0.9	17 06 02	-41 32.3	(-70,29)	(5.1,1.8)	(-21,-9)	(8,6)	
351.0+0.7	17 16 25	-36 02.2	(-60,40)	4.2	-5	10	
351.2+0.7	17 16 36	-35 54.9	(-60,40	8.8	-8	9	
351.3+0.8	17 16 36	-35 45.5	(-60,40)	0.6	-6	9	
351.2+0.6	17 17 00	-35 53.0	(-60,40)	10.2	-5	8	
351.3+0.6	17 17 13	-35 49.4	(-60,40)	5.4	-5	7	
351.4+0.6	17 17 23	-35 47.6	(-60,40)	11.3	-4	8	
351.2+0.5	17 17 31	-36 00.5	(-60,40)	1.9	-5	10	
351.4+0.6	17 17 32	-35 44.2	(-60,40)	13.0	-8	10	
351.3+0.5	17 17 42	-35 53.6	(-60,40)	2.2	-6	9	
348.7-1.0	17 16 39	-38 54.6	(-58,36)	11.3	-13	9	
353.2+0.9	17 21 30	-34 08.4	(-30,41)	2.8	-3	12	
353.1+0.6	17 22 18	-34 19.3	(-60,41)	(4.8,1.2)	(-2,20)	(15,9)	

Galactic Source No.	R.A. H.M.S.	DEC D.M.	Vel. Range Searched (Km/s)	Ant. Temp.	Radial Vel. (Km/s)	Half Power Linewidth	Remarks
6.1-0.1	17 57 00	-23 44.0	(-24,47)	≤1.3	---	---	
6.5+0.1	17 57 00	-23 18.0	(-24,47)	≤1.3	---	---	
6.6-0.1	17 57 48	-23 19.0	(-60,47)	1.5	19	9	
6.7-0.2	17 58 38	-23 190	(-60,47)	1.5	22	12	
6.8-0.5	18 00 00	-23 18.0	(-24,47)	≤1.3	---	---	
5.9-0.4	17 51 29	-24 04.8	(-25,46)	4.8	8	9	
7.0-0.2	17 59 19	-23 02.1	(-24,47)	(2.2,2.2)	(3,18)	(9,9)	
6.0-1.2	18 00 38	-24 230	(-40,47)	7.0	10	6	
10.3-0.1	18 05 58	-20 060	(-23,48)	(4.5,1.5)	(12,22)	(16,9)	
10.3-0.2	18 06 06	-20 10.2	(-23,48)	(2.8,1.5)	(11,30)	(16,6)	
10.1-0.3	18 06 23	-20 20.0	(-23,48)	(3.6,1.2)	(2,21)	(18.12)	
10.6-0.4	18 07 32	-19 56.9	(-23,48)	(8.4,1.5,2.7)	(-3,17,30)	(12,9,15)	
12.9+0.0	18 10 39	-17 47.3	(9,80)	(1.0,1.6,3.0)	(21,40,50)	(6,12,12)	
12.7-0.2	18 10 58	-18 00.3	(9,80)	(5.2,1.9,1.8)	(35,47,56)	(9,8,8)	
12.8-0.2	18 11 16	-17 56.9	(9,80)	(8.4,3.6)	(35.47)	(11,10)	
12.9-0.2	18 11 42	-17 53.1	(9,80)	(4.8,2.2)	(35,49)	(15,15)	
17.0+0.9	18 15 30	-13 43.1	(-30,66)	5.2	25	12	
16.9+0.8	18 15 34	-13 54.0	(-8,66)	1.6	23	12	
17.0+0.8	18 16 07	-13 49.8	(-8,66)	2.4	22	8	
19.7-4.4	18 40 20	-13 48.0	(-5,66)	50.9	---	---	

Galactic Source No.	R.A. HMS.	DEC D.M.	Vel.Range Searched (Km/s)	Ant. Temp.	Radial Vel. (Km/s)	Half Power Linewidth	Remarks
15.0-0.6	18 17 10	-16 12.0	(-30,60)	(7.5,1.6)	(19,31)	(9,6)	
15.0-0.7	18 17 34	-16 13.8	(-17,60)	10.6	21	9	
15.0-0.7	18 17 34	-16 12.5	(-17,60)	5.8	23	10	
15.1-0.7	18 19 37	-16 10.5	(-17,60)	6.6	22	6	
15.1-0.7	18 17 49	-16 12.0	(-17,60)	(2.8,1.2)	(23,34)	(6,9)	
15.1-1.0	18 18 57	-16 20.0	(-80,130)	<1.0	---	---	
15.3-0.9	18 18 57	-16 05.0	(-17,60)	1.0	20	8	
28.8+3.5	18 28 52	-02 07.7	(-46,37)	(2,2.1,3)	(6,12)	(6,3)	
23.1+0.2	18 30 33	-08,40.0	(58,130)	(1.5,2.7,3.3)	(77,89,106)	(6,9,7)	
23.0-0.3	18 31 27	-09 00.3	(32,104)	(2.4,4.8,2.1)	(54,65,75)	(6,9,9)	
23.5-0.0	18 31 38	-08 24.2	(58,130)	(2.1,2.8)	(87,102)	(12,15)	
23.0-0.3	18 31 39	-08 59.2	(32,104)	(2.4,4.8)	(62,75)	(18,12)	
24.0-0.3	18 31 41	-07 57.1	(58,130)	(3.9,1.9,2.5)	(79,97,108)	(12,9,12)	
22.8-0.5	18 31 42	-09 18.1	(32,104)	(2.1,5.1)	(59,76)	(15,15)	
23.3-0.5	18 31 55	-08 46.1	(32,104)	(3.3,3.6,1.6)	(65,78,91)	(9,12,9)	
23.4-0.2	18 31 59	-08 35.3	(58,130)	(4.0,6.9)	(80,101)	(8,15)	
29.9-0.0	18 43 31	-02 44.5	(56,143)	(1.2,9.5)	(68,100)	(6,14)	
30.2-0.1	18 44 24	-02 32.6	(56,143)	(2.4,1.8,6.9, 4.8)	(69,82,103, 110)	(12,9,9,9)	
30.6-0.0	18 44 41	-02 9.5	(56,143)	(6.5,1.8)	(92,118)	(15,8)	
30.8-0.0	18 45 01	-01 59.4	(56,143)	(3.9,5.8,3.0)	(84,97,110)	(12,12,12)	
30.9-0.0	18 45 03	-01 48.3	(62,143)	(1.2,3.0,1.8)	(84,110,121)	(9,12,9)	

Corrected 2%

Galactic Source No.	R.A. H.M.S.	DEC D.M.	Vel.Range Searched (Km/s)	Ant. Temp.	Radial Vel. (Km/s)	Half Power Linewidth	Remark
30.4-1.2	18 45 04	-02 25.6	(56,143)	(1.8,4.8,5.2)	(69,96,107)	(12,12,9)	
31.0+0.1	18 45 10	-01 42.0	(50,143)	(1.5,2.4)	(84,101)	(9,9)	
30.7-0.3	18 45 42	-02 10.0	(56,143)	(1.2,4.8,3.1)	(68,89,102)	(9,15,12)	
25.2-6.7	18 58 44	-10 01.8	(-3,200)	≤1.3	---	---	
34.2+0.1	18 50 48	01 10.0	(40,101)	(4.2,1.8,1.0)	(55,64,91)	(15,9,12)	
34.4-0.1	18 52 00	01 10.0	(-6,65)	(1.5,1.8)	(12,42)	(6,12)	
34.8-0.4	18 53 56	01 25.0	(-3,75)	(1.0,1.0,3.6)	(13,27,45)	(6,9,8)	
34.2-0.8	18 54 00	00 45.0	(-6,65)	(1.8,2.4)	(13,60)	(7,6)	
34.7-0.5	18 54 04	01 16.0	(-3,75)	(1.2,3.6)	(12,41)	(6,12)	
34.8-0.5	18 54 05	01 22.4	(-3,75)	(0.7,0.6,3.6, 0.6)	(13,28,45, 70)	(6,6,9,6)	
34.8-1.0	18 56 00	01 10.0	(-6,65)	(1.6,3.9)	(13,46)	(6,9)	
35.1-1.5	18 58 14	01 97.8	(0,84)	(2.8,1.0)	(44,60)	(15,6)	
35.0-1.7	18 58 45	01 00.0	(-10,84)	(3.3,1.2)	(41,49)	(9,9)	
35.2-1.7	18 59 15	01 08.0	(-10,84)	4.0	42	9	
35.3-1.8	18 59 52	01 14.3	(0,84)	21	49	9	
43.2+0.0	19 07 50	09 01.3	(-61,88)	(10.2,10.0)	(3,10)	(9,9)	
43.2-0.0	19 07 58	09 00.0	(-61,88)	7.5	10	12	
45.5+0.1	19 11 47	11 07.1	(10,94)	4.8	62	9	
45.5+0.1	19 11 54	11 05.3	(10,94)	2.8	58	9	
45.5+0.1	19 12 01	11 04.0	(10,94)	6.6	58	9	

Galactic Source No. G	R.A. H.M.S.	DEC D.M.	Vel.Range Searched (Km/s)	Ant. Temp.	Radial Vel. (Km/s)	Half Power Linewidth	Remarks
48.8-0.0	19 18 50	14 00.0	(27,99)	≤1.3			
49.0-3.3	19 20 03	14 00.9	(20,99)	6.0	70	9	
49.1-0.4	19 20 36	14 03.0	(20,99)	(1.2,3.3)	(59,73)	(10,9)	
49.2-0.3	19 29 43	14 10.0	(10,99)	4.8	68	9	
49.4-0.3	19 20 56	14 21.0	(10,99)	(5.7,2.1)	(54,66)	(15,6)	
49.5-0.4	19 21 23	14 24.5	(10,99)	(13.5,4.6)	(57,67)	(15,9)	
49.3-0.9	19 23 00	14 00.0	(27,99)	(1.5,1.5)	(38,56)	(9,6)	
70.3+1.6	19 59 50	33 24.3	(-70,26)	9.0	-24	9	
70.3+1.5	19 59 52	33 23.1	(-60,26)	1.8	-25	6	
70.3+1.6	19 59 52	33 24.6	(-64,26)	11.0	-24	9	
70.3+1.6	19 59 59	33 26.0	(70,26)	7.2	-23	8	
81.3+1.2	20 33 23	42 15.3	(-50,36)	2.8	9	9	
81.9+0.8	20 36 51	42 27.4	(-35,36)	(1.2,3.4,7.2)	(-22,-3,11)	(6,6,9)	
81.7+0.5	20 37 14	42 09.0	(-50,36)	(10.6,3.6)	(-2,10)	(9,9)	
81.7+0.5	20 37 15	42 12.2	(-50,36)	(10.2,2.7)	(-2,8)	(9,9)	
80.9-0.2	20 37 42	41 07.6	(-42,36)	(1.2,1.8)	(-11,-1)	(6,9)	
81.5+0.2	20 38 21	41 47.5	(-58,36)	(2.1,4.5)	(-12,0)	(4,9)	
81.5+0.0	20 39 01	41 42.8	(-50,36)	(2.5,2.4)	(-6,6)	(6,9)	
111.2+1.0	23 08 04	61 13.9	(-95,-23)	≤0.9			
111.4+0.9	23 09 54	61 13.9	(-80,0)	(2.2,1.2)	(-56,-14)	(8,6)	
111.5+0.7	23 10 36	61 08.5	(-99,-24)	(6.7,3.6)	(-57,-49)	(9,11)	
111.6+0.9	23 10 36	61 18.5	(-95,-24)	0.9	-54	11	

Galactic Source No. G	R.A. H.M.S.	DEC D.M.	Vel.Range Searched (Km/s)	Ant. Temp.	Radial Vel. (Km/s)	Half Power Linewidth	Remark
111.4+0.7	23 10 39	61 09.9	(-110,-24)	4.5	-54	12	
111.5+0.8	23 10 48	61 13.5	(-110,-24)	4.8	-57	9	
111.5+0.8	23 11 22	61 13.8	(-110,-24)	3.0	-54	10	
111.5+0.8	23 11 24	61 12.8	(-110,-24)	5.4	-57	9	
111.4+0.5	23 11 28	60 53.9	(-95,-23)	1.0	-49	6	
111.5+0.7	23 11 28	61 03.9	(-110,-23)	3.6	-54	9	
111.6+1.0	23 11 28	61 23.9	(-95,-23)	$\leq$0.9			
111.7+1.1	23 11 28	61 33.9	(-98,-23)	$\leq$0.9			
111.5+0.8	23 11 37	61 11.8	(-110,-24)	8.2	-57	10	
111.6+0.8	23 12 12	61 13.5	(-99,24)	4.0	-54	8	
111.6+0.8	23 12 13	61 13.9	(-110,0)	(5.8,0.6)	(-53,-11)	(6,6)	
111.8+0.7	23 12 33	61 13.9	(-110,0)	(4.0,2.7)	(-48,-11)	(10,6)	
111.7+0.7	23 12 53	61 13.9	(-80,0)	(3.6,1.6)	(-50,-10)	(9,6)	
111.7+0.8	23 12 53	61 18.9	(-110,0)	5.2	-49	(8,6)	
111.7+0.7	23 13 53	61 08.9	(-110,0)	(2.2,1.0)	(-49,-11)	7	
111.9+0.5	23 15 00	61 05.0	(-110,-23)	5.1	-52		
112.2+0.2	23 18 30	00 56.0	(-170,50)	$\leq$1.3			
111.7-21	23 21 05	58 34.1	(-110,38)	(1.2,1.0)	(-43,0)	(9,15)	
111.7-2.1	23 21 07	58 32.8	(-110,38)	(1.5,1.2)	(-42,-1)	(9,15)	
111.7-2.2	23 21 15	58 31.1	(-110,38)	(1.2,1.0)	(-43,1)	(12,6)	
111.8-2.2	23 21 40	58 31.1	(-110,38)	(1.2,1.0)	(-46,0)	(9,15)	
118.1+4.9	23 58 54	67 01.8	(-43,28)	1.2	-12	15	
118.4+6.0	23 59 56	68 11.4	(-43,28)	0.9	-12	4	

Table 2. Sources without CO emersion

Source	Galactic Source No.	R.A. H.M.S.	DEC D.M.	Vel.Range searched	Ant.Temp. (°K)	Remarks
NGC281	123.1-6.3	00 49 55	56 20.3	(-73,0)	≤0.8	HII region, S184
Taurus A	184.5-5.8	05 31 30	21 59.7	(-90,90)	≤0.8	SNR
S291	220.5-2.8	06 52 57	-07 56.9	(-110,35)	≤1.0	HII region
S301	231.5-4.1	07 07 36	-18 26.7	(-120,35)	≤1.0	HII region
OH0.739-14	231.8+4.2	07 39 59	-14 36.2	(-70,120)	≤0.8	OH IR source
RS PUP	252.4-0.2	08 11 08	-34 25.4	(-99,110)	≤1.0	REDO cluster
CP0950+08	228.9+43.7	09 50 31	08 09.8	(-99,110)	≤1.0	Pulsar
Virgo A	283.8+74.5	12 28 18	12 39.9	(-99,110)	≤0.9	Galaxy
M3	42.2+78.7	13 39 48	28 38.0	(-95,120)	≤2.0	Glob. Cluster
M5	3.9+46.8	15 56 00	02 17.0	(-99,110)	≤1.5	Glob. Cluster
HI Cloud	2.0+41.4	15 29 18	-02 13.2	(-91,75)	≤0.8	
S36	11.1+36.0	16 03 46	00 09.0	(-110,20)	≤1.0	HII region
SCO X-1	359.1+23.8	16 17 04	-15 31.2	(-86,68)	≤1.0	X-Ray Source
NGC 6543	96.5+30.0	17 58 34	66 38.1	(-111,68)	≤0.8	Planetary Neb.
Cygnus A	76.2+5.7	19 51 49	40 35.4	(-110,70)	≤0.8	Galaxy
NGC 7027	84.9-3.5	21 05 09	42 02.0	(-90,90)	≤0.7	Planetary Neb.
HI Cloud	113.7+12.3	22 41 15	72 34.0	(-175,45)	≤1.0	MED. Velocity

Table 3.

Source	Galactic Source No.	$^{13}C^{16}O$ Ant Temp(^{o}K)	Radial Vel. (Km/s)	Line-width (30B) (Km/s)	$T(^{12}C^{16}O)$ Optical Depth	T_{01} Excitation Temp(^{o}K)	Na^2 Column Density ($X10^{18}CM^{-2}$)
W3 cont	133.7+1.2	3.2	-41	7	26	21	6.0
W3 (OH)	133.9+1.1	2.2	-46	6	27	15	2.9
ORI A	209.0-19.4	4.9	9	6	12	52	14.7
ORI B	206.5-16.3	4.5	10	6	32	23	8.2
S 269	196.4-1.7	1.3	17	6	28	12	1.5
NGC 2264	203.4+2.1	1.2	7	6	17	15	1.5
NGC 6334	351.4+0.6	3.9	-4	6	28	22	6.8
N28S	5.9-0.4	3.0	9	6	58	12	4.6
W 29	6.0-0.4	1.8	9	6	27	15	2.3
W 31	12.8-0.2	4.0,1.0	-3,32	7,12	3,4,56	18,8	7.7,2.3
W 33	17.0+0.9	50,11	35,47	9,12	66,39	18,10	13.8,2.4
M 16	15.0-0.7	1.6	24	11	29	12	3.5
M 17	23.4-0.2	3.6	20	6	25	21	6.0
W 41	29.9-0.0	3.0	102	12	41	15	8.7
	29.9-0.0	1.2	110	9	26	.2	2.0
W 43	30.2-0.1	3.2	99	10	26	20	8.4
W 44	34.7-0.5	1.0	42	10	24	10	1.8
G45.5+0.1	45.5+0.1	3.3	58	7	55	14	5.9
W51 SNR	49.0-0.3	1.2	69	6	13	14	1.5
W51	49.5-0.4	5.1	57	15	44	26	25.1
bR 21	81.7+0.5	5.5	-3	7	44	23	12.5
W 75N	81.9+0.8	1.0,5.0	-4,9	6,7	30,82	9,16	1.1,11.2
K3 -50	70.3+1.6	2.0	-26	8	20	19	3.8

Source	Galactic Source No.	$^{13}C^{16}O$ Ant Temp(^oK)	Radial Vel. (Km/s)	Line-width (30 B) (Km/s)/	$T(^{12}C^{16}O)$ Optical Depth	T_{o1} Excitation Temp(^oK)	Na^2 Column Density ($X10^{18}CM^{-2}$)
NGC 6857	70.3+1.6	3.3	-22	8	54	16	6.6
NGC 7538	111.5+0.8	3.9	-57	9	51	17	9.5
CAS A	111.7-2.1	≤0.2			≤17	6	≤0.3

INTRODUCTION TO H_2CO DATA

The microwave transition line for formaldehyde was first detected in interstellar space by J. E. Snyder in 1969. (Phys. Rev. Letters 22,679) The transition is at 4830 MH_2 between the 1.1 and 1.0 levels of the molecule. Because it is believed that the molecule is very widespread, a general survey could aid in problems of galactic dynamics and the physics of the interstellar medium (T. L. Wilson, Astron. and Astrophysc. 19, 354). Several such surveys have been made (Ibid).

There are many reasons for such surveys. Among them is the attempt to resolve the distance ambiguity which is present for many HII regions closer to the galactic center than the sun. (Hence, the positions and objects sighted in the data.) Also important to consider are the problems of distribution of H_2CO clouds and their relationship to other parts of the interstellar medium (OH, H_2O, CO for instance).

MECHANISMS INVOLVED IN COOLING H_2CO

Many formaldehyde dark clouds produce a decrease in radiation intensity below that due to the $2.7^{o}K$ background radiation. (Palmer, Zuckerman, Buhl, Snyder, Astrophysc. J. 156, L147, 1969). The excitation temperature is lower than any other part of the cloud (about .8K for the CEM line). Therefore a nonequilibrium process, similar to maser action in OH + H_2O except in reverse.

Several processes have been suggested. One involves collision and then reradiation (Townes and Cheung, Astrophysc. J. 157, L.103, 1969). Radiative transitions allow molecules to decay rapidly, but from the lower level of one doublet (say 1_{11} or 1_{10}) the molecule can decay only to the lower level of another doublet. Thus the lowest state 1_{11} must have a larger population than the upper state of the same doublet. "This corresponds to a low excitation temp. for the pair. Thus a refigeration process can be operated by a heat source, say kenitic energy, and use the radiation field as a heat sink." (Townes, Rank, Welch, Science, 174, 1083-1101).

If any discrepencies were found in varying reports I have used later figures. The best overall surveys have been made by T. L. Wilson (Astron and Astrophysic. 19, 354-368). From which much valuable data has been taken.

Galactic Co-ordinate	Equatorial Co-ordinates R.A.	DEC.	K^o Source Temp	Line Half-width KM/S	H_2CO Vel. KM/S	Source Type
347.6+0.2	17 08 08	-39 04 50	2.3			HII region
348.2+0.5	17 08 56	-38 26 01	1.6	3.6	-8.4	SNR
348.1+0.1	17 11 05	-38 28 25	2.8			SNR
348.7-1.0	17 16 37	-38 54 19	8.2	4.3-3.2	-13.2,32.4	HII reg.
348.7+0.3	17 10 54	-38 08 00	2.6	6.3	-6.9	SNR
349.7+0.2	17 14 37	-37 23 16	2.8	6.0	-63.6	SNR
350.1+0.1	17 16 04	-37 07 39	2.1	7.6	-67.6	HII reg.
351.4+0.7	17 17 12	-35 45 58	17.0	5.5-1.0	-3.7,6.7	HII reg.
351.6+0.2	17 19 54	-35 51 28	2.9	5.8-6.8	-13,42	HII reg.
351.6-1.2	17 25 52	-36 37 35	6.0	5.4-6.8	-12.6,-24	HII reg.
353.1+0.7	17 22 17	-34 18 19	14.9	9.4-1.7	-4.6,+5.8	HII reg.
353.4-0.4	17 27 08	-34 39 56	2.6	4.3	-16.6	HII reg.
355.2+0.1	17 30 09	-32 52 43	1.5			
357.7-0.1	17 37 05	-30 56 45	3.3	0.7,3.6	-9.2,-13.8	SNR
				2.5,5.8	-59.7,+4.8	SNR
				3.6,7.8	-17.6,-2.6	
1.1-0.1	17 45 25	-27 58 12	2.3	37.0	+84.8	HII reg.
3.3-0.1	17 50 28	-26 10 23	1.7	7.8,8.8	+87.4,+100.4	HII reg.
4.4+0.1	17 52 18	-25 06 07	1.7	2.5	+7.0	HII reg.
5.9+0.4	17 57 34	-24 04 42	3.5	5.8,6.8	+10.8,18.4	SNR
5.5-0.1	17 57 51	-23 20 10	3.8	3.7,4.7	+14.6,+19.4	HII reg.

Galactic Co-ordinate	Equatorial Co-ordinates R.A.	DEC.	K^{o} Source Temp	Line Half-width KM/S	H_2CO Vel. KM/S	Source Type
7.0-0.2	17 59 19	-23 02 09	2.1	4.6,3.8	+5.2,+20.8	HII reg
8.5-0.3	18 02 47	-21 46 20	1.2	5.8,3.6	+13.4,+34.1	HII reg
10.2-0.3	18 06 24	-20 19 53	12.0	6.8,10.9	+2.2,+10.2, +25.6	HII reg
				3.4,4.0, 0.7	+31.4,+36.0	
10.3-0.1	18 05 58	-20 06 05	4.0	4.9,4.9	+11.21,+21.8	HII reg
				3.3,6.0	+37.8,44.8	
10.6-0.4	18 07 33	-19 56 32	2.5	4.2,5.8	+27.9,-2.2	HII reg
11.2-0.4	18 08 32	-19 27 52	2.0	4.3,4.9	-0.2,+29.4	SNR
12.8-0.2	18 11 15	-17 57 02	8.5	5.1	+33.8	HII reg
13.2+0.0	18 11 10	-17 29 28	1.1	4.0,5.5	+53.1,+63.1	HII reg
14.0+0.1	18 13 57	-16 14 38	2.0	2.2,6.0	+26.2,+44.4	HII reg
18.5+2.0	18 14 50	-11 57 20	1.4			HII reg
19.1-0.3	18 23 53	-12 29 02	2.5	1.9,4.4	+60.1,+65.1	HII reg
19.7-0.2	18 24 46	-11 53 42	2.3	3.0,3.8	+38.8,+44.5	HII reg
20.7-0.1	18 26 29	-10 54 47	2.3	2.5,2.2	+56.8,104.6	HII reg
21.5-0.9	18 30 47	-10 36 35	1.7			SNR
21.8-0.6	18 30 16	-10 13 00	2.2	5.8	+81.6	SNR
22.8-0.3	18 31 01	-09 11 39	1.3	2.5,3.0	+68.8,+71.6	HII reg
				2.5,4.0	+88.2,+104.9	
23.4-0.2	18 31 58	-08 34 55	3.1	5.1,7.0	+80.,+97.9	HII reg
					+109.0	

Galactic Co-ordinate	Equatorial Co-ordinates R.A.	DEC.	K^o Source Temp	Line Half-width KM/s	H_2CO Vel. KM/s	Source Type
24.8+0.1	18 33 30	-07 13 24	1.8	3.2,4.9,7.4	+46.2,+52.6	HII reg
25.4-0.2	18 35 32	-06 50 09	4.7	2.5,1.4	+51.2,+58.6	HII reg
				4.7,2.5	+91.8,+95.8	
25.8+0.2	18 34 55	-06 18 43	1.4			HII reg
28.6 + 0.0	18 40 52	-03 52 38	1.0	4.0,3.2,	+75.4,+80.8,	HII reg
				10.2	+103.4	
28.8+3.5	18 28 51	-02 07 29	5.5	1.4	+7.2	HII reg
29.7+0.0	18 43 29	-02 44 46	3.8	2.5,0.7	+6.6,+49.0,	HII reg
				6.4	+99.6	
31.9+0.0	18 46 48	-00 58 59	2.1			SNR
34.3+0.1	18 50 48	+01 11 07	3.9	4.0	+60.0	HII reg
34.7-0.6	18 54 04	+01 14 17	2.6	8.7	+45.4	SNR
35.2-1.7	18 59 15	+01 09 04	4.0	1.0,3.4	+37.1,+42.8	HII reg
37.6-0.1	18 57 48	+03 59 36	1.3	4.5	+80.6	HII reg
37.9-0.4	18 59 19	+05 09 36	2.2	1.1,11.2,	+13.2,+85.6,	HII reg
				3.6	+73.4	
39.2-0.3	19 01 38	+05 22 31	1.6			SNR
41.1-0.3	19 05 05	+0.7 03 23	2.0	4.7	+38.4	SNR
43.2+0.0	19 07 54	+09 01 01	12.6	9.4,1.4,2.1	+14.3,+39.8,	HII reg
					+62.4	
43.3-0.2	19 08 39	+09 01 54	4.3	3.1,4.7,	+40.2,+60.2	SNR
				4.0	+67.2	

Galactic Co-ordinate	Equatorial Co-ordinates R.A.	DEC.	K^{o} Source Temp	Line Half-width KM/S	H_2CO Vel. KM/S	Source Type
45.5+0.1	19 11 59	+11 04 17	2.6	4.9	+59.4	HII reg
48.6+0.0	19 18 07	+13 49 13	2.0	5.6	+18.4	HII reg
49.2-0.3	19 20 42	+14 13 57	3.0	3.4	+65.6	HII reg
49.2-0.7	19 21 56	+13 59 47	1.5			SNR
49.5-0.4	19 21 23	+14 24 29	23.4	7.4	+66.8	HII reg
55.5+80.5	13 29 50	+30 39 24	2.0			Extragalactic
69.9+1.5	19 59 17	+33 03 52	1.1			SNR
79.3+1.3	20 26 22	+40 41 39	3.2	3.4,1.0	+5.2,+14.4	HII reg
L B						
80.9-0.2	20 37 42	+41 07 35	2.8	2.2	+7.0	HII reg
81.5+0.0	20 39 01	+41 42 49	1.8	3.0,3.6	+4.0,5.4	HII reg
81.7+0.5	20 37 13	+42 08 51	5.9	3.6,2.5	-2.7,+8.6	HII reg
111.6+0.9	23 11 39	+61 21 42	6.1	7.8	-54.4	HII reg
130.7+3.1	02 01 42	+64 38 00	6.6			SNR
133.7+1.2	02 21 55	+61 51 59	13.8	3.0,3.6	-21.6,-40.1	HII reg
133.9+1.1	02 23 10	+61 38 15	$\leq$0.5	4.8	-45.9	OH center
138.4+1.7	02 58 58	+60 20 00	$\leq$0.5			Globule
190.5-0.4	06 04 00	+19 42 00	$\leq$0.5			Globule
206.4-1.9	06 30 00	+04 54 06	1.0			HII reg

Galactic Co-ordinate	Equatorial Co-ordinates R.A.	DEC.	K^o Source Temp	Line Half-width KM/S	H_2CO Vel. KM/S	Source Type
206.5-16.4	05 39 12	-01 55 42	12.4	1.4	+9.4	HII reg
281.8+67.4	12 16 58	+06 06 09	3.0			Extragalactic
283.8+74.5	12 28 18	+12 40 00	17.9			Extragalactic
289.9+64.5	12 26 33	+02 19 38	18.1	2.2	-8.0	Extragalactic

INTRODUCTION TO DATA ON H_2O

Most research into interstellar water vapor has attempted merely to gain an impression of its distribution. Water vapor was among the first molecules to be seriously studied by astronomers. For this reason much of the data was produced before conventions insisted upon the use of Galactic co-ordinates. I have given none in the data. Velocity ranges and limiting values for temperatures are given rather than specific values. There are two reasons for this: (1) most early surveys were interested only in the discovery of the molecule; (2) receiver selectivity and sensitivity limited the abilities of the observers.

As stated before, because of the great number of over lapping sightings, I have made no attempt to specify each discovery. When I have been in doubt as to which selection to use, I have opted for B. E. Turner's et al (Astron and Astrophysic. 4, 165-172. 1970).

Object	R.A.	DEC.	Velocity Range Searched KM/S	TA. (Maximum) Limit
W1	00 00 18	66 58 00	-75.1+59.9	10.0
N 66 281	00 50 00	56 21 00	-67.5,+67.5	10.0
CIT 3	01 03 48	12 20 00	-59.5,+75.5	10.0
S 263	05 18 40	08 18 00	-60.3,+74.7	14.1
S 282	06 35 27	01 32 00	-68.2,+66.8	14.1
S 308	06 52 02	-23 45 00	-64.7,+70.3	14.1
MR 06	06 52 05	-23 51 37	-67.5,+67.5	14.1
S 292	07 02 01	-10 21 00	-73.3,+61.7	10.0
N 6C 2327	07 03 27	-11 08 11	-67.5,+67.5	10.0
MR 07	07 10 30	-13 08 07	-67.5,+67.5	10.0
IR 7	07 29 37	28 14 11	-67.5,+67.5	10.0
3 311	07 50 50	-26 19 00	-68.6,+66.2	10.0
Puppis A	08 20 18	-42 48 00	-67.5,+67.5	10.0
CRC-20197	09 42 56	-21 48 06	-67.5,+67.5	7.1
CRC+10216	09 45 18	13 30 40	-63.2,+71.8	10.0
CIT 6	10 13 18	30 49 00	-98.9,-233.9	10.0
3C 274	12 28 16.9	12 39 57	-67.5,+67.5	5.2
T CRV	12 34 30	-17 15 14	-62.8,+62.8	10.0
S 313	12 50 48	-22 35 00	+13.8,+148.8	10.0
CRC-20254	13 26 58	-23 01 25	-66.7,+68.3	10.0
RG-A Boo	14 13 21.5	19 25 25	-67.5,+67.5	7.1
CIT 7	15 25 30	19 44 00	-68.5,+66.5	5.0
CRC+00266	15 26 17	04 00 12	-67.5,+67.5	10.0
L 134	15 50 50	-04 26 00	-65.3,+69.7	10.0

Object	R.A.	DEC.	Velocity Range Searched KM/S	TA. (Maximum) Limit
S1	15 55 51	-25 59 00	-67.5,+67.5	10.0
	15 55 51	-26 16 00	-67.5,+67.5	10.0
IRC+36283	10 08 12	25 12 00	-67.5,+67.5	10.0
SCO X-1	16 17 05	-15 31 13	-68.5,+66.5	10.0
S 27	16 31 13	-11 34 01	-67.5,+67.5	10.0
	16 31 36	-09 30 00	-67.5,+67.5	10.0
	16 34 22	-10 28 00	-67.5,+67.5	10.0
RG-A Sco	16 26 20	-26 19 23	-67.5,+67.5	10.0
G Hcr	16 27 00	-41 59 26	-67.5,+67.5	10.0
W 21	17 17 56	-00 57 00	-67.5,+67.5	7.1
N6C 6357	17 21 30	-34 08 38	-67.5,+67.5	7.1
	17 22 12	-34 19 35	-67.5,+67.5	10.0
W 23	17 30 39	-32 31 19	-67.9,+69.1	10.0
L	17 30 09	-32 52 43	-67.9,+69.1	10.0
Loo Boo	17 42 25	-28 55 12	-67.5,+67.5	10.0
NGC 6514	17 59 14	-23 02 00	-67.5,+67.5	10.0
W 30	17 59 58	-21 47 00	-47.5,+87.5	10.0
	18 02 26	-21 40 00	-47.5,+87.5	10.0
M8	18 00 06	-24 23 00	59.5,+75.5	10.0
W 3	18 06 24	-20 19 53	-57.5,+77.5	7.1
W 33	18 11 12	-19 01 30	-25.1,+100.1	10.0
W 37	-13 45	-13 40	-47.5,+87.5	10.0
	18 16 00	-13 48 00	-47.5,+87.5	14.1
W 41	18 31 47	-09 00 50	+2.5,+137.5	7.1

Object	R.A.	DEC.	Velocity Range Searched KM/S	TA. (Maximum) Limit
W 42	18 34 02	-07 26 00	-17.5,+117.5	7.1
Cygnus 2	20 19 57	37 19 00	-67.5,+67.5	10.0
Cygnus 4	20 26 54	38 56 00	-67.5,+67.5	10.0
NGC 3246	21 51 30	46 46 00	-67.5,+67.5	10.0
NGC 7538	23 11 23	61 13 50	-67.5,+67.5	10.0

REFERENCES

1. (Wilson, 1974).

2. G. R. Caughlan and W. A. Iowler, Astrophysc., 71, 868. 1970.

3. H. Spinrad, L. D. Kaplan, R. Connes, J. Connes, J. Knude, "Proceedings of the Conference on Late Type Stars" Kitt Peak Nat. Observ: Contrib. 554, 1970.

4. J. I. Clauser and P. Thaddeus, Topics in Relativistic Astrophysics. S. P. Maran and A. G. U. Cameron, Eds., Gordon and Breach, New York. (Based upon second rotational states of C. H. and CH at 1.32, .559 and .359 MM).

5. L. J. Stief, B. Donn, S. Glicker, et al "Photochemistry and Lifetimes of Interstellar Molecules." Astrophysc. J. 171, 1972.

6. Ibid.

7. G. Sandell, K. Mattila, "Radiation Density and Lifetimes of Molecules in Interstellar Dust Clouds," Astron. and Astrophysc. 42. 1975.

8. Ibid.

BIBLIOGRAPHY

T. Gold. "The Alignment of Galactic Dust" MNRAS 112, 215 (1952).

J. M. Greenberg. "Interstellar Grains" in Nebulget Interstellar Matter, B. M. Middlehurst and L. H. Aller, Ed., University of Chicago Press. (1968).

C. E. Hewish. "Normal OH Emission and Interstellar Dust Clouds," Ap. J. 157, 123 (1969).

L. M. Hobbs. "Regional Studies of Interstellar Sodium Lines." Ap. J. 158, 461 (1969).

R. V. Jones and L. Spitzer, Jr. "Magnetic Alignment of Interstellar Grains." Ap. J. 147, 943 (1967).

K. Kvenvolden, J. Lawless, K. Poring, E. Peterson, J. Flores, C. Ponnamperuma, I. R. Kaplan, and C. Moore. "Evidence for Extraterrestrial Amino-Acids and Hydrocarbons in the Murchison Meteorite" Nature 228, 923 (1970).

D. M. Rank, C. H. Townes, and W. J. Welch, "Interstellar Molecules and Dense Clouds" Science, 174, 1083 (1971).

L. Spitzer Jr., and M. Schwarzschild, "The Possible Influence of Interstellar Clouds on Stellar Velocities." Ap. J. 114, 394 (1951).

L. J. Stief, B. Donn. B. Glicker, E. P. Gentieu and J. E. Mentall. "Photochemistry and Lifetimes of Interstellar Molecules," Ap. J. 171, 21 (1972).

Ap J. 164 L23 (1971) 100 N map Galactic center

Ap J. 157 123 (1967) Temp and OH optical depth in Dust Clouds.

Astrophysics and Space Science 6, 422 (1970) Cocoon sight.

Ap. J. 179 L107 (1973) Hyperfine structure of DCN.