Infrared giants vs. supergiants

II. CO observations

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Received March 21; accepted September 17, 1997

Abstract. We report systematic observations of millimeter CO emission from a sample of 109 oxygen-rich evolved stars (AGB and supergiants), colour-selected from the IRAS Point Source Catalog ($0.69 < S_{25\mu\text{m}}/S_{12\mu\text{m}} < 1.20$). CO(1–0) has been searched with good sensitivity in 81 sources (74% of the sample). CO(1–0) is detected in 54 sources and a significant upper limit has been achieved in 27 sources.

In our previous paper we reported on the statistical results of these observations. We showed that in almost 50% of the sources, the ratio of the IRAS 60 μm flux to CO intensity, $\mathcal{R} = S_{60}/T_{\text{mb}}(1-0)$, is larger by a factor of 3 to more than 10 than what is expected according to the correlation found by Nyman et al. (1992). Supergiants only exhibit very high values ($\gtrsim 200$). In most cases, the observed spread in the values of this ratio can be explained by a large range of luminosities. This leads to a new criterion to identify AGB stars: an object with $\mathcal{R} < 150$ must have a low mass progenitor.

Here we study the correlations between $\mathcal{R}$ and various physical properties of the sources. Most sources with high values of $\mathcal{R}$ also have low galactic latitudes, small IRAS variability indices, and early spectral types (typically M1–M5). Conversely, there is no dependence on the IRAS colours, nor on the intensity of silicate 10 μm emission. However, a few AGB stars exhibit large $\mathcal{R}$; other factors than luminosity are required to explain these values. Different hypotheses, such as the possible presence of a chromosphere, a low ^{12}C abundance or a variable mass-loss rate, are examined. Considering the global high OH detection rate ($\sim 67\%$), we studied the correlations with CO and OH emission. The detection of OH seems to be a useful discriminator of mechanisms that enhance $\mathcal{R}$.

Key words: molecular processes — stars: circumstellar matter — stars: mass loss — stars: supergiants — radio lines: stars

1. Introduction

Circumstellar envelopes around evolved stars, in particular AGB stars and late-type supergiants, are a two-fluid system, composed of gas and dust. As gas and dust are expected to be coupled both dynamically and chemically, it is natural to look for correlations between their characteristics, and in particular their emission properties.

A consensus has grown (see e.g. Habing 1995, and references therein) concerning the essential role of dust driven out by radiation pressure in the generation of the largest mass-loss rates and the general complexity of mass-loss mechanisms. There is no simple universal estimator of mass-loss rate. Every estimator must be carefully tested with the help of both realistic physical models, and large statistical samples. However, it has been confirmed that among these estimators, the most useful for massive molecular and dusty envelopes are the intensity of millimeter CO lines and the far-infrared emission.

Because of its great stability, CO is thought to concentrate almost all the carbon in AGB oxygen-rich circumstellar envelopes, with the limitation that the radial extension is limited by photodissociation by interstellar UV radiation (see Mamon et al. 1988, and references therein). The intensity of millimeter lines was proposed by Knapp & Morris (1985) as a precise estimator of mass-loss rate. In parallel, the study of the dust component has been greatly improved by the use of IRAS colours (see e.g. van der Veen & Habing 1988; van der Veen 1991) and low resolution spectra (LRS, IRAS Science Team, 1986). In particular, a simple approximate relation using the 60 μm flux can be used to infer the dust mass-loss rate of large samples of sources (Jura 1986).

With the availability of large databases of CO observations (Nyman et al. 1992; Loup et al. 1993), it has been possible to compare CO and far-infrared emissions for all types of circumstellar envelopes. Both resulting determinations of the mass-loss rates appeared roughly consistent, as shown by Nyman et al. (1992), with a narrow

range of the ratio between the CO and 60 μm intensities for most sources. However, it had been known for a long time that the correlation between CO and far-infrared emission does not hold for some “extreme” objects. In particular, Heske et al. (1990) have shown that in the coldest OH/IR stars CO emission is generally weaker by at least one order of magnitude than that expected from the mass-loss rate deduced from the 60 μm IRAS intensity. Heske et al. partly explained such deficient CO emission by the very low kinetic temperature in those very cold envelopes or/and by variations of their mass-loss rates (see also Kastner 1992; Groenewegen 1994; Justtanont et al. 1994; Delfosse et al. 1996).

Our study focuses on a class of slightly warmer O-rich IRAS sources. We attempted to avoid previous biases due to selection criteria, such as the avoidance of the Galactic plane. Furthermore, our CO observations were conducted with a better sensitivity. In the first paper of this series, (Josselin et al. 1996, hereafter Paper I), we presented a statistical study of the CO observations of these objects, with a discussion of the S_{60}/T_{mb} ratio. The peak temperature of the CO line was preferred to the integrated intensity as it is easier to derive an upper limit for T_{mb} than for I_{CO} for the numerous non-detections. Furthermore, it stresses the distinction between AGB stars and supergiants, through the effect of the expansion velocity ($I_{\text{CO}} \propto T_{\text{mb}} V_{\text{exp}}$). We showed that a low CO emission with respect to the far-infrared emission occurs in fact in a significant fraction of O-rich envelopes. The objects in our sample have intermediate values of mass-loss rates and IRAS colours. They are located in regions IIIa1 and IIIa2 of the IRAS colour-colour diagram of Fig. 1 (i.e. $0.69 < S_{25}/S_{12} < 1.20$, where S_{12} and S_{25} are the 12 and 25 μm IRAS fluxes, respectively). This is a region where the 10 μm silicate feature is usually in emission and where many OH/IR stars are located (but not the coldest ones), as well as dusty supergiants. Their mass-loss rates are expected to be a few $10^{-6} - 10^{-5} M_{\odot}/\text{yr}$.

In this second paper, we detail the analysis of the set of CO data now available. In Sect. 2, we describe the observations of CO and OH. In Sect. 3, we show correlations of the $\mathcal{R} = S_{60}/T_{\text{mb}}(1-0)$ ratio with stellar characteristics, such as galactic coordinates, variability, and spectral type. In Sect. 4, we discuss the possible causes of a high $\mathcal{R}$ value in an AGB star. In Sect. 5, we compare CO and OH observations. Finally, we discuss some peculiar sources. Two forthcoming papers will deal with visible spectroscopy (hereafter Paper III) and infrared photometry (Paper IV), basis of the determination of luminosity, opacities and mass-loss rates.

Fig. 1. 12/25/60 μm IRAS colour-colour diagram of studied sources. The regions are those defined by van der Veen & Habing (1988), Omont et al. (1993). Objects with $S_{60}/T_{\text{mb}}(1-0)$ ratio larger and smaller than 100 Jy/K are represented by empty and full circles, respectively. All objects presented in the summary tables (see Appendix: Tables 7 to 11) are plotted here

2. Observations

2.1. Selection of the objects

Our main sample consists of all oxygen-rich sources in regions IIIa1 and IIIa2 (Fig. 1) from the list given by Omont et al. (1993). It contains all “northern” ($\delta > -34^\circ$) O-rich IRAS sources with a limit on the total mid- and far-infrared flux measured by IRAS (see Equats. (1) and (2) in Omont et al.): $F_{\text{IRAS}} \geq 400 L_{\odot}$ at 1 kpc, where F_{IRAS} is estimated according to (Loup et al. 1993)

$$F_{\text{IRAS}} = (6.9 S_{12} + 2.6 S_{25} + 1.2 S_{60}) L_{\odot} / (4\pi \text{ kpc}^2)$$

with the IRAS fluxes S_{λ} given in Jy. The oxygen richness is recognized mostly from the strong silicate emission band in the IRAS LRS spectra and in a few cases from known OH maser emission (see also Lewis 1995). This main sample was systematically observed in CO.

The limitation on IRAS fluxes of our sample guarantees a relative completeness for nearby (distance $\lesssim 2.5$ kpc) AGB stars which satisfy the colour criteria. But supergiants will be selected deeper ($\lesssim 10$ kpc), as they are more luminous. An important proportion of bright oxygen-rich IRAS sources is thus made of massive stars.

The similarly selected sample in the southern part of the sky ($\delta < -34^\circ$) contains 88 objects. It was however not systematically observed in CO.

2.2. Determination of the positions

The half power beam widths of the IRAM 30-m telescope are $22''$ for the 3 mm SIS receiver used to observe the

Table 1. Log of the observations

Period	telescope	observed lines	code	new detections (main sample)	new detections (misc. objects)	significant non-det. (main sample)
09/1988	IRAM-30 m	CO(2–1)	1	1	4	
03/1992, 03/1993	SEST	CO(1–0)	2	2	3	1
04/1993	IRAM-30 m	CO(1–0), CO(2–1)	3	14	4	2
07–08/1994	IRAM-30 m	CO(1–0), CO(2–1)	4	24	3	20

CO(1–0) line and $\sim 12''$ (theoretically $10.4''$, without taking into account a typical pointing jitter) for the 1.3 mm G1 SIS receiver used to observe the CO(2–1) line. As the position uncertainties of the IRAS Point Source Catalog (PSC) can reach 10 to $20''$ along the major axis of the error ellipse, we had to determine positions with a higher accuracy in order to have reliable CO measurements, in particular in the cases of non-detection or weak emission. To obtain better coordinates, we used the “XY machine” built by R. Vitry and F. Sevre (both at IAP), to measure the source positions on the prints of the Palomar Observatory Sky Survey (POSS). We used the SAO reference catalog for southern objects and the Agk3 catalog for northern objects. This gives a position accuracy better than $3''$, but this method misses objects that are too dust-obscured to be detected in the visible, i.e., with a R magnitude fainter than ~ 20 . This was not a problem for most of our sources; only a few of the coldest ones were not identified on the visible prints.

(Remark: Since then, the PPM catalogue has been implemented on this machine. The accuracy of the measured positions is now about $1''$.)

2.3. CO observations

A log of the observations is described in Table 1. We performed three runs of observations with the IRAM-30 m-telescope in 1988, 1993 and 1994 (runs 1, 3 and 4 in Table 1), and two at the SEST telescope in 1992 and 1993 (run 2 in Table 1). In total we observed 70 sources of our main sample. CO was previously detected in 17 objects by other observers. For the southern sample, only 5 objects have been observed (Table 10) and 10 were previously detected, mainly by Nyman et al. (1992). For various reasons, we also observed a few miscellaneous sources with different infrared colours which we add to the results. The total numbers of new detections and significant non-detections (see Sect. 3.1) are summarized in Table 1.

2.3.1. Observations at SEST

Observations have been done with the 15 m SEST telescope at ESO in March 1992 and March 1993 (run 2 in Table 1). We observed the CO(1–0) line only. Telescope

and system parameters are given in Table 2. As with the IRAM antenna, we observed in dual beam switch mode. The beam separation was $11'$. The velocity resolution was 1.8 km s^{-1} . These CO(1–0) observations were typically a factor 8 less sensitive than IRAM observations, because the SEST antenna is twice smaller in diameter, and the SEST Schottky receiver was about twice less sensitive than the IRAM SiS receiver. This explains why we made fewer detections with the SEST than at IRAM.

2.3.2. Observations at IRAM

For the 3rd and the 4th runs, both the CO(1–0) and CO(2–1) lines were observed simultaneously with the 3 mm and 1 mm SIS receivers. Their characteristics are given in Table 2. The velocity resolution was 2.6 and 1.3 km s^{-1} for the CO(1–0) and CO(2–1) lines, respectively. The observations were made in position switching mode with the wobbling secondary mirror, which provides very flat baselines. The calibration was done by successive observations of a cold load, a room temperature load and the sky.

The first observations, made in 1988, concerned mostly a few supergiants, and were limited to the CO(2–1) line. Its detection can be achieved with a shorter integration time than the CO(1–0) line, as its intensity is higher. However, the data analysis is more difficult, as the $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ ratio varies within a class of objects (see Sect. 4.4).

The present study of CO emission is mainly based on the CO(1–0) line. Its measurement is more reliable than that of CO(2–1). As the beam is nearly twice as wide, pointing errors have less influence on the measured intensity. It also means that the values given for the CO(2–1) line intensity are under-estimated in many cases.

A problem often encountered is interstellar contamination (see Fig. 2 and Heske et al. 1990). The presence of interstellar emission affects the quality of the detection or of the upper limit on the CO emission. Since the data were obtained in position switching mode, we tried to reduce the size of the offset to eliminate contamination. As often as possible, we used an offset of $30''$. In some cases we had to reduce it to $20''$ or even $15''$. Assuming a point source (i.e., a Dirac distribution) and a gaussian beam,

Table 2. IRAM-30 m-telescope and SEST-15 m-telescope efficiency data. The conversion from antenna to main-beam temperature is done according to $T_{\text{mb}} = T_{\text{a}} \times \text{forward efficiency}/\text{beam efficiency}$. The efficiency values correspond to rather good observing conditions and are given in main beam scale (see IRAM Newsletter No. 5 (1992) and 18 (1994))

runs	Line	Receiver	Half power beam width	Main Beam Efficiency	Forward Efficiency
IRAM, runs 3,4	CO(1-0)	3 mm SIS	22''	0.68	0.92
	CO(2-1)	1.3 mm G1 SIS	10.4''	0.39	0.86
SEST, run 2	CO(1-0)	Schottky	45''	0.70	...
IRAM, run 1	CO(2-1)	1.3 mm G1 SIS	11.6''	0.45	0.90

the subtraction of the intensity at the OFF position with small offsets induces a loss of 10% and 28% of the signal for the 20'' and 15'' offsets, respectively, for the CO(1-0) observations at IRAM (half power beam width of 22''). For an offset of 30'', the loss is 0.5%, and is considered as null. The affected measurements have been corrected by these factors. On a bright source unresolved by the IRAM-30 m-telescope, IRAS 22272+5435, a change in the offset from 30'' to 20'' induced a signal loss of 13%. This is reasonably consistent with our predictions. We then corrected the fluxes of the objects observed in such a way according to the calculated losses given above.

Fig. 2. Example of interstellar contamination: IRAS 20015+3019. OH has been unsuccessfully searched for circumstellar lines, so no velocity is known for this object

We rejected some observations when the contamination was too important to give a useful upper limit. An example is shown in Fig. 2. A list of these objects is given in Table 12 (Appendix A). Observations of such objects should be made with the special procedure described by Heske et al. (1990), which is, however, more time con-

suming. Some of our detections suffered from interstellar contamination (see e.g. the spectra of 18009-2019, 18550+0130, 18554+0231... in Fig. 12). This may lead to slight under-estimations of CO(1-0) intensity. These objects are indicated by a star (*) in Table 9.

2.3.3. Results of CO observations

The numbers of detections and non-detections are summarized in Table 1 for each observing run. The results and parameters of our CO observations are listed in Tables 13 to 17. Detected sources from our main sample are listed in Table 13, other detected sources in Table 14, tentatively detected sources in Table 15, significant non-detections (see Sect. 3.1) from our main sample in Table 16, and other significant non-detections in Table 17. In these tables, the expansion velocity is defined as half the full line width at zero power, and temperatures at the peak of the line are given in the main beam scale. The spectra of the new detections are shown in Figs. 10 to 12.

2.4. OH observations

Many sources of our main sample have been previously searched for 1612 MHz OH maser. We performed some observations with the Nancay radiotelescope, in order to improve the statistics. The observations were done in January and February 1995. The total observing time per source (ON+OFF) was one hour. One can then reach an rms of ~ 0.05 K. The velocity range where OH was searched was 144 km s^{-1} wide, centered on the star velocity if it was known from CO, or 288 km s^{-1} wide, centered on 0 if no velocity information was available.

The half-power beamwidth is $3'.5$ in α and $18'$ in δ . The ratio of flux to antenna temperature is 1.1 Jy K^{-1} at 0° declination. We obtained 6 new detections and 11 significant non-detections. The results are presented in Table 3 and are analyzed in Sect. 5. Tables 7 to 11 indicate for all the sources studied here whether they have been detected in OH or not, or not searched for OH emission.

Table 3. New OH observations made at the Nancay radiotelescope. Blue and red peak velocities and fluxes are given in km s^{-1} and Jy, respectively. Search for H_2O emission is compiled in Brand et al. (1993 and references therein)

IRAS name	V_b	V_r	F_b	F_r	V_{LSR}	V_{exp}	rms	H_2O
02153+5711							0.05 K	—
03572+5509							0.05 K	
07054-1039							0.05 K	+
17361+5746							0.05 K	
18386-0624	50.0	94.1	9.17	4.97	72.1	22.1		
18450-0922	-28.5		0.22					
18522+0021							0.05 K	-
18531+0016							0.05 K	+
19231+3555	-34.8	-13.9	0.85	1.85	24.4	10.5		-
19371+2855							0.05 K	+
19374+0550	-32.3	-0.9	0.59	1.35	-16.6	15.7		
20015+3019							0.05 K	
20194+3646							0.05 K	
22345+5809	-29.1	-21.5	0.33	0.38	-25.3	3.8		-
22546+6115							0.05 K	-
23000+5932	-32.0	-24.4	0.15	0.22	-28.2	3.8		
23278+6000							0.05 K	-

2.5. Summary of the source properties

We summarize the properties in Tables 7 to 11. Our main sample consists of the sources of Tables 7 and 9. In Table 9, sources are classified as a function of spectral type. First we list first supergiants, second identified giants, third objects with indications of spectral type without luminosity class, and finally sources with no information on spectral type. We give associations when available, with a priority on visible ones. IRAS parameters (variability index, colours, $60\ \mu\text{m}$ flux, LRS type) are indicated. We give the coordinates used during the observations and, when we measured them ourselves, the distance to the IRAS position. Finally, we give the galactic latitude, spectral type and OH detection, together with the value of $\mathcal{R}$. Table 12 lists the sources that are too strongly contaminated by interstellar features to be analyzed.

Tables 13 to 17 summarize CO observation parameters: LSR and expansion velocities, main beam temperature CO intensity if the source is detected, upper limit if not, and $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ and $\mathcal{R} = S_{60}/T_{\text{mb}}(1-0)$ ratios.

3. Analysis of CO observations

3.1. Distribution of $S_{60}/T_{\text{mb}}(1-0)$ values

In Paper I we showed that for a “normal” AGB star the typical value of $\mathcal{R} = S_{60}/T_{\text{mb}}(1-0)$ ranges between 20 and 220 Jy/K, with a mean value ~ 50 (T_{mb} is measured with a 30 m-antenna). In fact, only objects with extreme values of parameters can display $\mathcal{R}$ values above 120. Nevertheless, we found 37 objects out of 81 ($\sim 46\%$) with $\mathcal{R}$ larger than 120. The distribution is shown in Fig. 3. Non-detections are considered significant when $S_{60}/(2 \times \text{rms}(\text{CO}(1-0))) > 120$. As in Paper I, we de-

fine two groups: group 1 contains objects with $\mathcal{R} \leq 100$ and group 2 those with $\mathcal{R} > 120$ (Table 3.1).

Fig. 3. Distribution of the northern ($\delta > -34^\circ$) sources of regions IIIa1 and IIIa2 as a function of $S_{60}/T_{\text{mb}}(1-0)$. The grey-filled histogram refers to sources detected before our program, the “paved” histogram adds our detections and the empty one adds non-detections. In this case, $2 \times \text{rms}$ is taken for $T_{\text{mb}}(1-0)$

The discussion below is based on the assumption that the IRAS S_{60} flux is reliable, i.e. that it does not suffer of interstellar contribution, which would increase the $\mathcal{R}$ ratio. This could not be the case for a few objects, in particular those at low galactic latitude. Nevertheless, as

Table 4. Relation between $\mathcal{R} = S_{60}/T_{\text{mb}}(1-0)$ and spectral type, galactic latitude, and the IRAS variability index *var*

	Group 1 $\mathcal{R} < 100$	Group 2 $\mathcal{R} > 120$
Total	40	39
lum. class I	0	18
lum. class III	12	10
$\leq M5$	2	22
$\geq M6$	24	10
$ b < 5^\circ$	13	31
$ b > 5^\circ$	27	8
<i>var</i> < 80	11	25
<i>var</i> > 80	29	10

no correlation appears between the $\mathcal{R}$ ratio and $C_{32} = \log((25 \times S_{60})/(60 \times S_{25}))$ (Fig. 7), such an effect must be negligible. This is confirmed by the examination of the spectral energy distributions from 1 to 60 μm (Paper IV) which do not exhibit any excess at 60 μm .

Among the 37 sources with $\mathcal{R} \geq 120$, 22 (59%) have spectral types earlier than M5. The galactic distribution of our main sample is shown in Fig. 4. The highest values of $\mathcal{R}$ are clearly concentrated at low galactic latitude ($|b| < 5^\circ$). This is characteristic of a young disk population. This link with the initial mass of the star is confirmed by the correlation between $\mathcal{R}$ and the IRAS variability index, as shown in Fig. 5. High $\mathcal{R}$ values are preferentially found in objects with little or no known variability. Together with the average low galactic latitude, these are common characteristics of supergiants.

Table 9 shows that the 18 sources from our main sample identified as red supergiants (see Paper III) all have $\mathcal{R}$ larger than 160. In Paper I, we demonstrated that supergiants are expected to have high $\mathcal{R}$ values from about 200 to 2000, mainly because of their high luminosity, but also because of a relatively small photodissociation radius (R_{CO}). Among the identified supergiants, only 3 have been detected in CO: 17513–2313, 19307+1338 and 22512+6100 (the latter is only a tentative detection). All display very high values of $\mathcal{R}$ (306, 293 and 830, respectively).

As shown in Paper I, the value of $\mathcal{R}$ is a new tool to distinguish AGB stars from infrared supergiants. Indeed, both from theoretical (Loup et al., in preparation) and observational points of view, it is clear that an object with $\mathcal{R} < 150$ must be an AGB star and hence have a low mass progenitor. In our main sample, this leads to the identification of 13 new AGB stars with no spectral type, and 9 for with spectral types but without a known luminosity class.

However, we may not conclude that all the sources with a high $\mathcal{R}$ value are supergiants, as we find some counter-examples in our sample, as discussed in Sect. 4.1.

Fig. 4. Correlation of the $S_{60}/T_{\text{mb}}(1-0)$ ratio with the galactic latitude. Objects detected in CO(1–0) are represented by filled circles. Objects not detected in CO(1–0) are represented by bars and $2 \times \text{rms}$ is taken for $T_{\text{mb}}(1-0)$. Star symbols represent upper limits on CO emission, affected by interstellar contamination

3.2. Correlation with IRAS colours and LRS spectra

In the limited range of IRAS colours considered here, there is no correlation of $\mathcal{R}$ with either $C_{21} = \log((12 \times S_{25})/(25 \times S_{12}))$ or with $C_{32} = \log((25 \times S_{60})/(60 \times S_{25}))$, as shown in Figs. 6 and 7, respectively. The C_{21} colour is considered as a good estimator of opacity, and so we deduce that in this range the current mass-loss rate has no appreciable effect (see details in Paper IV). This does not exclude an influence of the mass-loss history.

We also looked for a possible correlation with the IRAS Low Resolution Spectra (LRS) type (IRAS team, 1986). For the range of infrared colours of our sample, objects with LRS types $2n$ and, in particular, types 28–29 (indicating strong silicate emission), are dominant. Some objects may be sufficiently optically thick to display self-absorption of silicate features. In particular it is well-known that some $4n$ objects are indeed oxygen-rich but a self-absorbed silicate feature at 9.8 μm can be confused with SiC emission at 11 μm . Such objects with a LRS type $4n$, but for which the chemical nature is established thanks to OH masers, are excluded in Fig. 8, as the LRS type is then meaningless. As far as objects of $2n$ class are concerned, no clear correlation with the index n ,

Fig. 5. $S_{60}/T_{\text{mb}}(1-0)$ ratio vs. IRAS variability index. For the meaning of the symbols, see Fig. 4

Fig. 6. $S_{60}/T_{\text{mb}}(1-0)$ vs. IRAS colour C_{21} for the main sample (Tables 7 and 9). The symbols are the same as in Fig. 4

Fig. 7. $S_{60}/T_{\text{mb}}(1-0)$ ratio vs. IRAS colour C_{32} . The symbols are the same as in Fig. 4

Fig. 8. S_{60}/T_{mb} ratio vs. IRAS LRS type for the northern sample of objects located in regions IIIa1 and IIIa2. This diagram is limited to $\text{LRS} = 2n$ (see text)

representing the strength of the silicate emission, seems to exist (see Fig. 8). However, there may be a slight predilection for high values of $\mathcal{R}$ in sources with low n ($n \leq 5$). Indeed, only two objects (20077–0625 and 20267+2105) out of nine with weak silicate emission ($\text{LRS} = 2n$ with $n \leq 5$) have a low value of $\mathcal{R}$ (< 100).

4. Discussion

4.1. AGB stars with a high $\mathcal{R}$ ratio

In Table 9, seven M giants (00428+6854–04575 +1251–17376–3021–17454– 3024–18556+0811–19422+3506–20010+3011) and 2 K giants (18079–1810–18450–0922) show $\mathcal{R}$ above 120. As shown in Paper I, a luminosity close to the theoretical AGB luminosity tip ($M_{\text{bol}} = -7.1$) and/or a high expansion velocity can lead to $\mathcal{R}$ values between 120 and 220, even for giants. Such objects should however be relatively rare. This may be the case for 4 M giants. There remains puzzling objects: 3 M giants (17376–3021, 19422+3506 and 20010+3011), the 2 K giants and 2 sources presumed to be AGB stars, 02407+3602 (TV Per) and 20000+4954 (Z Cyg). TV Per has a low $60\ \mu\text{m}$ flux (7 Jy) and is at high galactic latitude (-21°), likely being out of the Galactic disk where all the supergiants are located; 20000+4954 (Z Cyg) is discussed as a peculiar object in Sect. 6. One of these objects, IRAS 20010+3011 (V718 Cyg), is identified as an SRb variable star (Cameron & Nassau 1956).

For the objects with $\mathcal{R}$ values out of the range expected for AGB stars, one can consider some new factors. Observations of chromospheres in K giants are relatively common. This hypothesis is examined in Sect. 4.2. Additional causes, such as a low ^{12}C abundance or the influence of mass-loss history, are exposed in Sects. 4.3 and 4.5, respectively.

4.2. Chromospheres and photodissociation

The presence of a chromosphere in supergiants is widely accepted. The luminosity of supergiants combined with other parameters can explain large $\mathcal{R}$ values, but a low CO abundance is not excluded. In particular, in the case of α Ori (which has bluer colours than those of our sample), for which the carbon abundance problem has been largely addressed (see e.g. Huggins et al. 1994), it has been shown that the CO abundance is very low, but the dust condensation is also reduced and the $60\ \mu\text{m}$ emission lowered. Consequently, $\mathcal{R}$ has a “normal” supergiant value (1500).

The presence of a chromosphere in AGB stars might raise $\mathcal{R}$ by producing UV radiation which photodissociate CO. However, it has not been clearly established that all AGB stars, especially O-rich ones, have chromospheres, and even if present, the chromospheres of M giants would be very thin ($\lesssim 0.2 R_*$) (Eaton & Johnson 1988). Pasquini

& Brocato (1992) have shown that chromospheric activity in M giants on the RGB is linked to stellar mass via

$$F'_k \sim T_{\text{eff}}^\alpha (M/M_\odot)^\beta$$

with $\alpha = 8.09 \pm 0.57$ and $\beta = 1.0 \pm 0.1$. F'_k is the CaII K line flux, which traces the chromospheric activity. This is consistent with the fact that, in view of the range of $\mathcal{R}$ values, photodestruction would occur preferentially in massive objects. But this activity remains dependant on the evolution stage.

Another possible source of UV radiation is the interstellar medium, and in particular OB associations, where many supergiants are located. This UV field is particularly intense in the Galactic Plane. Whatever the origin of the UV field, the efficiency of photodissociation depends on the structure of the circumstellar envelope. As emphasized by Bertoldi & Draine (1996) for molecular clouds, photodissociation occurs in a transition layer between a relatively dense cloud and a tenuous medium, so that the clumpier the medium, the more efficient the photodissociation. This could be applicable to the interface between the atomic and molecular media in a circumstellar envelope. On the basis of observational evidence, Skinner & Whitmore (1988) asserted that M supergiants lose mass in the form of blobs. This would generate an envelope with a clumpy structure, comparable to that of a molecular cloud. The increased surface area of the interface could make photodissociation more efficient than if the envelope was smooth and unclumped. A photo-induced chemistry may dominate in these clumps (see e.g. Howe et al. 1994) and carbon could be present in forms other than CO. This theory is less meaningful for most AGB stars, since their envelopes are generally spherically symmetric and probably not very clumpy, at least at relatively large scale.

4.3. Abundance of carbon

For massive stars ($M \gtrsim 3-4 M_\odot$), hot-bottom burning occurs if the temperature is sufficiently high ($T \gtrsim 4 \times 10^7\ \text{K}$). ^{12}C is then partially converted into ^{13}C and ^{14}N , via the CNO cycle (see e.g. Renzini & Voli 1981; Leisy & Dennefeld 1995). The star will then be relatively ^{12}C -poor. On the contrary, if the temperature is relatively low, the envelope will be enriched in ^{12}C produced during the 3rd dredge-up. Considering recent investigations, we suggest that a high $\mathcal{R}$ in an AGB star could reflect a low abundance of ^{12}C , much of which could have been converted into ^{13}C and ^{14}N . This hypothesis could be checked by searching for ^{13}CO . However observing ^{13}CO might be difficult, considering the weak intensity of ^{12}CO .

4.4. Line ratio $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$

The study of the $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ ratio is limited to the objects observed and detected during the 3rd and 4th runs (Table 1). In particular, it is biased towards the

least massive objects, as only 3 supergiants were detected. It should also be kept in mind that the uncertainty in both the pointing accuracy and the source position might give a lower measured intensity of the (2–1) emission and thus would lead to an underestimate of $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$. However, the observed values of the $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ ratio are consistent with what is usually observed for such objects. It appears from the data in Table 13 and Fig. 9 that $\mathcal{R}$ tends to increase with $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$.

Since the supergiants are under-represented, it is very difficult to characterize the effect of luminosity class on the $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ ratio. Nevertheless, the few cases studied earlier, including α Ori (e.g. Heske et al. 1989), show a trend towards high values of this ratio.

Such a large spread in $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ might be attributed to different processes of CO excitation. Indeed, (see e.g. Groenewegen et al. 1996), a “normal” AGB star, with a large mass-loss rate ($> 10^{-6} M_{\odot}/\text{yr}$) and an expansion velocity close to $10\text{--}15 \text{ km s}^{-1}$, has $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ close to 2.

Many authors (Kahane & Jura 1994; Sahai 1990) agree that $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ is a good estimator of excitation conditions (kinetic temperature, opacity). Kahane & Jura (1994) observed values of $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ ranging from 2.5 to 6.0, from the coldest to the warmest envelopes, with an average around 3.5. Then, the highest values of $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ (up to ~ 7) in our sample might reveal different excitation processes for objects with high values of $\mathcal{R}$, i.e., supergiants and/or massive AGB stars.

4.5. Mass-loss history

A superwind phase has already been invoked to explain a CO emission deficiency in colder objects (region IIIb2; Heske et al. 1990). This also acts on the $I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$ ratio, by increasing it, because the outer layer, main contributor to the CO(1–0) emission, becomes negligible (see details in Delfosse et al. 1996). Such a phase has been invoked by many authors to fit observations of massive AGB stars. This is consistent with the fact that the highest $\mathcal{R}$ values are observed in a massive population. However, one has to confirm that this phase can occur in objects such as those of our sample.

5. Relations between CO and OH

5.1. OH detectability

OH 1612 MHz masers have been detected in about 67% of the sources searched in our main sample. This confirms what is expected from previous systematic OH surveys (e.g. Sivagnanam et al. 1990; Eder et al. 1988) for this range of IRAS colours. OH/IR stars are indeed very numerous in regions IIIa1 and IIIa2. This high detectability increases up to $\sim 74\%$ if we consider only objects with low $\mathcal{R}$ (< 100) values, as shown in Table 5. It is only slightly

Fig. 9. (S_{60}/T_{mb}) vs. ($I_{\text{CO}(2-1)}/I_{\text{CO}(1-0)}$) plotted for the detections made at IRAM (runs 3 and 4)

smaller ($\sim 59\%$) in the objects which display a relatively low CO emission ($\mathcal{R} > 120$).

Table 5. Relation between $\mathcal{R} = S_{60}/T_{\text{mb}}(1-0)$ and OH maser detectability

	Group 1 $\mathcal{R} < 100$	Group 2 $\mathcal{R} > 120$
OH detections	31	20 (of which 6 SG and 6 giants)
OH non-detections	11	14 (of which 11 SG and 2 giants)

5.2. AGB stars with OH and weak CO

Since OH is more sensitive to photodissociation than CO, if one admits that a weak CO emission reflects photodestruction of CO, one could expect that OH masers are rare in sources with weak CO. Since this is not verified, either CO photodestruction is negligible or there are other factors favouring OH masers in these sources. An obvious explanation of the relatively high OH detection rate in group 2 can be simply an efficient OH pumping resulting from the high infrared luminosity, characteristic of these objects. It should be also stressed that the relation of OH

Fig. 10. CO(1-0) and CO(2-1) spectra of the objects detected during the 2nd run (SEST)

masers to photodestruction is complex, since OH is both destroyed and formed (from H_2O) by photodissociation.

Table 6. Comments about the OH spectra for the objects with a high $60\ \mu\text{m}$ flux to CO intensity ratio

IRAS name	spectral type	Comment
00428+6854	S/M8+ III	no published spectrum
04575+1251	M8+ III	rather good quality spectrum
07180-1314		good quality spectrum
08357-1013	M7e	one peak spectrum
17239-2812		good quality spectrum
17313-1531		good quality spectrum
17376-3021	M8+ III ?	noisy spectrum; only 1 peak
17482-2824		no published spectrum
18025-2113	M3-4 I	blue peak at $\leq 2\sigma$
18079-1810	K0-2 III	no published spectrum
18304-0728	M7:	no published spectrum
18551+0323		3 peak spectrum
18556+0811	M8+ III	one peak spectrum
18585+0900		rather good quality spectrum
19043+1009		no published spectrum
19422+3506	M8+ III	good quality spectrum
20000+4954	M5e	no published spectrum
21245+6221	M3.5 I	no published spectrum
22345+5809	K0 Ia	good quality spectrum
22525+6033	M6-7 Iab	noisy spectrum; only 1 peak
23000+5932	M2-3 I	good quality spectrum
23416+6130	M2-4 Ia	good quality spectrum

In fact, a more precise study of the OH spectra of such objects tends to reduce the number of those with

significant circumstellar OH. It is possible that a few of the OH detections may be interstellar, as only one peak is clearly visible. Since these objects are mainly at low galactic latitude, such contamination is not surprising. Also, some spectra are unusual, such as those of 18551+0323 ($\mathcal{R} = 293$, OH data from Le Squeren et al. 1992), having 3 peaks, or 22525+6033 (MY Cep, $\mathcal{R} > 364$, OH data from Sivagnanam et al. 1990), where the 1612 and 1667 MHz emission are not at the same velocity (but the signal is very faint: $\sim 0.1\ \text{K} \sim 2\sigma$). Furthermore, because of the large beam of centimeter telescopes, contamination by other sources is possible.

The remaining stars with reliable OH data are: 04575+1251 ($\mathcal{R} = 196$), 07180-1314 ($\mathcal{R} > 156$), 17239-2812 ($\mathcal{R} = 282$), 17313-1531 ($\mathcal{R} = 183$), 18585+0900 ($\mathcal{R} = 277$), 19422+3506 ($\mathcal{R} = 258$), 22345+5809 (W Cep, $\mathcal{R} > 278$), 23000+5932 (AS Cep, $\mathcal{R} > 233$), and 23416+6130 (PZ Cas, well-known supergiant only observed in CO(2-1)).

Of these, we have spectral types for 04575+1251 (M8 + III), 19422+3506 (M8 + III), 22345+5809 (K I), 23000+5932 (M3 I), and 23416+6130 (M2 - 4 I). For the two giants, while the first case is not really puzzling and may just be a very luminous AGB star, the second one is slightly more problematic.

If one considers the hypotheses considered in Sect. 4, the explanation of weak CO emission based on a chromosphere may not fit here, since OH, formed closer to the

star than CO, would also be affected. However, the clumpy structure of envelopes, especially around supergiants could contribute to protect OH inside blobs or clumps against photodestruction by UV radiation. Finally a change in mass-loss remains a possible explanation both for AGB stars and supergiants. The mass-loss is presently large for the OH masering region, but in the past the mass loss rate was small at large radii where CO arises.

In summary, the quality of the OH data does not allow precise conclusions in many cases. However, in a significant number of objects, CO lines are weak, not only with respect to the infrared emission, but also to the OH maser. The main reason is probably again the large luminosity which enhances the far-infrared pumping of OH masers. Additional effects of time variations of the mass-loss are also possible. An enhanced photodestruction of CO with respect to that of OH could be surprising. However, it could be favoured by a clumpy structure of the circumstellar envelope and by the fact that OH is not only destroyed by photodissociation but also produced by photodissociation of H_2O .

5.3. AGB stars with strong CO and no OH

Ten sources show strong CO emission but were not detected in OH. They are mainly at high galactic latitude and have spectral types typical of red giants or AGB stars. Two of them seem to have slightly self-absorbed silicates ($\text{LRS} = 1n$ or $3n$). Then their envelopes should be rather optically thick and should produce masers. Lewis (1994) has proposed possible explanations for the lack of OH 1612 MHz emission, and in particular the possible combined effect of a superwind phase (to increase the opacity) and a hot companion that emits UV radiation and destroys OH. The result is what he calls a “symbiotic nova”, but their reality is by no means proved. For statistical reasons, binarity could be a good scenario.

6. Peculiar sources

6.1. Objects of regions IIIa1 and IIIa2

IRAS 20000+4954 (Z Cyg):

One of the most striking properties of this star is its very high radial velocity ($\sim 150 \text{ km s}^{-1}$). It is a Mira variable with a relatively short period (~ 264 days, GCVS). For this type of miras, it has been suggested (see e.g. Habing et al. 1994) that radiation pressure on dust is less effective. If this is the case in Z Cyg, either dust condensation is relatively low or the star might have a low luminosity. Yet this is not consistent with the high (~ 180) value of $\mathcal{R}$. The expansion velocity measured in OH is very small: 2.1 km s^{-1} (Sivagnanam et al. 1989), and slightly greater in CO (4.5 km s^{-1}). This may indicate an asymmetric envelope. Groenewegen et al. (1996) estimated the mass-loss rate from CO(2–1) emission to be $4.1 \cdot 10^{-6} M_{\odot}/\text{yr}$.

IRAS 20194+3646 (BI Cyg):

This object is a known binary with irregular variability (Lc) and supergiant luminosity (Proust et al. 1981). It displays one of the highest value of $\mathcal{R}$: $\gtrsim 930$. Binarity may be at least partially responsible for this high value, since the geometry of the envelope is probably affected by the companion. Also, if the companion is hot, it could photodissociate CO in the external regions of the shell.

IRAS 20547+0247 (U Equ):

OH and H_2O masers have been found to vary in velocity and character in this unusual star over short timescales (Barnbaum et al. 1996). The outflow velocities are small in OH and H_2O (4 km s^{-1} and 5 km s^{-1} , respectively), and double peaked profiles are not always present. We recently detected a weak CO(2–1) line at IRAM (3 sigma) ($T_{\text{peak}} = 0.011 \text{ K}$; integrated intensity: $0.403 \text{ K km s}^{-1}$) with an expansion velocity of 16 km s^{-1} , which, unlike the masers, is in the normal range for an evolved star.

U Equ has a number of interesting characteristics that point to an unusual circumstellar environment. Its optical spectrum shows anomalously deep, yet narrow molecular absorption lines of TiO, AlO and VO and bright molecular emission lines of the same compounds. Its $25/12 \mu\text{m}$ colour indicates optically thin dust, yet the LRS spectrum shows strong silicate absorption and a strong $60 \mu\text{m}$ excess, consistent with a thick, dusty envelope. It is possible, then, that this star has a cold Keplerian disk viewed edge on, with axial nebulosity from which the optical emission arises (Barnbaum et al. 1996). The spectral type of the central star is difficult to identify with certainty. The presence of $\text{H}\delta$, $\text{H}\gamma$ and $\text{H}\beta$ absorption and an absence of photospheric molecular bands indicate an early-K spectral type, yet the presence of the Paschen series points to a warmer type, early to mid-G. Luminosity sensitive absorption lines in the blue indicate a giant luminosity.

6.2. Be stars: *IRAS 06259–1301 (FS CMa)* and *IRAS 06491–0654*

Neither object is detected in CO, with $S_{60}/T_{\text{mb}} > 168$ and 157, respectively. In these cases, the origin of the low CO emission is probably related to photodissociation by strong UV radiation from the Be stars. The case of 06259–1301 is well studied, and Brown et al. (1995) find that the star is surrounded by an inhomogeneous disk of dust and gas and has a circumstellar extinction in the FUV that could be characteristic of PAHs. H_2 is photodissociated and CO has disappeared. Other observations suggest a bipolar object (a Herbig Ae/Be star, surrounded by a disk, according to Sitko et al. 1994). In 06491–0654, two components in the wind have been identified (Hutsemekers 1985), probably due to an outburst. This object would be in a transition state between Be and B[e] stars (Jaschek et al. 1992).

6.3. Objects with warmer infrared colours

05132+5331, 07120–4433, 09076+3110, 16235+1900, 19510–5919 and 21088+6817 (Tables 14 and 17):

All these objects are located in region II in the van der Veen & Habing (1988) diagram. This indicates that they are surrounded by small amounts of circumstellar material. Indeed their LRS is of class $1n$ or $2n$ with $n \leq 3$, which, for such low opacity, indicates no silicates or very little. Then, the $60 \mu\text{m}$ flux could be more photospheric than circumstellar and so, the S_{60}/T_{mb} would be less meaningful.

7. Conclusion

We have demonstrated that the occurrence of high values of the far infrared-to-CO emission ($\mathcal{R}$) in circumstellar envelopes around evolved stars (AGB stars or infrared supergiants) is not limited to the coldest objects (Heske et al. 1990), where a low kinetic temperature was invoked to explain the high values of $\mathcal{R}$. Warmer objects, i.e., those with a lower opacity ($-0.48 < C_{21} < -0.24$) are also often found to have high values of $\mathcal{R}$. $\mathcal{R}$ is related to intrinsic parameters of the object, such as the luminosity and hence the initial mass. A low value of this ratio is characteristic of a low mass star ($M_i \lesssim 8 M_{\odot}$). As shown in Paper I, This represents a new tool to discriminate between AGB stars and supergiants. However a few AGB stars have $\mathcal{R}$ values comparable to what is observed for supergiants. The cause is not clear, but it seems that only the more massive stars ($M_i \gtrsim 3 M_{\odot}$) or peculiar objects are so affected. The mass-loss history, the geometry of the envelope, a low abundance of CO, taken together, are possible factors.

Acknowledgements. We want to thank the IRAM and SEST-ESO staffs for their assistance during the observations which constitute the basis of this paper. We also thank T. Forveille for his contribution to the first observations and a careful reading of this paper, and M. Groenewegen for the observation reported in Table 17 of CO(1–0) in U Equ. This research has made use of the Simbad database, operated at CDS, Strasbourg, France. The Nançay Radio Observatory is the Unité Scientifique de Nançay of the Observatoire de Paris, associated as Unité de Service et de Recherche (USR) No. B704 to the French Centre National de Recherche Scientifique (CNRS). The Nançay Observatory also gratefully acknowledges the financial support of the Conseil Régional of the Région Centre in France.

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Appendice

A. Summary tables

We present here tables that summarize various parameters of the studied sources: coordinates determined as explained in Sect. 2.2, IRAS properties (variability, LRS, fluxes), spectral types, OH detections, and the S_{60}/T_{mb} ratio. These tables are the basis of the statistical analysis and are referenced in the text.

The list of objects is divided according to the following: first, the observations performed before 1994 and published by several authors are presented, with the S_{60}/T_{mb} ratio using a correction for the surface of the antenna; then, we present our own observations, starting with the main sample studied here, and continuing with miscellaneous objects.

Table 7. Northern ($\delta > -34^\circ$) bright ($L_{\text{IRAS}} > 400 L_\odot$) oxygen-rich sources in regions IIIa1 and IIIa2 from Omont et al. (1993) detected in CO(1–0) before 1994. The S_{60}/T_{mb} ratio is corrected to a 30 m antenna (IRAM). Size of the other telescopes: FCRAO: 14 m; SEST: 15 m; OSO: 20 m; BTL: 7 m; NRAO: 12 m. See Table 8 for references of OH observations

IRAS name	Other name	Var	C_{21}	C_{32}	S_{60}	LRS	b	sp. type	OH	ref. OH	$\frac{S_{60}}{T_{\text{mb}}^*}$	tel.	Ref. CO
01038+1219	WX Psc	18	−0.40	−1.03	215.2	4no	−50	M10	+	7	80	IRAM	1
01085+3022	AW Psc	52	−0.45	−1.19	18.9	29	−32	M9-10 III	−	11	28	FCRAO	2
03287−1535		07	−0.33	−0.98	12.8	29	−51	M6 III	+	2	16	SEST	3
06193−0349	V654 Mon	99	−0.47	−1.02	14.2	27	−08	M10 III	−	3	44	SEST	3
06297+4045	IRC+40156	93	−0.36	−1.04	20.7	27	14	M8+ III	+	3	34	OSO	3
06300+6058	AP Lyn	99	−0.46	−1.05	45.7	28	22	M7-9	+	3	35	BTL	4
07180−1314	AFGL 5229	99	−0.26	−1.16	7.8	25	00		+	2	> 156	IRAM	5
09235−2347	LP Hya	99	−0.46	−1.03	19.7	28	19	M9	−	3	38	SEST	3
14086−0730	IO Vir	23	−0.45	−1.15	17.2	2n	50	M6-8 III	+	3	72	SEST	3
17297+1747	V833 Her	99	−0.47	−1.12	73.7	14	25	M1-2 III	−	3	20	BTL	4
17371−3021		99	−0.40	−0.99	23.4	42	00		+	2	39	IRAM	6
18333+0533	AFGL 2199	99	−0.29	−1.00	76.5	42o	06		+	p.c.	30	BTL	4
18585+0900		97	−0.27	−1.03	14.4	41	02		+	8	277	IRAM	5
20077−0625	V1300 Aql	60	−0.39	−1.07	215.5	23	−20	M:	+	3	45	BTL	4
20234−1357		99	−0.34	−0.99	11.1	27	−27	M8+ III	+	3	36	IRAM	8
20267+2105		99	−0.32	−0.92	17.8	24	−10		+	2	39	IRAM	8
22556+5833	V627 Cas	16	−0.37	−1.22	24.8	29	−01	M4 IIIe	+	7	17	NRAO	7
23496+6131	V657 Cas	25	−0.48	−1.13	45.3	27	−00	M9 III	+	7	43	FCRAO	9

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Table 8. Southern ($\delta < -34^\circ$) bright ($L_{\text{IRAS}} > 400 L_\odot$) oxygen-rich sources in regions IIIa1 and IIIa2 detected in CO(1–0) before 1994. The S_{60}/T_{mb} ratio is corrected to a 30 m antenna. See Table 8 for references of OH observations

IRAS name	Other name	Var	C_{21}	C_{32}	S_{60}	LRS	b	sp. type	OH	ref. OH	$\frac{S_{60}}{T_{\text{mb}}^*}$	tel.	Ref. CO
03074−8732		99	−0.334	−1.106	16.3	27	−29		+	3	41	SEST	1
11296−4431		80	−0.282	−1.094	8.9	24	18		+	3	56	SEST	1
12379−4959		83	−0.448	−1.098	12.1	29	13		−	3	191	SEST	1
12384−4536		22	−0.367	−1.142	26.5	24	17		+	3	47	SEST	1
15099−5509		96	−0.425	−1.127	44.8	26	02		+	3	80	SEST	2
15332−6430		99	−0.447	−1.037	11.0	26	−07		+	3	39	SEST	1
17125−4814		99	−0.269	−0.936	16.1	42o	−06		+	3	67	SEST	1
20042−4241		97	−0.466	−1.130	28.1	28	−32		−	3	50	SEST	1
20135−7152	NSV 12961	99	−0.427	−1.141	16.1	29	−32	M	+	3	134	SEST	1
23213−4521	AFGL 4296	02	−0.445	−1.137	16.8	28	−65		..		38	SEST	1

References CO:

- 1: Nyman, et al., 1992, A&AS 93, 121.
- 2: Kastner, et al., 1993, A&A.

Table 9. Summary of the properties of the observed sources of the northern main sample (O-rich sources from the regions IIIa1 or IIIa2, with $\delta > -34^\circ$). The positions given in italic are from the IRAS-PSC; the other ones were measured by ourselves (see text). When necessary, the S_{60}/T_{mb} ratio is corrected to be normalized to a 30-m antenna. When given with a $>$ sign, the S_{60}/T_{mb} ratio corresponds to a non-detection and T_{mb} was replaced by $2 \times \text{rms}$. Values marked by a star (*) correspond to observations affected by interstellar contamination. Some spectral types were determined from observations made at Lick Observatory (see text). The others were found in SIMBAD. The references concerning the OH observations correspond to: (1) this paper; (2) Le Squeren et al. (1992); (3) te Lintel Hekkert et al. (1991); (4) Sivagnanam et al. (1990); (5) Lewis et al. (1990); (6) Galt et al. (1989); (7) te Lintel Hekkert et al. (1989); (8) Eder et al. (1988); (9) Lewis et al. (1987); (10) Ukita & Le Squeren (1984)

IRAS name	Other name	Var	C_{21}	C_{32}	S_{60}	LRS	coordinates	$\Delta\alpha$	$\Delta\delta$	b sp. type	OH ref.	S_{60}/T_{mb}
02153+5711	BU Per	02	-0.48	-1.16	5.2	29	02 15 21.0 +57 11 30	+2.4	+05	-3.47 M4 Ib	- 1	> 156
02469+5646	W Per	69	-0.38	-1.11	14.9	28	02 46 55.3 +56 46 38	+1.6	+03	-2.20 M3 Ia	- 2	> 434
03030+5532	IO Per	69	-0.43	-1.10	35.1	27	<i>03 03 04.3 +55 32 33</i>			-2.25 M3-4 Iab	.	> 433
17513-2313	V774 Sgr	38	-0.46	-1.13	27.0	29	17 51 23.6 -23 13 38	0.0	00	1.23 M4-5 I	- 3	306
18025-2113	IRC-20427	83	-0.39	-0.98	38.4	2n	18 02 35.8 -21 13 59	0.0	+02	0.01 M3-4 I	+ 3	> 701
18248-1229	UY Sct	11	-0.45	-1.11	36.5		18 24 48.1 -12 29 52	0.0	-02	-0.47 M2-4 Ia	- 3	> 522(*)
19307+1338	NSV 12135	00	-0.42	-1.25	8.8	29	19 30 42.9 +13 38 11	0.0	+02	-2.73 M0 I	- 5	293
19325+2346	V336 Vul	00	-0.45	-1.01	7.6	29	19 32 35.2 +23 46 44	0.0	+01	1.83 M2-3 I	- 5	> 234
20015+3019	V719 Cyg	90	-0.47	-1.03	25.6	29	20 01 35.4 +30 19 22	+6.5	-02	-0.36 M4 I	- 1	> 250 (*)
20194+3646	BI Cyg	24	-0.45	-1.06	51.2	29	20 19 29.0 +36 46 20	0.0	+01	0.11 M2-4 Iab	- 1	> 928 (*)
21245+6221	SW Cep	01			10.6	29	21 24 32.3 +62 21 25	-0.7	+02	+8.57 M3.5 I	+ 8	> 296
22212+5542	RW Cep	01	-0.35	-0.91	27.4	26	22 21 13.9 +55 42 35	-1.7	+01	-1.12 G8 Ia-M0 Ia	- 2	> 705
22345+5809	W Cep	08	-0.46	-1.24	12.1	29	22 34 32.7 +58 09 59	-2.4	+03	0.06 K0 Ia	+ 1	> 278
22512+6100	IRC+60374	26	-0.38	-1.13	16.7	28	22 51 13.9 +61 01 02	+0.7	+04	1.60 M3-4 I	- 2	~ 830 (*)
22525+6033	MY Cep	03	-0.40	-1.12	17.1	24	22 52 32.0 +60 33 43	-1.5	+05	1.12 M6-7 Iab	+ 4	> 546
23000+5932	AS Cep	04	-0.48	-1.12	7.0	28	<i>23 00 00.8 +59 32 55</i>			-0.19 M2-3 I	+ 1	> 233
23278+6000	V582 Cas	13	-0.45	-1.15	19.2	2n	<i>23 27 52.8 +60 00 01</i>			-0.99 M4 I	- 1	> 311
23416+6130	PZ Cas	15	-0.72	-2.49	96.5	69	<i>23 41 39.1 +61 30 43</i>			-0.04 M2-4 Ia	+ 2	
00127+5437		03	-0.47	-1.25	5.5	29	00 12 44.4 +54 37 38	-1.7	+03	-7.60 M8+ III	- 4	92
00428+6854	V524 Cas	19	-0.46	-1.09	9.9	27	<i>00 42 53.2 +68 54 31</i>			6.32 S/M8+ III	+ 7	197
04575+1251	AFGL 5134	99	-0.36	-1.18	19.6	27	<i>04 57 35.4 +12 51 42</i>			-17.57 M8+ III	+ 2	196
05423+2905		99	-0.42	-0.95	10.6	29	05 42 19.1 +29 05 55	+2.6	+01	0.07 M8+ III	+ 6	30
16260+3454	V697 Her	99	-0.42	-1.06	10.3	28	16 26 00.0 +34 54 45	-3.7	+02	43.53 M9 III	+ 3	54
17361+5746	TY Dra	32	-0.48	-1.17	7.6	28	17 36 11.6 +57 46 06	-0.8	00	32.49 M6-8 III	- 1	39
17376-3021		15	-0.46	-1.00	31.6	2n	17 37 41.3 -30 21 08	-5.2	-04	0.30 M8+ III ?	+ 3	> 288
17389-2045	IRC-20378	87	-0.37	-0.87	18.9	28	17 38 55.5 -20 45 38	+12.6	-05	4.98 M8+ III	+ 2	82
17454-3024		99	-0.48	-0.92	10.1	2n	17 45 25.5 -30 24 12	+14.2	-04	-1.32 M8+ III	.	> 162
18009-2019	V4120 Sgr	99	-0.47	-1.18	46.5	29	<i>18 00 57.8 -20 19 11</i>			0.76 M8+ III	- 3	62
18079-1810		75	-0.36	-0.91	31.3	2n	18 07 57.3 -18 10 36	-11.4	-14	0.40 K0-2 III	+ 7	> 573
18450-0922		72	-0.45	-1.07	12.0	25	<i>18 45 05.4 -09 22 44</i>			-3.44 K III	- 1	> 296
18502-0253	NSV 11461	98	-0.47	-1.19	7.4	28	18 50 18.3 -02 53 10	+7.5	+01	-1.62 M9 III	.	102
18556+0811		99	-0.41	-1.30	10.3	27	18 55 40.3 +08 11 24	+10.3	+02	2.29 M8+ III	+ 8	> 186 (*)
19231+3555	NSV 12009	99	-0.41	-1.22	13.2	29	19 23 10.6 +35 55 44	+1.2	+03	9.39 M8+ III	+ 1	44
19361-1658	AFGL 2425	99	-0.43	-1.26	10.2	29	19 36 08.7 -16 58 50	-13.0	-01	-17.93 S/M8+ III	+ 3	85
19371+2855	NSV 12260	99	-0.43	-1.19	6.0	2n	19 37 07.7 +28 55 43	+4.0	+02	3.48 M8+ III	- 1	75
19422+3506	AFGL 2445	08	-0.39	-1.16	28.4	28	19 42 15.7 +35 06 52	+2.5	+01	5.59 M8+ III	+ 2	258
19586+3637	V1511 Cyg	06	-0.39	-1.15	13.1	29	19 58 38.8 +36 37 51	-3.6	+01	3.52 M10 III	- 2	123
20010+3011	V718 Cyg	17	-0.47	-1.06	8.6	27	20 01 04.8 +30 11 45	-5.2	00	-0.34 M6 III	.	> 225
20403+3700		99	-0.47	-1.05	9.7	26	20 40 23.3 +37 00 53	0.0	+02	-3.10 M8+ III	+ 6	24
23425+4338	EY And	34	-0.44	-1.15	9.2	26	<i>23 42 32.9 +43 38 43</i>			-17.34 M10 III	+ 10	84
02407+3602	TV Per	01	-0.42	-1.19	7.6	29	02 40 42.9 +36 02 21	-3.6	+01	-21.32 M2	5	> 380(*)
07536-2830	HU Pup	40	-0.33	-1.11	15.4	28	<i>07 53 38.6 -28 30 55</i>			-0.15 M3	- 2	> 768
08357-1013		15	-0.34	-1.12	10.7	25	08 35 44.5 -10 13 40	0.0	-03	18.10 M7e	+ 2	134
08391+0222	AFGL 1283	87	-0.46	-1.16	6.8	2n	<i>08 39 10.2 +02 22 05</i>			25.40 M7-9	- 5	32
18304-0728	IRC-10434	00	-0.48	-1.10	9.5	2n	18 30 28.0 -07 28 35	+1.5	-01	0.63 M7:	+ 7	> 136(*)
18386-0624	IRC -10453	99	-0.41	-1.34	7.2	2n	18 38 39.1 -06 24 52	0.0	-01	-0.66 M:	+ 1	75
18436+4334	RW Lyr	99	-0.43	-1.10	9.7	27	18 43 38.8 +43 34 55	+1.1	-01	19.41 M7e	+ 7	81
19059-2219	V2880 Sgr	99	-0.46	-1.17	34.0	28	<i>19 05 54.7 -22 19 10</i>			-13.61 M8:	+ 3	85
20000+4954	Z Cyg	00	-0.40	-1.18	10.7	69	20 00 02.4 +49 54 09	-1.9	+02	10.23 M5e	+ 7	~ 180 (*)

Table 9. continued

IRAS name	Other name	Var	C_{21}	C_{32}	S_{60}	LRS	coordinates	$\Delta\alpha$	$\Delta\delta$	b	sp. type	OH ref.	S_{60}/T_{mb}	
17122-2707		99	-0.26	-0.88	17.3	24	<i>17 12 15.5 -27 07 18</i>			6.54		+	2	108
17239-2812		87	-0.43	-1.02	19.1	23	<i>17 23 56.2 -28 13 00</i>			-0.18		+	4	282
17313-1531		99	-0.37	-1.17	9.2	2n	<i>17 31 18.6 -15 31 03</i>			9.29		+	3	> 183
17482-2824	AFGL 5146	19	-0.27	-1.02	109.1	42o	<i>17 48 16.7 -28 24 55</i>	0.0	+03	-0.83		+	2	> 1000 (*)
18069+0911		02	-0.36	-1.14	10.8	28	<i>18 06 55.3 +09 11 40</i>	+1.5	+01	13.50		+	2	72
18274-0738		99	-0.28	-1.00	15.1	31	<i>18 27 24.0 -07 39 06</i>	0.0	+09	1.23		+	2	86
18535+0726		99	-0.27	-1.17	11.5	12/2n	<i>18 53 31.5 +07 26 31</i>			2.42		+	2	64
18551+0323	AFGL 2287	99	-0.29	-0.96	21.5	42	<i>18 55 06.2 +03 23 21</i>	-6.0	+01	0.21		+	2	> 440
18554+0231		90	-0.27	-1.06	12.3	31	<i>18 55 25.7 +02 31 10</i>			-0.27		+	2	90
19043+1009		80	-0.33	-1.09	10.4	25	<i>19 04 21.2 +10 09 52</i>	+3.0	+01	1.30		+	2	208 (*)
19240+3615		99	-0.40	-1.24	11.1	29	<i>19 24 02.6 +36 15 27</i>			9.39		-	9	43
19374+0550		99	-0.45	-1.26	15.3	2n	<i>19 37 26.2 +05 50 56</i>			-7.95		+	1	73
19495+0835		99	-0.41	-1.23	11.8	28	<i>19 49 33.1 +08 35 10</i>			-9.24		+	8	54
19558+3333		94	-0.29	-0.95	12.5	31	<i>19 55 53.3 +33 33 11</i>			2.38		-	2	48
20024+1727		99	-0.32	-1.19	9.5	2n	<i>20 02 24.6 +17 27 22</i>			-7.39		+	8	37

Table 10. Observed O-rich sources from regions IIIa1 or IIIa2, with $\delta < -34^\circ$

IRAS name	Other name	Var	C_{21}	C_{32}	S_{60}	LRS	coordinates	$\Delta\alpha$	$\Delta\delta$	b sp. type	OH ref.	OH S_{60}/T_{mb}	rk
08544-4431		52	-0.37	-0.83	56.3	21	<i>08 54 29.5 -44 31 44</i>		0.39	.	.	> 213	
11179-6458	HD 98658	02	-0.47	-1.19	14.7	29	<i>11 17 58.0 -64 58 38</i>		-4.06	.	.	> 245	
13517-6515		04	-0.30	-1.09	22.4	24	<i>13 51 47.6 -65 15 55</i>		-3.46	.	.	160	
14531-5337		99	-0.45	-1.20	18.1	27	<i>14 53 08.7 -53 37 38</i>		4.62	.	.	101	
17215-7114	HD 157045	00	-0.33	-0.93	29.9	2n	<i>17 21 33.9 -71 14 38</i>		-19.24	.	.	> 311	

Table 11. Other observations (see Sect. 6 for some comments)

IRAS name	Other name	region	Var	C_{21}	C_{32}	S_{60}	LRS	coordinates	$\Delta\alpha$	$\Delta\delta$	b sp. type	OH ref.	S_{60}/T_{mb}
02192+5821	S Per		12	-1.20	-2.84	40.6	26	<i>02 19 14.5 +58 21 30</i>			-2.19 M3 I	+	7
05132+5331	R Aur	II	99	-0.72	-1.29	22.6	15	<i>05 13 15.2 +53 31 57</i>	+0.9	+02	8.97	.	32
05524+0723	α Ori		24	-1.87	-2.86	298.8	02	<i>05 52 27.8 +07 23 58</i>			-8.96 M2 I	.	
06259-1301	FS CMa	IIIa	38	-0.33	-1.14	24.8	24	<i>06 25 59.0 -13 01 12</i>	0.0	-01	-10.98 Be	-	2
06491-0654		IIIa	14	-0.37	-1.06	13.3	24	<i>06 49 07.6 -06 54 21</i>	0.0	-01	-3.14 Be	-	2
07120-4433	L2 Puppis	II	12	-0.78	-1.33	94.1		<i>07 12 01.8 -44 33 17</i>			-15.04	.	1069
07284-0940	U Mon	IIIa1	97	-0.47	-0.90	26.6	26	<i>07 28 24.3 -09 40 15</i>	+4.4	+04	4.15 K0 I	-	3
07446-3210A	IRC -30100	IIIa	00	-0.42	-1.02	21.7	27	<i>07 44 38.5 -32 10 54</i>			-3.70 A0	+	3
09076+3110	RS Cnc	II	11	-0.68	-1.19	32.6	22	<i>09 07 37.8 +31 10 05</i>	+1.3	-01	42.08	.	14
10215-5916	AFGL 4106	VIb	06	-0.62	-0.69	851.8	66	<i>10 21 32.5 -59 16 53</i>			-1.88	.	2130
10226-5229		IIIb2	20	-0.18	-1.03	16.9	42	<i>10 22 36.7 -52 29 01</i>			3.96	.	121
11438-6330		IIIb1	07	-0.01	-0.79	165.7	38	<i>11 43 48.8 -63 30 32</i>			-1.82	.	> 942
16235+1900	U Her	II	99	-0.76	-1.20	27.2	23	<i>16 23 34.7 +19 00 18</i>	-1.4	+03	40.35	.	247
17328-3327		IIIa	17	-0.45	-0.83	198.6	29	<i>17 32 53.6 -33 27 50</i>	0.0	00	-0.69 B	.	> 1374
18050-2213	VX Sgr		92	-1.53	-2.76	262.7	26	<i>18 05 02.5 -22 13 56</i>			-1.00 M7 I	+	7
18550+0130		VIb	71	-0.30	-0.67	25.5	32	<i>18 55 01.9 +01 31 01</i>	-9.0	+11	-0.64 K0/F/G I ?	-	3
19075+0921		IIIb2	93	-0.23	-0.86	54.9	12	<i>19 07 34.0 +09 21 56</i>			0.23	-	2
19510-5919	S Pav	II	22	-0.71	-1.22	29.2	14	<i>19 51 01.5 -59 19 38</i>			-31.12	.	> 456
20547+0247	U Equ	IIIa1	75	-0.45	-0.91	10.0	32	<i>20 54 45.0 +02 47 10</i>			-26.11 (note)	+	4
21027+5309	V1899 Cyg	IIIa	96	-0.46	-1.04	9.9	44	<i>21 02 43.0 +53 09 06</i>	-3.6	+02	4.30 C	.	76
21088+6817	T Cep	II	70	-0.77	-1.19	41.6	15	<i>21 08 52.5 +68 17 11</i>	-4.4	-01	13.84	.	119
22480+6002	IRC+60370	IIIb2	13	-0.23	-1.03	39.8	69	<i>22 48 00.8 +60 02 01</i>	-0.8	00	0.89 M0 I	-	2

U Equ: cf. Barnbaum et al. (1996): peculiar spectral type.

Table 12. List of sources seen as strongly contaminated by interstellar CO emission and/or absorption with no hints of circumstellar CO emission

IRAS name	Other name	coordinates			$\Delta\alpha$	$\Delta\delta$
17360–3140	IRC -30309	17 36	07.0	–31 40 50	+33.2	–01
18135–1740	AFGL 2102	18 13	29.3	–17 40 09	–21.4	+01
18522+0021	IRC+00392	18 52	14.1	+00 21 35	0.0	+02
18531+0016		18 53	08.3	+00 16 55	+1.5	+02
19135+0931	AFGL 2350	19 13	29.0	+09 31 37	–23.7	+05
22546+6115	IRC +60377	22 54	37.0	+61 15 06	–2.2	+04

Table 13. CO detections for sources of the main sample (northern sources in regions IIIa1 and IIIa2). Only the S_{60}/T_{mb} ratio is corrected for the surface when the observations were made at SEST (noted with a !). The measurements corrected for the effect of the offset reduced to avoid interstellar contamination (see Sect. 2.3.1) are marked with a*

IRAS name (km s ^{–1})	l (K)	b (K)	region (K km s ^{–1})	CO (1–0) line	V_{lsr} (Jy/K)	V_{exp}	T_{mb}	rms	I_{co}	$\frac{(2-1)}{(1-0)}$	S_{60}/T_{mb}	run
00127+5437	117.7	–7.6	IIIa2	(1–0) (2–1)	–91.4 –86.9	11.9 16.9	0.06 0.09	0.015 0.034	1.45 2.73	1.9	92 (*)	4 4
00428+6854	122.5	6.3	IIIa1	(1–0) (2–1)	–21.0 –24.5	11.5 14.5	0.05 0.19	0.015 0.019	1.1 4.5	4.1	197	3 3
04575+1251	187.7	–17.6	IIIa2	(1–0) (2–1)	1.0 0.5	15.5 15.5	0.10 0.23	0.020 0.023	2.4 5.0	2.1	196	3 3
05423+2905	179.8	0.1	IIIa1	(1–0) (2–1)	29.6 29.0	10.6 11.3	0.35 0.90	0.029 0.070	7.03 17.58	2.5	30 (*)	4 4
08357–1013	235.3	18.1	IIIa2	(1–0) (2–1)	58.0 60.0	17.5 17.5	0.08 0.18	0.020 0.045	2.3 5.7	2.5	134	3 3
08391+0222	224.2	25.4	IIIa2	(1–0) (2–1)	–34.1 –34.1	11.9 11.8	0.23 0.59	0.020 0.074	5.04 12.29	2.4	32 (*)	4 4
16260+3454	56.4	43.5	IIIa1	(1–0) (2–1)	56.0 55.5	15.5 15.0	0.19 0.35	0.026 0.028	5.1 8.9	1.7	54	3 3
17122–2707	357.8	6.5	IIIa1	(1–0)	–13.8	37.0	0.04	0.008	2.65		108 (!)	2
17239–2812	352.6	–0.2	IIIa1	(1–0) (2–1)	–27.5 –26.0	22.4 23.8	0.07 0.33	0.040 0.094	1.96 9.79	5.0	282	4 4
17361+5746	86.1	32.5	IIIa2	(1–0) (2–1)	–18.0 –17.3	9.3 10.6	0.20 0.66	0.019 0.065	3.81 12.42	3.2	39 (*)	4 4
17389–2045	6.5	5.0	IIIa1	(1–0) (2–1)	31.0 30.5	16.0 18.0	0.23 0.75	0.039 0.036	6.3 19.9	3.2	82	3 3
17513–2313	5.9	1.2	IIIa2	(1–0) (2–1)	–12.5 –11.5	30.6 30.4	0.09 0.36	0.028 0.074	4.10 18.45	4.5	306 (*)	4 4
18009–2019	9.5	0.8	IIIa2	(1–0) (2–1)	14.2 11.9	15.6 14.6	0.75 2.12	0.036 0.093	15.96 44.29	2.8	62 (*)	4 4
18069+0911	36.5	13.5	IIIa2	(1–0) (2–1)	–13.5 –13.5	16.5 18.0	0.15 0.31	0.030 0.034	4.6 8.7	1.9	72	3 3

Table 13. continued

IRAS name	l	b	region	CO line	V_{lsr} (km s ⁻¹)	V_{exp} (km s ⁻¹)	T_{mb} (K)	rms (K)	I_{co} (K km s ⁻¹)	$\frac{(2-1)}{(1-0)}$	S_{60}/T_{mb} (Jy/K)	run
18274-0738	23.7	1.2	IIIa1	(1-0)	-5.6	8.2	0.18	0.023	3.12	1.8	86 (*)	4
				(2-1)	-2.9	18.2	0.32	0.071	5.48			4
18386-0624	26.1	-0.7	IIIa2	(1-0)	49.5	12.9	0.11	0.026	2.82	2.3	67 (*)	4
				(2-1)	47.7	11.3	0.39	0.071	6.35			4
18436+4334	72.8	19.4	IIIa1	(1-0)	-20.5	11.0	0.12	0.030	2.5	2.1	81	3
				(2-1)	-21.0	10.0	0.37	0.027	5.2			3
18502-0253	30.6	-1.6	IIIa2	(1-0)	32.3	17.6	0.07	0.021	3.14	4.3	102	4
				(2-1)	33.0	18.4	0.42	0.045	13.62			4
18535+0726	40.1	2.4	IIIa2	(1-0)	47.2	21.2	0.18	0.026	5.90	2.6	64	4
				(2-1)	49.2	18.5	0.49	0.065	15.06			4
18554+0231	36.0	-0.3	IIIa1	(1-0)	8.5	24.9	0.14	0.032	4.95	2.0	90 (*)	4
				(2-1)	8.7	14.1	0.44	0.099	9.83			4
19059-2219	14.7	-13.6	IIIa2	(1-0)	21.7	19.6	0.10	0.012	2.65		85 (!)	2
19231+3555	68.7	9.4	IIIa2	(1-0)	-25.9	9.2	0.30	0.022	5.51	3.9	44	4
				(2-1)	-24.6	12.2	1.32	0.055	21.71			4
19240+3615	69.1	9.4	IIIa2	(1-0)	36.4	14.5	0.26	0.032	6.74	3.2	43	4
				(2-1)	35.6	17.8	0.89	0.076	21.63			4
19307+1338	49.9	-2.7	IIIa2	(1-0)	41.6	28.2	0.03	0.012	0.99	6.6	293 (*)	4
				(2-1)	43.6	28.2	0.14	0.043	6.57			4
19361-1658	22.8	-17.9	IIIa2	(1-0)	56.5	10.5	0.12	0.028	2.5	1.0	85	3
				(2-1)	57.5	8.0	0.15	0.032	2.4			3
19371+2855	63.9	3.5	IIIa2	(1-0)	22.8	16.7	0.08	0.014	2.49	3.0	75	4
				(2-1)	21.2	20.9	0.26	0.036	7.56			4
19374+0550	43.9	-8.0	IIIa2	(1-0)	-15.5	16.5	0.21	0.043	6.3	1.6	73	3
				(2-1)	-16.5	16.5	0.35	0.033	10.2			3
19422+3506	69.9	5.6	IIIa2	(1-0)	-49.0	18.5	0.11	0.023	3.4	3.4	258	3
				(2-1)	-49.0	19.5	0.38	0.025	11.7			3
19495+0835	47.8	-9.2	IIIa2	(1-0)	45.0	12.9	0.22	0.023	4.83	4.3	54 (*)	4
				(2-1)	44.7	13.8	1.00	0.059	21.00			4
19558+3333	70.0	2.4	IIIa1	(1-0)	7.6	16.5	0.26	0.025	5.53	1.6	48	4
				(2-1)	8.1	18.3	0.45	0.071	9.02			4
19586+3637	72.9	3.5	IIIa2	(1-0)	18.3	18.5	0.11	0.017	1.94	5.8	123 (*)	4
				(2-1)	17.1	17.5	0.51	0.045	11.16			4
20024+1727	57.1	-7.4	IIIa2	(1-0)	-1.4	9.9	0.26	0.022	4.11	1.6	37	4
				(2-1)	-2.5	7.5	0.44	0.080	6.60			4
20403+3700	78.0	-3.1	IIIa1	(1-0)	-47.4	15.6	0.41	0.019	7.89	2.6	24	4
				(2-1)	-49.6	16.3	1.10	0.042	20.38			4
23416+6130	115.1	-0.0	IIIa1	(2-1)	-49.	34.	0.55	0.09				1
23425+4338	110.5	-17.3	IIIa2	(1-0)	-41.5	13.5	0.11	0.024	2.7	2.4	84	3
				(2-1)	-41.5	15.5	0.27	0.022	6.6			3

Table 14. Other CO detections. The notations are the same as in Table 13

IRAS name	l	b	region	CO line	V_{lsr}	V_{exp}	T_{mb}	rms	I_{co}	$\frac{(2-1)}{(1-0)}$	F_{60}/T_{mb}	run
02192+5821	134.6	-2.2	IIIa2	(2-1)	-37.	17.	0.25	0.11				1
05132+5331	156.4	9.0	II	(1-0) (2-1)	-1.5 -2.0	9.0 10.5	0.7 2.0	0.046 0.056	11.2 30.1	2.7	32	3 3
05524+0723	199.8	-9.0	II	(2-1)	3.	14.	1.82	0.14				1
07120-4433	255.8	-15.0	II	(1-0) (2-1)	33.5 31.9	6.1 5.8	0.02 0.07	0.007 0.015	0.25 0.42	0.8	1069 (!)	2 2
09076+3110	194.5	42.1	II	(1-0) (2-1)	7.0 6.5	7.5 9.0	2.3 5.4	0.118 0.046	17.1 39.3	2.3	14	3 3
10215-5916	285.1	-1.9	V	(1-0)	-15.8	40.9	0.10	0.011	4.52		2130 (!)	2
10226-5229	281.7	4.0	IIIb2	(1-0)	35.8	30.3	0.04	0.009	1.15		121 (!)	2
13517-6515	309.5	-3.5	IIIa1	(1-0)	-21.1	22.9	0.04	0.007	0.85		160 (!)	2
14531-5337	320.9	4.6	IIIa2	(1-0)	-45.9	29.2	0.05	0.007	1.63		101 (!)	2
16235+1900	35.4	40.4	II	(1-0) (2-1)	-12.0 -15.0	10.0 9.0	0.11 ≥ 0.13	0.026 0.035	2.1 (2.3)	≥ 1.1	247	3 3
17080-3215	353.1	4.3	VII	(2-1)	-15.	23.	0.98	0.22				1
18050-2213	8.4	-1.0	IIIa3	(2-1)	05.	22.	1.22	0.064				1
18550+0130	35.0	-0.6	VIb	(1-0) (2-1)	37.8 39.7	9.9 12.2	0.61 0.77	0.025 0.066	5.25 10.41	2.0	42 (*)	4 4
21027+5309	92.9	4.3	IIIa1	(1-0) (2-1)	-8.0 -10.6	16.0 15.6	0.13 0.51	0.019 0.044	2.94 9.95	3.4	76 (*)	4 4
21088+6817	104.8	13.8	II	(1-0) (2-1)	-3.0 -3.5	5.0 7.0	0.35 1.17	0.071 0.025	2.4 7.0	4.0	119	3 3
22480+6002	108.4	0.9	IIIa1	(1-0) (2-1)	-47.5 -49.4	22.7 30.1	0.04 0.35	0.015 0.041	1.70 14.88	8.8	1017 (*)	4 4

Table 15. CO tentative detections. Some of them were affected by interstellar contamination and are noted with a*. In that cases, the rms was measured out of the contaminated region of the spectrum

IRAS name	l	b	region	CO line	V_{lsr}	V_{exp}	T_{mb}	rms	I_{co}	$\frac{(2-1)}{(1-0)}$	F_{60}/T_{mb}	run
02407+3602	147.0	-21.3	IIIa2	(1-0) (2-1)	-24.0	9.5	0.06	0.015 0.015	1.00	$\gtrsim 3.$	$\gtrsim 380$	3 3
18248-1229*	19.2	-0.5	IIIa2	(1-0) (2-1)	-25.5	20.7	$\lesssim 0.07$ 0.22	0.015 0.029	8.185		$\gtrsim 522$	4 4
18304-0728*	24.2	0.6	IIIa2	(1-0) (2-1)	-43.8	27.6	$\lesssim 0.07$ 0.25	0.027 0.073	~ 2.34 13.52	~ 5.8	$\gtrsim 136$	4 4
19043+1009	43.8	1.3	IIIa1	(1-0) (2-1)	-49.6 94.7	18.4 84.9	0.05 $\lesssim 0.06$	0.017 0.057	0.50 $\lesssim 1.03$	$\lesssim 2.1$	208	4 4
20000+4954	84.4	10.2	IIIa2	(1-0) (2-1)	-148.5	4.5	0.28	0.023 0.021	0.5 1.7	~ 3.4	$\gtrsim 180$	3 3
22512+6100*	109.2	1.6	IIIa2	(1-0) (2-1)	-52.0	16.5	~ 0.02 0.12	0.012 0.012	0.9 3.1	~ 3.4	~ 830	3 3

Table 16. CO non-detections. In the $S_{60}/(2 \times \text{rms})$ ratio, the rms is corrected for the surface when the observation was made at SEST (noted with a !). Only the significative non-detections (i.e. with $S_{60}/(2 \times \text{rms}) > 100$) are reported here

IRAS name	l	b	region	CO line	rms	$S_{60}/(2 \times \text{rms})$	run
02153+5711	134.5	-3.5	IIIa2	(1-0)	0.017	156	4
02469+5646	138.7	-2.2	IIIa2	(1-0)	0.017	434	4
03030+5532	141.2	-2.3	IIIa2	(1-0)	0.027	433	3
07284-0940	226.1	4.1	IIIa1	(1-0)	0.024	369	4
17313-1531	10.0	9.3	IIIa2	(1-0)	0.025	183	4
17376-3021	358.1	0.3	IIIa1	(1-0)	0.055	288	4
17454-3024	359.1	-1.3	IIIa1	(1-0)	0.031	162	4
18025-2113	8.9	0.0	IIIa1	(1-0)	0.027	701	4
18079-1810	12.2	0.4	IIIa1	(1-0)	0.027	573	4
18450-0922	24.2	-3.4	IIIa1	(1-0)	0.020	296	4
18551+0323	36.7	0.2	IIIa1	(1-0)	0.024	440	4
18556+0811	41.0	2.3	IIIa2	(1-0)	0.018	186	4
19325+2346	59.0	1.8	IIIa1	(1-0)	0.016	234	4
19510-5919	338.1	-31.1	II	(1-0)	0.008	456 (!)	2
20010+3011	67.7	-0.3	IIIa1	(1-0)	0.019	225	4
20015+3019	67.9	-0.4	IIIa1	(1-0)	0.022	250	4
20194+3646	75.3	0.1	IIIa1	(1-0)	0.018	928	4
21245+6221	101.6	8.6	IIIa2	(1-0)	0.018	197	4
22212+5542	103.2	-1.1	IIIa1	(1-0)	0.019	705	4
22345+5809	106.0	0.1	IIIa2	(1-0)	0.022	278	4
22525+6033	109.2	1.1	IIIa2	(1-0)	0.016	546	4
23000+5932	109.6	-0.2	IIIa2	(1-0)	0.015	233	4
23278+6000	113.0	-1.0	IIIa1	(1-0)	0.031	311	3

Table 17. Other CO non-detections. The reason why these objects do not belong to the main sample is recalled in the last column

IRAS name	l	b	region	CO line	rms (K)	$F_{60}/(2 \times \text{rms})$ (Jy/K)	run	remark
06259-1301	222.1	-11.0	IIIa2	(1-0)	0.049	252	4	Be star
06491-0654	219.2	-3.1	IIIa1	(1-0)	0.028	236	4	Be star
07446-3210	247.6	-3.7	IIIa1	(1-0)	0.010	272 (!)	2	A0 star
08544-4431	265.5	0.4	IIIa1	(1-0)	0.022	213 (!)	2	south
11438-6330	295.8	-1.8	IIIb1	(1-0)	0.022	942 (!)	2	$\delta < -34^\circ$
17215-7114	321.4	-19.2	IIIa1	(1-0)	0.008	311 (!)	2	south
17328-3327	355.1	-0.7	IIIa1	(1-0)	0.072	1374	4	B star
19075+0921	43.4	0.2	IIIb2	(1-0)	0.017	1586	4	region IIIb2
19510-5919	338.1	-31.1	II	(1-0)	0.008	456 (!)	2	$\delta < -34^\circ$ and region II
20547+0247	51.4	-26.1	IIIa1	(1-0)	0.025	200	4	see Sect. 6.1

Fig. 11. CO(1-0) and CO(2-1) spectra of the objects detected during the 3rd run (IRAM 30 m)

Fig. 12. CO(1-0) and CO(2-1) spectra of the objects detected during the 4th run (IRAM 30 m)

Fig. 12. continued

Fig. 12. continued