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Detection of linear C_3H_2 in absorption toward continuum sources

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Abstract. We report the detection of the 1_{01}-0_{00} line of linear C_3H_2, an isomer of the ubiquitous cyclic C_3H_2, toward the sources W51E1/E2, W51D, and W49. The line is seen in absorption against the radio continuum of these sources. The column density of *l*-C_3H_2 is very low, with typical values of a few 10^{11} cm^{-2}. The abundance ratio between the cyclic and linear isomers of C_3H_2 is found to be 3–5 in the sources where *l*-C_3H_2 has been detected. Toward Sgr B2 and 3C 123, we derive for the abundance ratio 3σ lower limits of 150 and 1, respectively.

The abundance ratio between cyclic and linear C_3H_2 in the diffuse interstellar medium appears to be an order of magnitude lower than the value obtained in TMC1 by Cernicharo et al. (1991a). This difference is probably a consequence of the distinct mechanisms leading to the destruction of the cyclic and linear isomers and/or their progenitor ions.

Upper limits to the column density of C_6H, the J=15/2–13/2 lines of which are within the observed frequency range, have also been obtained in the same sources.

Key words: line: identification – ISM: abundances – ISM: clouds – ISM: molecules – radio lines: ISM

1. Introduction

H_2CCC, a linear isomer of the widely distributed interstellar ring C_3H_2 was detected by Cernicharo et al. 1991a in the cold dark cloud TMC1. *l*-C_3H_2 (propadienylidene) is the first stable member of the cumulene carbon chains characterized by double bonds between the carbons and terminal non-bonded electrons. The rotational constants of the ground state have been derived with high accuracy by Vrtilek et al. (1990). The observed abundance ratio between cyclic and linear C_3H_2 in TMC1 is 70 (Cernicharo et al., 1991a). The same authors tried to detect the linear isomer in other sources without success but the upper limits they obtained to the intensity of the 5_{14}-4_{14} line at 102992 MHz were limited by line confusion in the sources they selected (Sgr B2 and Ori A). Only in the direction of IRC+10216 they found three lines at the right frequencies and derived a column density of 2.6 10^{12} cm^{-2}. In the same source they also detected H_2CCCC (Cernicharo et al., 1991b), the next member of the H_2C_n family, and found that the H_2CCCC/H_2CCC abundance ratio was 6, i.e., carbenes with an even number of carbons seem to be more abundant that those having an odd number of carbon atoms. H_2CCCC has also been detected in TMC1 by Kawaguchi et al. (1991). In this source they found an H_2CCCC/H_2CCC abundance ratio of 4, i.e., similar to the value found in IRC+10216 by Cernicharo et al. (1991b). To some extent, the abundance ratios between different members of the cumulene family are similar to those found for the long carbon chain radicals (Suzuki et al. 1986, Cernicharo et al. 1987a, 1987b, Cernicharo and Guélin 1996, Guélin et al. 1997). Recently, H_2C_6 has also been detected in TMC1 and IRC+10216 (Langer et al. 1997; Guélin et al. 1997).

To our knowledge, and in spite of the importance of the abundance ratio *c*-C_3H_2/*l*-C_3H_2 to probe the interstellar chemistry models (see, e.g., Adams & Smith, 1987; Bettens & Herbst 1996; 1997), no systematic search for *l*-C_3H_2 has been made in molecular clouds. In order to derive the abundance of *l*-C_3H_2, and to study the cyclic over linear C_3H_2 abundance ratio for different physical conditions, we have made a search for its absorption in the line-of-sight toward strong radio continuum sources. The selected sources have been reported to show absorption features in the 1_{10}-1_{01} transition of ortho *c*-C_3H_2 at 18.3 GHz (Matthews et al. 1986; Cox et al., 1988 - hereafter CGH; Madden et al., 1989).

Absorption line studies toward strong background continuum sources are of interest because they allow one to probe low density, low column density media where the lines of *l*-C_3H_2 will be too weak to be observed in emission with the sensitivity of available radio telescopes. Moreover, the determination of the line opacity is independent of the excitation temperature if $T_{ex} << T_c$, where T_c is the brightness temperature of the continuum source. In addition, the dynamical range is superior to that of emission line studies by a factor $T_c/(T_{ex}$ - 2.7) (see, e.g., Liszt & Lucas 1998). Such absorption line observations also allow measurements of column densities one or two orders of magnitude lower than those obtained through emission line studies. Hence, absorption line studies could allow us to derive the abundance of the long carbon chains in the diffuse interstel-

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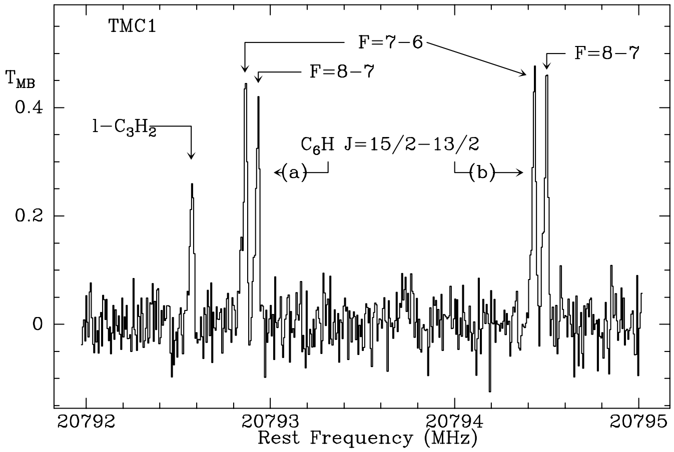

Fig. 1. Spectrum of the dark cloud TMC1 observed at the cyanopolyyne peak between 20.792 and 20.795 GHz. The hyperfine lines of the (a) and (b) Λ-doubling components of the J = 15/2–13/2 transition of C_6H are identified together with the nearby 1_{01} - 0_{00} transition of linear C_3H_2.

lar medium and to ascertain their role, through their electronic transitions, in the production of diffuse interstellar bands (DIBs; Douglas 1977).

In this paper, we report the detection of the linear isomer of C_3H_2 in absorption against the continuum emission of W49, W51D and W51E1/E2. Upper limits are derived toward Sgr B2 and 3C 123. In Sect. 2 we describe the observations and in Sect. 3 we present the results. In Sect. 4 we discuss the derived column densities and the ratio of the cyclic over linear isomer abundances.

2. Observations

The observations were made during two sessions in March 1992 and May 1995 with the 100-meter telescope of the Max-Planck-Institut für Radioastronomie at Effelsberg (F.R.G). We observed simultaneously the J=15/2–13/2a and J=15/2–13/2b transitions of C_6H $^2\Pi_{3/2}$ at 20792.91 and 20794.48 MHz together with the 1_{01}–0_{00} line of para $l-C_3H_2$ at 20792.590 MHz (see Fig. 1). The telescope is equipped with a cooled maser, which provides a system temperature outside the atmosphere of about 60 K at the zenith. A 1024 channel autocorrelator with a bandwidth of 6.25 or 12.5 MHz yielded a velocity resolution of 0.09 and 0.18 $\mathrm{km\,s^{-1}}$. The antenna beamsize at 20.7 GHz is $48''$. Reference positions were one degree in α away from the sources. Pointing and calibration were monitored by regularly observing the continuum sources 3C 123, NGC 7027 and the radio continuum sources of the present study. The derived line parameters or the corresponding upper limits are given in Table 1. TMC1 was observed to check the frequency setting of the receiver and the line intensities which were found to be in good agreement with previous data (Cernicharo et al., 1987a). The spectrum obtained toward TMC1 is shown in Fig. 1. Fig. 2 shows the observed spectra in W51E1/E2, W49 and W51.

3. Results

3.1. Column density determination

In order to derive *l*-C_3H_2 column densities from absorption line studies, we have first to check that under the conditions of optically thin lines and low H_2 volume density, the excitation temperature of the 1_{01}-0_{00} para line is close to 2.7, i.e., the temperature of the cosmic background. No collisional cross sections rates are available for *l*-C_3H_2. However, the para energy levels of this molecule are of the type J_{0J} for energies below 64 K (J=0 to 9). Because most of the observed absorbing gas has low density and moderate kinetic temperatures only the lowest energy levels will be populated. Hence, we can consider *l*-C_3H_2 as a linear molecule and only use the J_{0J} rotational levels (J from 0 to 9). Collisional cross sections can be estimated from those of HC_3N (Green & Chapman, 1978) lowered by a factor 1/2, or from those of para H_2CO $0_{00}\rightarrow J_{0J}$ (Green et al., 1978) increased by a factor of 2, to take into account the different geometrical sizes between *l*-C_3H_2 and HC_3N or H_2CO. Using a spherical large-velocity gradient model for the radiative transfer and under the conditions n(H_2) $<$ 3 10^3 $\mathrm{cm^{-3}}$, T_K = 10–30 K and τ for the 1_{01}-0_{00} line lower than 1 (corresponding to $T_{\rm ex}$ $<$ 4 K, i.e, much lower than the brightness temperature of the continuum emission), *l*-C_3H_2 column densities can be obtained assuming an ortho/para ratio of 3 from the relation N(*l*-C_3H_2) = 3.6$\pm$0.5 10^{13} $\tau\Delta$v, where Δv is the linewidth in $\mathrm{km\,s^{-1}}$ and τ is the line opacity. The same calculations predict that the excitation temperature and the opacity of the 1_{01}-0_{00} line will be negative in the optically thin case for densities around 5 10^4 $\mathrm{cm^{-3}}$, i.e., a similar effect to that calculated for other linear molecules like HC_3N.

C_6H is a $^2\Pi$ molecule with a negative value for the spin-orbit interaction constant, i.e., the lowest energy ladder is $^2\Pi_{3/2}$. The ratio between its spin-orbit and rotation constant is around 300 (Cernicharo et al., 1987b) and hence all rotational levels populated under the physical conditions prevailing in cold molecular clouds will follow Hund's case (a) coupling. The $^2\Pi_{1/2}$ ladder, which is 20 K above the $^2\Pi_{3/2}$ one, has not been considered as its contribution to the partition function of C_6H, and hence to its column density, will be negligible for low rotational temperatures (e.g., 15% of the total C_6H column density for gas thermalized at 10 K). As for *l*-C_3H_2, the collisional cross section rates available for this molecule can be estimated from those of HC_3N. Line strengths for pure (a) case coupling are given by S = (Ju^2 - Ω^2)/Ju, where Ω=3/2 (see Kovács, 1969). For n(H_2) $<$ 1–2 10^3 $\mathrm{cm^{-3}}$ and τ<1, we derive N(C_6H)=1.8 10^{13} τ Δv $\mathrm{cm^{-2}}$, where Δv is the linewidth in $\mathrm{km\,s^{-1}}$ and τ is the total opacity of the J=15/2–13/2 line (roughly four times the opacity of that of each hyperfine components).

For comparison purposes, the TMC1 column densities for *c*-C_3H_2 (Cox et al., 1988), *l*-C_3H_2 (Cernicharo et al., 1991a; Kawagushi et al., 1991), and C_6H (Cernicharo et al., 1987b) are 1.5 10^{14} $\mathrm{cm^{-2}}$, 2.5 10^{12} $\mathrm{cm^{-2}}$ and 10^{13} $\mathrm{cm^{-2}}$, respectively. The column densities for the last two molecules have been also derived for TMC1 with the LVG models quoted above, adopting n(H_2)=3 10^4 $\mathrm{cm^{-3}}$ and T_K=10 K, and the line parameters de-

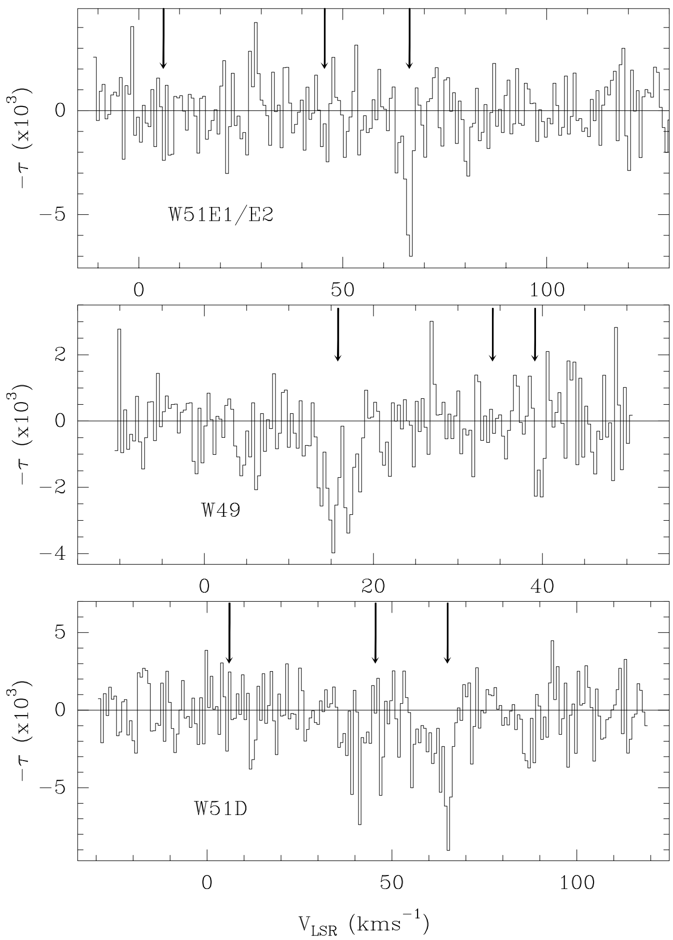

Fig. 2. Observed absorption spectra of linear C_3H_2 toward the continuum sources W51E1/E2, W49, and W51D. Arrows indicate the velocity of the absorption features observed in C_3H_2 by CGH and Madden et al. (1989).

rived from the data in Fig. 1. We obtain $N(l\text{-}C_3H_2)_{ortho+para} \simeq$ 2 10^{12} cm^{-2} and $N(C_6H)=10^{13}$ cm^{-2}, in excellent agreement with previous determinations which assumed a rotation temperature of 7 K (Cernicharo et al., 1987b; 1991a).

3.2. Individual sources

W51E1/E2: The absorption spectrum toward W51E1/D1 is shown in Fig. 2 (upper panel). A narrow absorption dip is detected toward this source at 66 $km\,s^{-1}$. With a linewidth of Δv=1.8 kms^{-1} and a line opacity of 0.0063 we derive for *l*-C_3H_2 a column density of 4.7 10^{11} cm^{-2}. From the data of Madden et al. (1989), we estimate a column density for the cyclic isomer of 1.6 10^{12} cm^{-2} implying a ratio of the column densities of cyclic over linear-C_3H_2 - hereafter N_c/N_l - larger than 3.5. We adopt a lower limit because the data for *c*-C_3H_2 are contaminated by emission of the same molecule at the velocity of the W51 complex. The absorption line is at a kinematically forbidden velocity for W51 and it is attributed to foreground material unrelated to this cloud (Madden et al., 1989). No C_6H is detected toward W51E1/E2. The 3σ upper limit is equivalent to an upper limit of 10^{11} cm^{-2} for the C_6H column density.

W49/1: The observed spectrum toward W49 is displayed in the middle panel of Fig. 2. A broad and a weak absorption feature, with perhaps several different velocity components, are detected at 15.8 kms^{-1} corresponding to the envelope of the W49 complex (which has a velocity of 7 $km\,s^{-1}$) or to local interstellar gas (Nyman, 1983). The opacity of the feature is 0.0027$\pm$0.0006 yielding a *l*-C_3H_2 column density of 4 10^{11} cm^{-2}. At that velocity the *c*-C_3H_2 spectrum also shows an absorption feature slightly contaminated by emission at the velocity of the W49 complex (CGH). An estimation of the *c*-C_3H_2 absorbing column density is 3 10^{12} cm^{-2} implying an abundance ratio N_c/N_l>8. For all the other velocity features detected in *c*-C_3H_2 by CGH and in many other molecular species corresponding to gas in the Sagittarius spiral arm (see Nyman, 1983, 1984), we derive N(*l*-C_3H_2) <2–4 10^{11} and N_c/N_l > 7–10. As in the previous source, we did not detect any C_6H in W49/1 with a 3σ upper limit to the column density of 3 10^{11} cm^{-2}.

W51D: Fig. 2 (bottom panel) presents the *l*-C_3H_2 spectrum measured in the direction of W51D. The strongest absorption feature is detected at 66 kms^{-1} corresponding to the velocity of the gas detected in absorption toward W51E1/E2. The estimated *l*-C_3H_2 column density is 5.5 10^{11} cm^{-2}. This feature associated with low density foreground gas (see above) is also contaminated in *c*-C_3H_2 by emission of the W51 ambient cloud. From the data in Madden et al. (1989), we estimate a *c*-C_3H_2 column density of 1.8 10^{12} cm^{-2} yielding an abundance ratio N_c/N_l = 3.5. Other components are marginally detected, in particular a feature at 41.2 kms^{-1}. With an estimated linewidth of 2 $km\,s^{-1}$, we derive N(*l*-C_3H_2)=2 10^{11} cm^{-2} which compared to the *c*-C_3H_2 results of Madden et al. (1989) implies a value of 8 for N_c/N_l. Again the spectrum of W51D does not show any of the C_6H hyperfine components. In this case, we derive an upper limit to the C_6H column density of 3 10^{11} cm^{-2}.

Sgr B2: Strong *c*-C_3H_2 absorption features covering more than 200 kms^{-1} in velocity have been detected toward this galactic center source by Madden et al. (1989). However, no *l*-C_3H_2 was detected. For the strongest *c*-C_3H_2 absorption feature at 60 kms^{-1}, we measure a 3σ upper limit to the *l*-C_3H_2 opacity of 0.006 which corresponds to a 3σ upper limit to the total *l*-C_3H_2 column density of 3 10^{12} cm^{-2}. From the relation N(*c*-C_3H_2) = 1.8 $10^{13}\Delta$v τ (see CGH) and the parameters quoted by Madden et al. (1989) for this velocity feature, we derive a column density for *c*-C_3H_2 of 1.7 10^{14} cm^{-2}. The cyclic over linear abundance ratio for this cloud is thus > 50 and could even be higher because of the observed strong opacity in the *c*-C_3H_2 absorption. Madden et al. (1989) give a column density for *c*-C_3H_2 of 5 10^{14} cm^{-2} based on emission measurements at high frequency of the 13-carbon isotopic species. If we adopt this value, then the cyclic over linear abundance ratio in this cloud will be larger than 150. Several absorption features at negative velocities were present in our spectrum of Sgr B2. However they were partially blended with the strong 7(5)-7(5) absorption line of NH_3 at -150 kms^{-1}, preventing the determination of meaningful line parameters. For N(C_6H), we derive a 3σ upper limit of 2.5 10^{12} cm^{-2}.

3C 123: 3C 123 is an extragalactic radio continuum source lying in the direction of a layer of low density gas in the Taurus complex. CGH detected weak absorption of *c*-C_3H_2 towards this source and estimated N(*c*-C_3H_2) = 3.6 10^{12} cm^{-2}. For *l*-C_3H_2, we derive a 3σ upper limit to the opacity of 0.04 and the corresponding limit to the columm density is of 4 10^{12}. The 3σ cyclic over linear abundance ratio is 0.9. However, due to the low column density of cyclic C_3H_2, this limit to the abundance ratio is not significative. Finally, the search for C_6H in 3C 123 yields a 3σ upper limit to its column density of 3.5 10^{12} cm $^{-2}$.

4. Discussion

The main result of this paper is that in low density regions the abundance ratio N_c/N_l of cyclic to linear-C_3H_2 has a value of 3–5. We will discuss in turn the possible sources of uncertainties in the derivation of this ratio and then the physical and chemical implications of its value.

One possible source of error in the determination of N_c/N_l is related to the estimate of N(*c*-C_3H_2). The line profiles of *c*-C_3H_2 consist of emission and absorption features. The line absorption profile could be contaminated by the emission features which would increase the value of N_c/N_l. Emission and absorption features in *c*-C_3H_2 have similar intensities but much lower than the continuum background. As the velocity of the *c*-C_3H_2 and *l*-C_3H_2 absorption features is the same we do not expect large errors in the determination of N(*c*-C_3H_2). Another possible error is the assumption of T_{ex} = 2.7 K for *l*-C_3H_2, i.e., assuming low gas densities. Opacities will be underestimated and column densities too. However, this error will lower the N_c/N_l abundance ratio. This error will be less severe for *c*-C_3H_2 because the collisional rates are probably lower than for *l*-C_3H_2 and higher densities are needed to produce a rotational temperature above the 2.7 K cosmic background. However, the abundance ratio determined under the assumption of low gas density will be completely erroneous if the density is larger than 1–3 10^4 cm^{-3} because T_{ex} will then be significantly different from 2.7 K. Nevertheless, for high densities weak maser amplification of the continuum is expected for $c-C_3H_2$ (Cox et al., 1987; Avery & Green, 1988) and for the linear isomer masering is expected if densities are around 5 10^4 cm^{-3}. Since no emission has been found toward the continuum sources in the linear isomer, the implied densities are less than 10^4 cm^{-3}. If densities are larger than 10^5 cm^{-3} then the linear isomer will be thermalized and the cyclic isomer will amplify the continuum. This is also not observed. Hence, we are confident that densities must be lower than 10^4 cm^{-3}. In conclusion, the N_c/N_l abundance ratio in diffuse clouds is larger than unity, probably around 5, and at least ten times lower than in TMC1 (where it has a value of 70).

For further comparison, we have also observed the cold dark cloud L183. We have obtained only upper limits to the emission of *l*-C_3H_2, $T_B(3\sigma) < 0.15$ K with a spectral resolution of 0.09 kms^{-1}. This value corresponds, for the physical conditions of this cloud (see Swade & Schloerb, 1992), to a 3σ upper limit to the *l*-C_3H_2 column density of 8 10^{11} cm^{-2} (we have also assumed an ortho/para ratio of three and used the LVG model quoted above). In the same cloud Madden et al. (1989) derived N(*c*-C_3H_2)= 3 10^{13} cm^{-2}. The cyclic over linear C_3H_2 abundance ratio in this dark cloud is > 40 which is, within a factor of two, comparable to the value obtained in TMC1.

In IRC+10216, the only circumstellar envelope where linear and cyclic C_3H_2 species have been detected, the column density of the cyclic isomer is $\simeq 8\,10^{13}$ cm^{-2} (assuming T_{rot}=25 K and the observed line paremeters of Cernicharo et al., 1999). The column density for the linear isomer is 2.6 10^{12} cm^{-2} (Cernicharo et al., 1991a. Hence, in this C-rich circumstellar envelope the N_c/N_l abundance ratio is $\simeq$30.

It appears thus that in dark molecular clouds and in the IRC+10216 circumstellar envelope the ratio N_c/N_l has a value of at least 30 (with a firm measurement of 70 in TMC1 and of 30 in IRC+10216) whereas for the diffuse gas we derive ten times lower values. In the case of Sgr B2, known to have a high gas density and an enormous richness of molecular species, although the column density of C_3H_2 is very large (about 5 10^{14} cm^{-2}) no *l*-C_3H_2 has been detected down to a very low limit. Our estimate of N_c/N_l is larger than 100–150 or a factor of 2–3 higher than the value derived for dark clouds. An independent estimate can be made from the upper limits to the emission of *l*-C_3H_2 at millimeter waves obtained by Cernicharo et al. (1991a). For the high density case (n_{H_2} = 10^5 cm^{-3}, T_K = 60 K) we get N(*l*-C_3H_2) $<$ 9 10^{12} cm^{-2}. From this emission measurement the abundance ratio of cyclic to linear C_3H_2 is larger than 55, which is consistent with the value derived from the present absorption data.

As both Sgr B2 and the diffuse clouds have a higher kinetic temperature than the cold dark clouds TMC1 and L183, the observed trend of the N_c/N_l abundance ratio is likely to be related to other parameters than the temperature.

The production mechanism of cyclic and linear C_3H_2 has been discussed by Adams & Smith (1987). They experimentally found that the radiative association of C_3H^+ and H_2 produces mainly the ion ${C_3H_3}^+$, with roughly the same amounts in linear and cyclic forms. Invoking dissociative recombination and assuming a branching ratio of one, one can form *c*-C_3H_2 and *l*-C_3H_2 (and the cyclic and linear isomers of C_3H too). This path has been contested by Gerlich & Horning (1992). With their ring-electrode experiment they found that, under conditions close to interstellar ones, the main product of radiative association of C_3H^+ and H_2 is ${C_3H_2}^+$. Maluendes and al. (1993) suggest that *c*-${C_3H_2}^+$ then reacts with H_2 to form the cyclopropenium ion *c*-${C_3H_3}^+$, which leads to *c*-C_3H_2 by dissociative recombination.

How do observations relate to these different mechanisms? The path proposed by Gerlich & Horning (1992) could explain the excess of the cyclic isomer of C_3H_2 with respect to the linear one observed in TMC1. But it is less suited to explain the value of 3–5 we found in the less dense medium. On the other hand, if the radiative association of C_3H^+ and H_2 forms *c*-${C_3H_3}^+$ and *l*-${C_3H_3}^+$ equally (as suggested by the work of Adams &

Table 1. Line parameters

Source	T_{mb} K	v km s^{-1}	Δv	N(l-C_3H_2) 10^{11} cm^{-2}	N(c-C_3H_2) 10^{12} cm^{-2}	N(C_6H) 10^{11} cm^{-2}
W51E1/E2	–0.13 (0.02)	66.3	1.8	4.7 (0.8)	1.6	<1.0
	<0.06	6.0	3.0	<4	1.7	<2.0
	<0.06	45.5	0.8	<1	0.5	<0.5
W49	–0.07 (0.02)	15.8	4.1	4.0 (1.1)	3.0	<3.0
	<0.06	34.1	4.6	<4.5	3.5	<3.0
	<0.06	39.1	2.6	<2.6	3.5	<1.5
	<0.06	55.9	3.9	<3.8	2.3	<3.0
	<0.06	60.0	3.0	<2.9	2.5	<2.0
	<0.06	63.0	2.2	<2.2	2.8	<1.4
W51D	–0.09 (0.02)	65.0	2.7	5.5 (1.2)	1.8	<3.0
	<0.06	6.0	3.0	<1.9	2.0	<3.3
	<0.06	45.5	0.8	<1.0	0.7	<1.0
Sgr B2	<0.06	60.0	15.0	<30	500	<25
3C123	<0.12	4.1	3.2	<4	3.6	<35

Comments: Upper limits represent 3σ values. For undetected sources or velocity components upper limits to the *l*-C_3H_2 column density have been derived assuming a linewidth similar to that of the cyclic isomer. Data for *c*-C_3H_2 are from CGH and Madden et al. (1989)

Smith 1987), and if we make the reasonable assumption that the skeleton of the ion is unspoiled by dissociative recombination, then we have several possible processes which are able to explain the observed abundance ratios. For example, Maluendes et al. (1993), whose ab initio calculations support Adams and Smith's experimental results, propose to explain the excess of *c*-C_3H_2 by its inert behavior with respect to neutral-neutral reactions, while *l*-C_3H_2, as well as *c*/*l*-C_3H, is easily destroyed by these reactions. In this scheme, *c*-C_3H_2 is only destroyed by ion-neutral reactions. It could explain the values of 70 found in TMC1 for N_c/N_l. Moreover, if the relative abundance of reactive ions in the diffuse medium is ten times that in dark clouds like TMC1, it can also explain the low N_c/N_l value observed in the absorption data.

We propose here an alternative mechanism which could explain the differences between the relative abundance of *c*-C_3H_2 and *l*-C_3H_2 in TMC1 and toward continuum sources. As quoted above, the precursor ions *c*-$C_3H_3{}^+$ and *l*-$C_3H_3{}^+$ are formed at the same rate from the radiative association reaction C_3H^++H_2. The dissociative recombination of both linear and cyclic ions will produce *c*-C_3H_2, *l*-C_3H_2, *c*-C_3H and *l*-C_3H, and other isomers of C_3H_2 like the quasi-linear carbene propargylene, HC-CCH (see Cernicharo et al., 1991a). The branching ratios for the *l*-$C_3H_3{}^+$ and *c*-$C_3H_3{}^+$ dissociative recombination are unknown and could have a temperature dependence. Furthermore, Adams & Smith (1987) found that the reaction of *c*-$C_3H_3{}^+$ with other molecular species is slow and will form essentially *c*-C_3H_2 in contrast to $l-C_3H_3^+$ which reacts quickly with C_2H_2 and with C_2H_4. Acetylene is an abundant molecule in molecular clouds and its reaction with *l*-$C_3H_3{}^+$ can compete with dissociative recombination as soon as n(C_2H_2)k= $k_e n_e$, where k_e is the dissociative recombination rate (10^{-6} cm^3 s^{-1}), n_e the electronic density, and k is the rate for reaction of acetylene with *l*-$C_3H_3{}^+$ (k=10^{-9} cm^3 s^{-1}; Adams & Smith, 1987). Since X(C_2H_2) should be larger than $10^3 X_e$ this reaction competes with dissociative recombination. In cold dark clouds where X_e can be lower than 10^{-8} the situation could be similar. However, in diffuse clouds where X_e is probably larger than 10^{-7} the required abundance of acetylene will be too high. Other abundant molecules or atoms could also affect the abundance of *l*-$C_3H_3{}^+$. For example, the reaction with CO could be an alternative path, even more efficient than the reaction involving acetylene, to remove linear $C_3H_3{}^+$ (Smith & Adams, 1987, have also found that the reaction of *l*-$C_3H_3{}^+$ with CO is many times faster than the same reaction involving the cyclic ion). For CO the constraint X(CO) $> 10^3 X_e$ is fullfilled for a large variety of physical conditions in the interstellar gas.

In summary, while *l*-$C_3H_3{}^+$ can be efficiently removed through ion-neutral reactions lowering the amount available to produce $l-C_3H_2$, *c*-$C_3H_3{}^+$ will be mainly affected by dissociative recombination leading to the formation of *c*-C_3H_2. The cyclic over linear abundance ratio will thus depend on the ion-neutral reactions of *l*-$C_3H_3{}^+$ that do not affect the cyclic ion. Our data indicates that the abundance ratio of cyclic over linear C_3H_2 is definitively larger than one, reaching values of 70 in cold dark clouds. The destruction mechanisms for the linear ion thus appear to be efficient in high density gas whereas the situation for low density gas is somewhat less clear due to the uncertainties involved in the determination of the column densities of both isomers. We could also argue that the branching ratios of the reaction $C_3H^+ + H_2$ leading to the formation of the linear and cyclic progenitor ions are different. In this case the abundance ratio N_c/N_l could be a measurement of these ratios.

Finally, we note that a different explanation could be related to different photodissociation rates for both species. Unfortunately, nothing is known about these rates. A larger photodissociation rate for *c*-C_3H_2 than for the linear isomer could explain our results. The similar N_c/N_l value, within a factor of two, found in IRC+10216 and TMC1 suggests that both objects have a very similar chemistry for the carbon chains (as already known from the behaviour of the carbon chain radicals; see, e.g., Cernicharo et al., 1987b). The shell where the radicals are detected in IRC+10216 (Guélin et al. 1993) has a volume densitiy similar to that of TMC1. The main difference between both objects is that the shell of IRC+10216 is, perhaps, less protected against the UV photons than the cores in the TMC1 cloud, which are surrounded by an envelope of a few magnitudes of visual absorption (Cernicharo & Guélin 1987; Cernicharo et al., 1984). A different UV field in both objects could also produce different ionization conditions. Hence, it will be difficult to relate the present results to a larger photodissocitation rate for the cyclic isomer or to the chemical reactions discussed above.

Concerning C_6H, we have only derived upper limits for the column densities in the diffuse interstellar gas. They are between 10^{11} and 10^{12} cm^{-2}, i.e., 10–20 times lower than in TMC1. In L183, we derive an upper limit of 0.06 K (3σ) to the C_6H emission (averaging over the four hyperfine lines) implying a 3σ upper limit to the C_6H column density of 3 10^{12} cm^{-2}. This value is only three times lower than the corresponding column density in TMC1.

Several molecular species have been observed in the diffuse interstellar gas (Liszt & Lucas, 1998 and references therein). The detection of *l*-H_2C_3 in the diffuse gas is important because the cumulene carbon chains, H_2C_n, could contribute through their electronic transitions, to the DIBs observed at optical and infrared wavelenghts (see, e.g., Thaddeus et al., 1993). However, our results indicate that the abundance of the C_nH radicals in the diffuse interstellar medium is significantly lower than in cold dark clouds and C-rich circumstellar envelopes and that their contribution to the DIBs could be marginal.

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