A large $^{12}\text{C}/^{13}\text{C}$ isotopic ratio in M 82 and NGC 253

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ABSTRACT

Aims. Our aim is to derive carbon isotopic ratios from optically thin tracers in the central regions of the starburst galaxies M 82 and NGC 253.

Methods. We present high-sensitivity observations of CCH and two of its ^{13}C isotopologues, C^{13}CH and ^{13}CCH , as well as the optically thin emission from C^{18}O and $^{13}\text{C}^{18}\text{O}$. We assume the column density ratio between isotopologues is representative of the $^{12}\text{C}/^{13}\text{C}$ isotopic ratio.

Results. From CCH, lower limits to the $^{12}\text{C}/^{13}\text{C}$ isotopic ratio of 138 in M 82, and 81 in NGC 253, are derived. Lower limits to the $^{12}\text{C}/^{13}\text{C}$ ratios from CO isotopologues support these. $^{13}\text{C}^{18}\text{O}$ is tentatively detected in NGC 253, which is the first reported detection in the extragalactic ISM. Based on these limits, we infer ratios of $^{16}\text{O}/^{18}\text{O} > 350$ and > 300 in M 82 and NGC 253, respectively, and $^{32}\text{S}/^{34}\text{S} > 16$ in NGC 253. The derived CCH fractional abundances toward these galaxies of $\lesssim 1.1 \times 10^{-8}$ agree well with those of molecular clouds in the Galactic disk.

Conclusions. Our lower limits to the $^{12}\text{C}/^{13}\text{C}$ ratio from CCH are a factor of 2–3 larger than previous limits. The results are discussed in the context of molecular and nucleo-chemical evolution. The high $^{12}\text{C}/^{13}\text{C}$ isotopic ratio of the molecular ISM in these starburst galaxies suggest that the gas has been recently accreted toward their nuclear regions.

Key words. galaxies: abundances – galaxies: individual: NGC 253 – galaxies: individual: M 82 – galaxies: ISM – galaxies: nuclei – galaxies: starburst

1. Introduction

Isotopic ratios in the interstellar medium (ISM) of starburst (SB) galaxies provide important clues on their nucleo-chemical evolution. In particular, the $^{12}\text{C}/^{13}\text{C}$ isotopic ratio is believed to be a good tracer of the chemical evolution of the Galaxy (see e.g. Audouze 1985). This ratio is understood to be a direct measurement of the primary to secondary nuclear processing (Wilson & Rood 1994). While ^{12}C is a primary product of stellar nucleosynthesis, quickly produced via He burning in massive stars that can be formed in first generation metal-poor stars, ^{13}C is a secondary nuclear product from ^{12}C seeds (Meyer 1994; Wilson & Matteucci 1992; Wilson & Rood 1994).

So far, only lower limits to the $^{12}\text{C}/^{13}\text{C}$ abundance ratios could be determined for some starburst galaxies. A value of $^{12}\text{C}/^{13}\text{C} \gtrsim 40$ was derived toward the nuclei of the nearby galaxy NGC 253 based on observations of CN, CS, and HNC (Henkel et al. 1993) and further supported by CO, HCN, and HCO^+ data on M 82 and NGC 4945 (Henkel & Mauersberger 1993; Henkel et al. 1994). Additional CN data on M 82 and IC 342 resulted in lower limits to the ratio of > 40 and > 30 respectively (Henkel et al. 1998). The CO and ^{13}CO multi-transition non-LTE study toward M 82 by Mao et al. (2000) excludes $^{12}\text{C}/^{13}\text{C}$ ratios below 25 and points toward a ratio > 50 . Apart from these multi-molecule studies toward the nearest SB galaxies, and limited by sensitivity, only the $^{12}\text{CO}/^{13}\text{CO}$ ratio is available for a small sample of nearby sources (Young & Sanders 1986; Sage & Isbell 1991; Aalto et al. 1991; Casoli et al. 1992; Paglione et al. 2001).

However, the lines from the species used so far can be severely affected by optically depth effects as estimated by Henkel et al. (1993). Thus optically thin species are crucial to derive accurate isotopic ratios.

Ethynyl (CCH) has the brightest line in the 2 mm spectral scans carried out toward NGC 253 and M 82 (Martín et al. 2006; Aladro et al. in prep.). Its hyperfine structure, unresolved in these objects, can help to constrain the opacity through the observed lineshape. Within the Galaxy, CCH emission appears tightly bound to massive star formation at all evolutionary stages (Beuther et al. 2008).

In this paper, we present observations of CCH and two of its ^{13}C isotopologues, and provide a more stringent lower limit to the $^{12}\text{C}/^{13}\text{C}$ isotopic ratio in the nuclear starburst ISM of M 82 and NGC 253. Additionally we present CO observations in the ^{18}O substitution and the double isotopologue $^{13}\text{C}^{18}\text{O}$. The derived $^{12}\text{C}/^{13}\text{C}$ ratio from CO, though not as stringent as that from CCH, supports the idea of higher isotopic ratios in these starbursts than previously determined.

2. Observations and results

We observed the $J = 2-1$ group of hyperfine (hf) transitions of CCH (174.635 GHz), C^{13}CH (170.491 GHz), and ^{13}CCH (168.274 GHz), and the $J = 1-0$ transition of C^{18}O (109.782 GHz) and $^{13}\text{C}^{18}\text{O}$ (104.711 GHz) toward M 82 and NGC 253. Observations were carried out with the IRAM 30m telescope (Pico Veleta, Spain). For M 82,

Fig. 1. Observed spectra of the $J = 2-1$ transitions of CCH, $^{13}\text{C}^{13}\text{CH}$, and $^{13}\text{C}^{12}\text{CH}$, and the $J = 1-0$ transitions of ^{18}O and $^{13}\text{C}^{18}\text{O}$ toward M 82 and NGC 253. The intensity of the ^{18}O spectrum in M 82 has been multiplied by a factor of 3 for comparison and visualization purposes. The fit to the CCH and ^{18}O profiles are shown with grey lines. For the undetected isotopologues we overlay the expected spectra assuming a $^{12}\text{C}/^{13}\text{C}$ isotopic ratio of 40 (dotted lines), as well as the upper limit profile derived in this work (grey lines). Vertical lines represent the relative intensities of the hyperfine components used to fit the detected CCH profiles, and to calculate the upper limit to the intensities for the isotopologues. $^{13}\text{C}^{18}\text{O}$ is tentatively detected blended to a H_2CS feature toward NGC 253. Spectra are presented at the original 4 and 2 MHz (~ 7 and 5 km s^{-1}) resolution for CCH and ^{18}O , respectively. $^{13}\text{C}^{13}\text{CH}$ and $^{13}\text{C}^{12}\text{CH}$ data were smoothed to 16 MHz ($\sim 28 \text{ km s}^{-1}$) and $^{13}\text{C}^{18}\text{O}$ to 8 MHz ($\sim 23 \text{ km s}^{-1}$).

observations were aimed toward the northeastern molecular lobe at the offset position ($+13''$, $+7.5''$) from the center ($\alpha_{J2000} = 09^{\text{h}}55^{\text{m}}51^{\text{s}}.9$, $\delta_{J2000} = 69^{\circ}40'47''.1$). NGC 253 observations were aimed at the central position ($\alpha_{J2000} = 00^{\text{h}}47^{\text{m}}33^{\text{s}}.3$, $\delta_{J2000} = -25^{\circ}17'23''.15$) for ^{18}O while the $^{13}\text{C}^{18}\text{O}$ observations were slightly offset at ($+3''$, $-4''$). The beam widths at these frequencies were $\sim 14''$ and $\sim 23''$ for the CCH and CO lines, respectively. We used the wobbler switched observing mode with a symmetrical beam throw of $240''$ in azimuth and a wobbling frequency of 0.5 Hz. As spectrometers we used the 256×4 MHz filter banks and WILMA autocorrelator (2 MHz) for CCH and CO, respectively. The CCH data for NGC 253 were extracted from the 2 mm line survey by Martín et al. (2006). Figure 1 shows the observed spectra.

The hf structure of CCH is unresolved. We fitted a comb of Gaussian profiles at the positions of the hf lines and intensity ratios fixed by their spectroscopic parameters (Müller et al. 2001), shown as vertical lines in Fig. 1. In M 82, the wing of emission

at low velocities in CCH is a contribution of both the fainter hf components and the emission from the nuclear region, as also seen in the ^{18}O profile. Though two velocity components could be fitted to the CCH profile in NGC 253 (Martín et al. 2006), for the purposes of this paper we just fit a single velocity component. We assumed optically thin emission to fit the line profiles. We show the resulting fits as grey lines in Fig. 1, while the fitting parameters are shown in Table 1. Neither $^{13}\text{C}^{13}\text{CH}$ nor $^{13}\text{C}^{12}\text{CH}$ emission were detected toward M 82 and NGC 253. No line contamination by other species is expected at the frequencies of the isotopologues. We estimated upper limits to the integrated intensities of the overall line profile of these isotopologues, calculated from the corresponding spectral parameters (Müller et al. 2001). We assumed a peak intensity of the overall profile at a 3σ level (for 187 and 224 km s^{-1} wide channels, corresponding to that from a single Gaussian fit to the CCH features) for M 82 and NGC 253, respectively.

Line emission from $^{13}\text{C}^{18}\text{O}$ is not detected toward M 82 and only tentatively toward NGC 253. This tentative $^{13}\text{C}^{18}\text{O}$ detection, the first in the extragalactic ISM, appears blended to the H_2CS $3_{1,2}-2_{1,1}$ transition at 104.616 GHz. The derived intensity of $\sim 1 \text{ mK}$ supports the tentative detection reported by Martín et al. (2005).

With the fitted integrated intensities we estimated the beam-averaged column densities for each species under the local thermodynamic equilibrium assumption. An excitation temperature of $T_{\text{ex}} = 10 \text{ K}$ was assumed for the calculations. The assumed temperature, which is the same for all isotopologues, has no effect on the derived column density ratios. As reported from CO observations, the different isotopologues might be tracing different gas components (Wall & Jaffe 1990; Aalto et al. 1994; Meier et al. 2000), and therefore the similar excitation temperature assumption would not be fulfilled. As a test case, if the ^{13}C isotopologue were emitted from a gas component with $T_{\text{ex}} \sim 50 \text{ K}$, our assumption would lead to the $^{12}\text{C}/^{13}\text{C}$ ratio being overestimated by a factor of ~ 1.7 . Multi transition observations of CCH and its ^{13}C isotopologues would be needed to accurately establish the magnitude of this effect. On the other hand, we do not expect it to be significant in the optically thin CO isotopologues. The derived CCH and CO beam-averaged column densities and upper limits are shown in Table 1.

The derived lower limits to the $^{12}\text{C}/^{13}\text{C}$ ratios are of >110 and >56 for M 82 and NGC 253, respectively. We can further constrain these limits by averaging the spectra of both $^{13}\text{C}^{13}\text{CH}$ and $^{13}\text{C}^{12}\text{CH}$. The resulting limit to the column densities raises the limits to the isotopic ratios up to $^{12}\text{C}/^{13}\text{C} > 138$ and > 81 , respectively. Using CO we obtain ratios of >56 and $\gtrsim 60$, respectively.

3. $^{12}\text{C}/^{13}\text{C}$ isotopic ratio from CCH and CO

Estimating the interstellar isotopic ratio from the derived molecular abundances one has to discuss two main drawbacks, opacity and fractionation effects.

The lines of ^{12}C isotopologues of CO and abundant species such as HCN or HCO^+ are likely to be optically thick. If our derived lower limits to the carbon isotopic ratio applies to CO, it would imply opacities of $\tau_{12\text{CO}} \sim 5$ and ~ 9 for NGC 253 and M 82, respectively, as derived from the observed ^{12}CO to ^{13}CO integrated intensity ratios by Sage & Isbell (1991). Higher opacities will lead to a decrease of the measured $^{12}\text{C}/^{13}\text{C}$ ratio from CO and possibly other abundant species. Therefore, molecules with opaque lines poorly constrain the $^{12}\text{C}/^{13}\text{C}$ ratios. From the hf fit to the line profile we can exclude large opacity effects affecting the CCH lines. Moreover, small opacity effects on the

Table 1. Observed lines parameters, and derived column densities and $^{12}\text{C}/^{13}\text{C}$ ratios.

Source	Isotopologue	$J - J'$	$\int T_{\text{MB}} dv$ (K km s $^{-1}$)	v_{LSR} (km s $^{-1}$)	$\Delta v_{1/2}^a$ (km s $^{-1}$)	T_{MB}^a (mK)	$\text{rms}_{1\sigma}^b$ (mK)	N^c ($\times 10^{13}$ cm $^{-2}$)	$^{12}\text{C}/^{13}\text{C}$
M 82	CCH	2–1	34.2 ± 0.6	307	97	119	7.6	55 ± 1	...
	C^{13}CH	2–1	$<0.42^d$	...	...	...	2.3	<0.7	>78
	^{13}CCH	2–1	$<0.30^d$	...	...	...	1.7	<0.5	>110
	$^{13}\text{CCH} + \text{C}^{13}\text{CH}$	2–1	$<0.25^d$	...	...	...	1.5	<0.4	>138
	C^{18}O	1–0	6.2 ± 0.1	293	106	55	1.9	620 ± 10	...
	$^{13}\text{C}^{18}\text{O}$	1–0	<0.11	...	...	...	0.8	<11	>56
NGC 253	CCH	2–1	45.8 ± 0.6	216	171	90	8.4	73 ± 1	...
	C^{13}CH	2–1	$<0.91^d$	...	...	...	4.5	<1.6	>46
	^{13}CCH	2–1	$<0.73^d$	...	...	...	3.3	<1.3	>56
	$^{13}\text{CCH} + \text{C}^{13}\text{CH}$	2–1	$<0.51^d$	...	...	...	2.2	<0.9	>81
	C^{18}O	1–0	34.7 ± 0.2	270	183	178	3.7	3470 ± 20	...
	$^{13}\text{C}^{18}\text{O}$	1–0	$\sim 0.58 \pm 0.13^e$	270	183	3	1.5	58 ± 13	≥ 60

Notes. ^(a) This value refers to the brightest component in the group. ^(b) 1σ rms at the resolution shown in Fig. 1. ^(c) Beam averaged column density assuming a $T_{\text{ex}} = 10$ K. ^(d) 3σ limit to the integrated intensity ^(e) Tentative detection blended to an H_2CS transition. Velocity and width parameters were fixed to fit both lines simultaneously.

CCH observed lines would result in an increase of our lower limits to the $^{12}\text{C}/^{13}\text{C}$ isotopic ratios.

Fractionation (Watson et al. 1976; Langer et al. 1984; Wilson & Rood 1994) might produce an enhancement of ^{13}CO in the outer layers of molecular clouds. Thus the observed CO would be tracing regions with lower $^{12}\text{CO}/^{13}\text{CO}$ ratio than the actual $^{12}\text{C}/^{13}\text{C}$ isotopic ratio. The CCH observations reported by Sakai et al. (2010) toward the dark cloud TMC-1 and the star-forming region L1527 also show a $^{12}\text{C}/^{13}\text{C}$ ratio a factor of 2–4 higher than the interstellar ratio. However, the chemical fractionation claimed in their work is mostly effective at very low temperatures ($T_{\text{kin}} \sim 10$ K), while isotopic exchange reactions rates tend to balance out at higher temperatures (Woods & Willacy 2009). This fractionation is also expected to affect species other than CO, such as HCO^+ and HCN. Moreover, the models by Woods & Willacy (2009) show how species such as HCN and HNC should result in even larger ratios than those from CCH, which is not observed in galaxies. Thus, chemical fractionation cannot explain the high CCH ratio observed in the warm ISM in the central regions of galaxies. $^{12}\text{C}/^{13}\text{C}$ isotopic ratios of 20–25 derived from CCH in the GC (Armijos et al. in prep.), similar to those derived from other molecular species, support the hypothesis that fractionation does not play an important role.

We conclude that our limits for the $^{12}\text{C}/^{13}\text{C}$ isotopic ratios derived from CCH isotopologues are representative of the ISM in the observed SB galaxies.

4. A high $^{12}\text{C}/^{13}\text{C}$ isotopic ratio in starbursts

Our results from CCH show that the $^{12}\text{C}/^{13}\text{C}$ isotopic ratio in the SB environment is much higher than the value of ~ 20 measured in the Galactic Center (GC) region (Wilson & Rood 1994). Moreover, our limits are clearly higher than previous limits for SB galaxies of ~ 40 – 50 (Henkel et al. 1993; Henkel & Mauersberger 1993). We can exclude a ratio of 40 or lower, since in that case we would have detected the ^{13}CCH emission in both galaxies and that of C^{13}CH in M 82. If the $^{12}\text{C}/^{13}\text{C}$ ratios derived from CCH are representative of the overall $^{12}\text{C}/^{13}\text{C}$, it would imply this ratio to be at least a factor of 2–3 higher than previously reported in the starburst ISM. Though lower, the limits to the ratios we derive from CO isotopologues also suggest higher $^{12}\text{C}/^{13}\text{C}$ isotopic ratios than previously measured.

Single dish $^{12}\text{CO}/^{13}\text{CO}$ ratios have been measured as high as 55 and 44 toward NGC 4195 and NGC 6240, respectively (Casoli et al. 1992). However, the latter was disproved by further mapping resulting in a $^{12}\text{CO}/^{13}\text{CO}$ ratio of ~ 20 (Aalto & Hüttemeister 2000). In Arp 299 (consisting of a merger of IC 694 and NGC 3690), a ratio of 60 was found toward the nucleus of IC 694, and ~ 10 in the surrounding disk (Aalto et al. 1999), with the ratio ranging over ~ 20 – 35 at single dish resolution. Recently, a $^{12}\text{CO}/^{13}\text{CO}$ $J = 3$ – 2 ratio of >40 was reported toward the Cloverleaf quasar at $z \approx 2.6$ (Henkel et al. 2010).

5. Revisited carbon isotopic ratio implications

5.1. The oxygen $^{16}\text{O}/^{18}\text{O}$ ratio

The uncertainty in the measured $^{12}\text{C}/^{13}\text{C}$ ratio directly affects the determination of the $^{16}\text{O}/^{18}\text{O}$ ratio based on measurements of ^{13}CO and C^{18}O . For NGC 253, Harrison et al. (1999) presented ^{13}CO and C^{18}O measurements. If we use our revised lower $^{12}\text{C}/^{13}\text{C}$ limit of >81 , their $^{13}\text{CO}/\text{C}^{18}\text{O}$ intensity ratio would correspond to an abundance ratio of $^{16}\text{O}/^{18}\text{O} > 300$. Toward M 82, using the ^{13}CO observations from Mao et al. (2000), observed at the same position, we derive a $^{16}\text{O}/^{18}\text{O} > 350$. Both limits are now closer to the ratio of ~ 330 found within the 4 kpc molecular ring of the Milky Way (Wilson & Rood 1994).

5.2. The sulfur $^{32}\text{S}/^{34}\text{S}$ ratio

The $^{32}\text{S}/^{34}\text{S}$ ratio based on measurements of ^{13}CS and C^{34}S will also be affected, like that derived by Martín et al. (2005) for NGC 253. Their value of the $^{32}\text{S}/^{34}\text{S}$ ratio of 8 ± 2 would be doubled up to a value >16 , closer to the value of ~ 24 measured in the Galactic disk (Chin et al. 1996). The ratio of $^{32}\text{S}/^{34}\text{S} \sim 13.5$ toward NGC 4945 (Wang et al. 2004) might also be underestimated because it was based on the $\text{CS}/\text{C}^{34}\text{S}$ ratio assuming no significant saturation of the CS lines.

5.3. H_2 column density determination

Our high lower limits to the $^{12}\text{C}/^{13}\text{C}$ ratio impacts the H_2 column density (N_{H_2}) derived from the optically thin CO isotopologues. These isotopologues, less affected by optical depth, are expected to be better suited to trace the overall molecular material than

the main isotopologue. However, the determination of the N_{H_2} will depend on the isotopic ratios. If we apply our new limits to the oxygen isotopic ratio to estimate the N_{H_2} from C^{18}O , and assuming a conversion factor $\text{CO}/\text{H}_2 \sim 8.5 \times 10^{-5}$ (Frerking et al. 1982), we derive beam averaged limits of $N_{\text{H}_2} > 2.6 \times 10^{22} \text{ cm}^{-2}$ for M 82 and $N_{\text{H}_2} > 1.2 \times 10^{23} \text{ cm}^{-2}$ for NGC 253. We then infer CCH fractional abundances of $< 2 \times 10^{-8}$ and $< 0.6 \times 10^{-8}$, respectively, in good agreement with the Galactic abundances found in prestellar cores (1×10^{-8} , Padovani et al. 2009), dark clouds ($< 6 \times 10^{-8}$, Wootten et al. 1980), diffuse clouds (3×10^{-8} , Lucas & Liszt 2000) and about two orders of magnitude above the abundances in hot cores ($2\text{--}8 \times 10^{-10}$, Nummelin et al. 2000).

Moreover, assuming our derived ratio of $^{16}\text{O}/^{18}\text{O} \sim 300$, a better agreement is found between the gas-mass estimate from 1.3 mm dust observations (Krugel et al. 1990) and that from C^{18}O (see Table 2 in Mauersberger et al. 1996, where a ratio of $^{16}\text{O}/^{18}\text{O} \sim 150$ was used). This agreement further supports our result.

We can estimate a conversion factor of $X_{\text{CO}} = N(\text{H}_2)/\text{CO} \sim 1.3 \times 10^{20} \text{ cm}^{-2} (\text{K km s}^{-1})$, using the CO 1–0 integrated intensity of 920 K km s^{-1} (Mauersberger et al. 1996). This conversion factor, significantly lower by a factor of ~ 2 than the “standard” value within the Galaxy of $2\text{--}3 \times 10^{20} \text{ cm}^{-2} (\text{K km s}^{-1})$ (Solomon et al. 1987; Strong et al. 1988), is a factor of 3 higher than the values proposed for the starburst ISM of $0.3\text{--}0.4 \times 10^{20} \text{ cm}^{-2} (\text{K km s}^{-1})$ (Mauersberger et al. 1996; Martín et al. 2010).

6. Chemical evolution of starburst galaxies

After several cycles of star formation, nucleosynthesis will enrich the interstellar medium with processed material, which could be “dated” by using the $^{12}\text{C}/^{13}\text{C}$ isotopic ratio. Thus, the $^{12}\text{C}/^{13}\text{C}$ ratio is expected to decrease with time. The solar system ratio of 89 (Wilson & Rood 1994) is thought to be representative of the local ISM when the Solar System formed, 4.6 billion years ago. Although the $^{12}\text{CO}/^{13}\text{CO}$ ratio toward both M 82 and NGC 253 is observed to be a factor of ~ 1.7 higher within the nuclear region than in the outer disk, this ratio is unlikely to be representative of the $^{12}\text{C}/^{13}\text{C}$ ratio due to opacity effects and/or variation of the CO/H_2 conversion factor, as reported by Paglione et al. (2001). On the contrary, a positive gradient toward the central region is expected, owing to the molecular material being further processed by stars, and similar to what is observed with optically thin tracers in the Milky Way (Langer & Penzias 1990; Wilson & Rood 1994). It is remarkable that taking into account the ratios derived in this work, the $^{12}\text{C}/^{13}\text{C}$ ratio in SB galaxies is higher than in the Galactic center, the solar neighborhood (Wilson & Rood 1994) and even in the low metallicity ISM of the Large Magellanic Cloud (LMC; $^{12}\text{C}/^{13}\text{C} = 49$, Wang et al. 2009). Similarly, the oxygen and sulfur isotopic ratios measured do not show an enrichment of ^{18}O and ^{34}S in the starburst ISM with respect to the values measured in the local ISM (Wilson & Rood 1994). Moreover, our lower limit to $^{16}\text{O}/^{18}\text{O}$ is slightly above the value of 250 measured toward the Galactic Center (Wilson & Rood 1994), and the $^{32}\text{S}/^{34}\text{S}$ would be at least a factor of 2 above the expected ratio within the central 3 kpc of the Galaxy from the gradient found by Chin et al. (1996). The $^{16}\text{O}/^{18}\text{O}$ and $^{32}\text{S}/^{34}\text{S}$ are significantly lower and similar, respectively, to those measured in the LMC ($^{16}\text{O}/^{18}\text{O} = 2000$, $^{32}\text{S}/^{34}\text{S} \sim 15$, Wang et al. 2009).

An enhanced star formation was likely triggered across the disk of M 82 as a result of a close encounter with M 81 about 220 Myr ago. However, the ongoing nuclear starbursts started

~ 15 Myr ago, with nuclear star clusters dated between 7 and 15 Myr (Konstantopoulos et al. 2009). This dating agrees with the two short-duration bursts of star formation in the nuclear region of M 82, with peaks at 5 and 10 Myr (Förster Schreiber et al. 2003). The nucleus of NGC 253 appears to host an even younger starburst with a median age of ~ 6 Myr (Fernández-Ontiveros et al. 2009). With a average lifetime of 10 Myr, massive star clusters formed in the starburst appear not to have efficiently enriched the ISM in their nuclear region. Furthermore, the enriched material could have been banished from the nuclear region via the starburst driven super-winds in both galaxies (Heckman et al. 1990).

One possible interpretation would be that in very young SBs one should find high $^{12}\text{C}/^{13}\text{C}$ ratios owing to the fast evolution of very massive stars, leading to a overproduction of ^{12}C relative to ^{13}C , synthesized in intermediate mass stars (Henkel & Mauersberger 1993). However, this fast evolution might also result in an overproduction of ^{18}O (Henkel & Mauersberger 1993), which is not observed. Moreover, if the timescale of the main burst in the nucleus of M 82 is less than 15 Myr (Förster Schreiber et al. 2003; Konstantopoulos et al. 2009), then most of the ^{12}C enriched material would be in the hot outflow with a contribution to the molecular gas. The timescale is rather short to have the ^{12}C enriched material well mixed over the ~ 300 pc of our beam size, in both M 82 and NGC 253. It would mean that the enhanced ^{12}C molecular gas is confined to shells around the stellar clusters with a huge $^{12}\text{C}/^{13}\text{C}$ ratio.

Thus, our measured isotopic ratios suggest that the bulk of the mass of molecular material within the nuclear regions of M 82 and NGC 253 consists of little or unprocessed gas by massive stars. This suggests that the ISM which is supporting the starbursts in M 82 and NGC 253 has been recently funneled toward their centers from the outer regions or was accreted by these galaxies. The evolution of these isotopic ratios as a function of metallicity is not clear from the available observations. However, Wang et al. (2009) found the $^{16}\text{O}/^{18}\text{O}$ ratio to be a good tracer of metallicity. The lower limits to the ratio found toward M 82 and NGC 253, higher than the value toward the Galactic Center, is consistent with that found within the 4 kpc molecular ring and even with that within the local ISM. This would support the idea of inflowing material from the outer regions of these galaxies toward their centers, conforming the gas concentration unleashing their starburst events, where enriched material from previous star-formation events would contribute little to the bulk of the starburst molecular material.

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