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Kinematics of carbon stars in the outer regions of the Small Magellanic Cloud*

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Abstract. We present a radial velocity survey of a sample of the field population of carbon stars in the outer parts of the Small Magellanic Cloud (SMC). This first set of results includes radial velocities for 71 carbon stars, with an individual precision of $\pm 2 - 5$ km/s. The mean heliocentric velocity of the stars (excluding one very high velocity star) is 149.3 ± 3.0 km/s with a velocity dispersion of 25.2 ± 2.1 km/s. These values drop to 145.5 ± 2.7 km/s and 20.6 ± 1.9 km/s respectively, if we exclude the stars belonging to the Outer Wing. The velocity distribution does not show the multiple peaks seen in some samples of Population I objects. The mass of the SMC as inferred from the above velocity dispersion (without the outer Wing stars) is $\simeq 1.2\ 10^9 M_{\odot}$.

Key words: stars: carbon stars — galaxies: kinematics — Magellanic clouds

1. Introduction

The structure and dynamics of the Small Magellanic Cloud (SMC) remain poorly understood, despite the increased volume and quality of data that have become available in recent years. A fundamental question is the extent to which the dynamics of the SMC are influenced by its interaction with the Large Magellanic Cloud (LMC). Most of the kinematical studies to date concentrated on young stars and gas (see e.g. Torres & Carranza 1987 for a review; Mathewson et al. 1988), or they were limited to the central regions of the SMC. However, most of the gravitating mass of the SMC is associated with the intermediate-age and old populations. Therefore a complete understanding of the SMC dynamics and of the interaction between the LMC and the SMC requires kinematical studies of relatively old populations. Another reason for selecting old stars for such a study is that the kinematics of gas and young stars (formed from it) can be significantly affected by hydrodynamic processes. These may be associated both with interactions between the gaseous components of the two galaxies during a close encounter, and with the star formation mechanisms themselves, through the interactions of stellar winds and supernovae with the interstellar medium. The very complicated picture of the kinematical field in the SMC, arising from the latter processes, can be seen clearly in the new high resolution 21-cm hydrogen maps constructed by Staveley-Smith et al. (1995).

There have been four major studies of the kinematics of older populations in the SMC published to date. Hardy et al. (1989) derived radial velocities for a sample of 150 carbon stars located in the central $1 - 2$ kpc of the SMC. They found no evidence for rotation or of velocity splitting in their sample. Similar results had been found earlier by Dopita et al. (1985) from a study of the kinematics of 44 planetary nebulae lying mostly in the main body of the SMC. It is difficult however to extrapolate these results to the SMC as a whole, the radial extent of which is > 6 kpc in projection (see e.g. Morgan & Hatzidimitriou 1995). In the outer regions of the SMC there have been two kinematical studies of old stars. However, both were restricted to small regions, and contain relatively small numbers of stars. Suntzeff et al. (1986) derived the radial velocities of 11 "halo" giants located close to the star cluster NGC 121. There was no evidence in their sample of a bimodal velocity distribution, though the sample was too small for any firm results. Hatzidimitriou et al. (1993) studied the radial velocity distribution of a sample of 29 red horizontal-branch stars to the NE of the SMC, distributed within a 40 arcmin field, at a projected distance of $\simeq 3.3$ kpc from the optical centre of the SMC. The sample was located in a region of alleged large depth along the line of sight (Hatzidimitriou & Hawkins 1989). The data showed a well-defined correlation between distance along the line of sight and radial velocity, which was tentatively

* Tables 1a and 1b are available in electronic form at the CDS via anonymous ftp 130.79.128.5 or http://cdsweb.u-strasbg.fr/abstract.html

interpreted as the result of the tidal interaction between the LMC and the SMC. This result is suggestive of disturbed dynamics along the line of sight, at least in one particular direction. It reinforces the usefulness of kinematical studies of older stars in the outer parts of the SMC, where the stars are less strongly bound to their parent galaxy and hence may be more easily seen to reflect the gravitational effects of the SMC-LMC interaction. Nevertheless, it is obvious that kinematical information for much larger samples of old stars distributed over larger areas is necessary to understand properly the kinematics of the SMC.

Carbon stars are very well suited for this type of study: by being easily found and unambiguously recognised they provide an observationally well-defined sample; astrophysically they belong to a reasonably well-understood intermediate-age population and are often used as tracers of such populations in nearby galaxies. In the Magellanic Clouds in particular, carbon stars are sufficiently numerous and bright to be particularly useful for kinematical and dynamical studies. It is important to note that the population of carbon stars in the SMC maps closely the distribution of intermediate-age and old stars, as can be seen by a comparison of their spatial distribution with that of clump/red horizontal-branch stars, which are generally older than $\simeq 1$ Gyr (Gardiner & Hatzidimitriou 1992; Morgan & Hatzidimitriou 1995) and with that of RR Lyrae stars (Hatzidimitriou 1993).

In this paper, we present the kinematical study of a sample of 71 outlying carbon stars in the SMC. We also observed a small sample of 16 carbon star candidates in the LMC halo on the side nearest to the SMC. Sect. 2 describes the observations and reductions; in Sect. 3 the resulting radial velocities and their accuracy are presented, while in Sect. 4 we discuss the significance of the results.

2. Observations and reductions

2.1. The sample

The SMC carbon stars observed were selected from the catalogue of carbon star candidates in the outer regions of the SMC produced by Morgan & Hatzidimitriou (1995). Although a number of carbon star surveys exist for the Magellanic Clouds, they have been, until recently, mostly concentrated on the central regions of the Clouds (see Azzopardi 1993 for a review). Morgan & Hatzidimitriou (1995) have published results of a survey of SMC carbon stars identified on objective-prism photographs taken with the UK Schmidt Telescope. This survey covers a total of $15^\circ \times 15^\circ$, improving by fortyfold on the spatial coverage of previous catalogues and resulting in the discovery of more than one thousand new candidate carbon stars, mostly in the outer regions of the SMC. Most of the SMC carbon stars for which we obtained velocities lie beyond the second to last carbon-star isopleth (of Fig. 6 of Morgan & Hatzidimitriou 1995). Actually we have obtained velocities for 35% of the carbon star candidates identified in these outermost regions.

A small sample of 16 carbon star candidates in (or superimposed on) the outer halo of the LMC, were also observed. These stars were identified on UKST plate YJ13472P which is centred on ESO/SERC Field 32 (4 24, −75 00). The plate is similar to those used by Morgan & Hatzidimitriou (1995) and was scanned as part of a project to identify carbon stars in the LMC.

Table 1a (Tables 1a,b are available electronically) gives the coordinates of the 71 SMC stars observed for which reliable velocities could be determined (see Sect. 3). The projected distances of these stars from the dynamical centre of the SMC (RA:$01^{\rm h}\ 05^{\rm m}\ 22^{\rm s}$, Dec:$-72^\circ 20' 52''$ (2000), e.g. Brück 1980), are also given in Table 1a. Table 1b gives the coordinates of the LMC stars observed and their projected distances from the centre of the SMC. We used the centre of the SMC as a reference point for these stars as well, in order to be able to compare them readily with the outer Wing/intercloud stars included in the "SMC" sample.

Figure 1 shows the spatial distribution of the observed stars. The contours represent the overall distribution of carbon stars in the SMC derived by Morgan & Hatzidimitriou (1995). It can be seen immediately that the majority of the stars observed lie in the outer parts of the SMC.

2.2. Spectroscopic observations

The data were obtained during two observing runs, the first in November 1993 (three nights) and the second from the end of December 1995 to early January 1996 (5 nights), with the Australian National University's 2.3 m telescope at Siding Spring Observatory. We used the Double Beam Spectrograph. In the 1993 observing run, the detectors employed were two thick Loral CCDs, while in the 1996 observing run, the CCDs had been replaced with higher quantum efficiency thinned anti-reflection coated SITe chips. The 1993 spectra covered the following wavelength regions: 4656 Å − 5785 Å at a dispersion of 1.1 Å/pixel (corresponding to a radial velocity of 64 km/s/pixel) and 8335 Å − 8879 Å at a dispersion of 0.53 Å/pixel (corresponding to a radial velocity of 19 km/s/pixel). The wavelength coverage was larger in the second run, due to the larger size of the CCDs used (4243 Å−6173 Å for the blue spectra, and 7920 Å−8850 Å for the red spectra), while the dispersions were the same.

During the first run, the seeing was $\simeq 1$ arsec on the first two nights and $1.5 - 3$ arcsec on the third night. During the second run the weather conditions were poorer (though the seeing was still good, $\simeq 1$ arcsec, in most cases), so a smaller percentage of the time available was usable, hence the small number of new observations, despite the increased quantum efficiency of the CCDs. In the

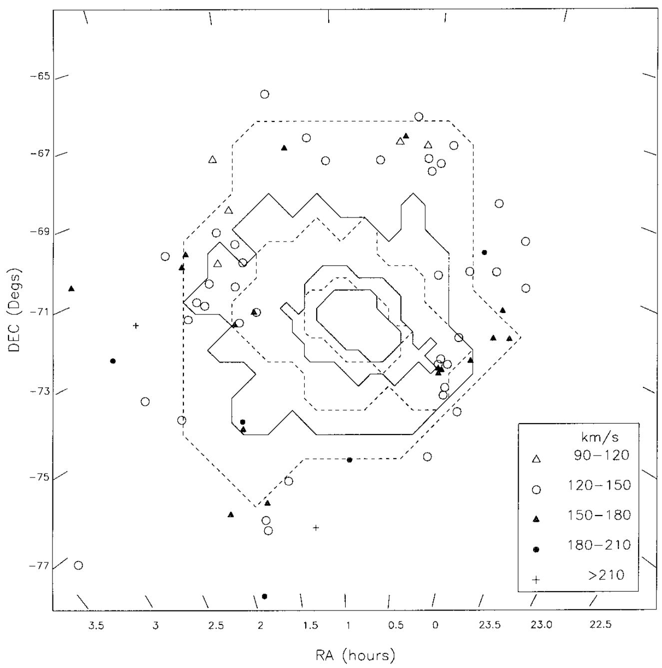

Fig. 1. The spatial distribution of the observed stars, in the SMC (stars MH 1177, MH 1181 and MH 1185 are beyond the margins of the figure). The contours represent the overall distribution of carbon stars in the SMC from Morgan & Hatzidimitriou (1995). Different symbols were used for the different velocity ranges, as indicated

last column of Table 1 we note the observing run during which each spectrum was obtained.

Typical exposure times ranged from 300 to 1200 s for both the blue and the red spectra. The maximum length of a single exposure was 600 s, while multiple exposures were secured for the fainter stars. A series of carbon star radial velocity standards were also observed, in both observing runs: details are given in Table 2.

The blue spectral region included the three Swan bands of molecular C_2 and provided immediate confirmation that the programme objects were indeed carbon stars.

2.3. Reductions

The spectra were reduced using the FIGARO package (Shortridge 1990). Standard techniques were applied to correct for the bias offset and pixel-to-pixel response. As most stars had two consecutive observations, it was possible to remove cosmic ray events using the technique described by Croke (1995). For single observations, cosmic ray events were removed using the CLEAN routine of the FIGARO package. When cosmic rays were located near night-sky emission lines, the image was sky-subtracted before attempting to remove the cosmic rays. The spectra were extracted and sky subtracted using the optimal extraction algorithm of Horne (1986). Programme stars and standards were reduced in exactly the same manner.

3. Radial velocities

Relative radial velocities of both the programme and the standard stars were calculated from cross-correlating (using the cross-correlation programme available in the FIGARO package) each programme star with a set of appropriate model spectra. The stellar atmosphere models were produced using the MARCS code (Gustafsson et al. 1975), and the synthetic spectra generated using the SSG code (Bell & Gustafsson 1978).

The models had a range in $T_{\rm eff}$ between 3700 K and 4500 K, and log g between 0 and 0.7, following roughly the corresponding ranges in the model atmospheres for carbon stars of Querci et al. (1974). We also assumed metal abundance of $[A/H] = -1.0$, carbon abundances [C/A] in the range between 0.0 and 2.0, and $^{12}C/^{13}C$ in the range between 3 and 30. The radial velocity corresponding to the highest cross-correlation peak (from a series of peaks obtained from cross-correlating the programme star with the set of model spectra) was adopted in each case. The corresponding model can be considered as being closest to the particular stellar spectrum.

Zero-point of the velocity system: The absolute zero-point of the velocity system was determined from the velocities of the standard stars. During the first observing run, the zero-point was determined with an accuracy of ± 3.2 km/s (which becomes ± 1.7 km/s, if we exclude one discrepant point). In the second observing run, a larger number of observations of standards was secured, and the zero-point was determined with an accuracy of ± 1 km/s. This very good agreement between the standard (carbon) stars confirms in an indirect way the suitability of the models used. However, two stars (HD 75021 and HD 223392) showed a systematically different velocities from the bibliographic values (of $\simeq 7$ km/s in both cases). They are suspected variables, and they were excluded from the zero-point determination. Finally, it should be noted that the velocities of the five programme stars that were observed in both observing runs (Table 1) showed a mean difference of 0.9 ± 2.7 km/s, which is well within the combined zero-point error from the two observing runs.

The final heliocentric radial velocities of the programme stars are given in Table 1. All of the programme stars given in Tables 1a and b yielded cross-correlation peaks (ccp) higher than 30%. Whenever two consecutive observations were available, the two spectra were co-added before deriving the final velocity appearing in Table 1.

Random errors in the velocity measurements:
1. From repeated observations: To estimate the random errors in the velocities, we compared the velocities derived from the individual observations of the same star for the

Table 2. The carbon stars used as velocity standards. *Column 1* gives the names of the stars, *Columns 2 and 3* their coordinates (1950), *Column 4* the radial velocity adopted for each star (using values from the bibliography, obtained by a search in the SIMBAD database), *Column 5* shows the mean observed radial velocity for each star (average from both runs), *Column 6* gives the number of observations obtained for each star, and *Column 7* denotes the run during which the observations were made

Name	**RA** (2000)	**Dec** (2000)	$\mathbf{RV}_{\rm bib}$ (km/s)	$\mathbf{RV}_{\rm obs}$ (km/s)	**no.**	**run**
HD 16115	02 35 06.34	−09 26 34.8	16.0	18.1	3	1
					2	2
HR 977	03 12 32.99	−57 19 18.7	14.3	14.3	3	1
					7	2
HD 52432	07 01 01.92	−03 15 08.1	21.6	24.2	3	1
					4	2
HD 67160	08 05 19.92	−38 46 35.6	28.0	24.6	1	1
					9	2
HD 75021	08 46 36.23	−29 43 41.2	11.0	17.4	1	1
					9	2
HD 79319	09 13 50.05	14 12 39.3	3.4	3.6	2	1
					5	2
HD 91793	10 35 12.93	−39 33 45.3	37.0	39.3	1	1
					7	2
HD 223392	23 49 05.35	06 22 56.6	−25.0	-13.3	2	1
					2	2

cases for which all repeated spectra yielded ccp higher than 30%. For the first observing run, there were 30 such cases, yielding a rms of the velocity difference of 4.7 km/s for the whole sample, or 3.4 km/s, if we remove two discrepant stars from the sample (with velocity differences between the two measurements of 13.0, and 14.5 km/s respectively). For the second observing run, there were 25 such cases yielding a rms of the velocity difference of 1.7 km/s. It should be noted that for the majority of the repeats in the second observing run both measurements gave ccp higher than 60%, while in the first observing run, most ccp were less than 60%, hence the higher absolute velocity difference in the latter case. The final velocities of Table 1 come from the co-addition of the repeated observations, therefore they should be more accurate than the individual measurements. All these repeats were generally done consecutively. There is one case where a programme star was observed on two different nights of the same observing run (star MH 1185). The velocity difference between the two velocities was 0.4 km/s. As mentioned in the discussion of the zero-point above, there were also five programme stars that were observed in both observing runs (see Table 1a). The rms of the velocity difference for the five stars was 6.1 km/s, or 2.4 km/s excluding one discrepant point (MH 1153). It should be noted that this particular star was observed twice in each of the observing runs. In the first run the velocity difference between the two measurements was 3 km/s, and in the second run, 2 km/s. Therefore, it is unlikely that the 10 km/s difference between the two runs is just due to random errors. It is possible that the star (MH 1153) is a binary (see below).

2. From simulation: Finally, we conducted the following experiment: we artificially added different amounts of noise to a high signal-to noise spectrum of a standard star, and cross-correlated the resulting spectrum with the series of models, as was done for the real data. This was repeated several times in each case. We found that, the rms of the velocity difference was 3.6 km/s (with a maximum of 6.7 km/s) for a ccp of 30%. This rms decreased to 1.1 km/s (max of 2.7 km/s) for a ccp of 55%, and to 0.3 km/s (max of 0.6 km/s) for a ccp of 70%.

Using all of the above, we estimate that the individual random errors in the velocities of Table 1 range from about 5 km/s for the lowest ccp (i.e. < 0.40) to 1 km/s for the best observed stars. Most of the stars have velocity determinations of intermediate accuracy, i.e. of $2-4$ km/s.

The effect of the choice of models on the derived velocities:
The choice of models used as cross-correlation templates may have an influence on the derived radial velocities. We examined the cases for which more than one exposure was available, and for which all individual spectra gave acceptable ccp (this exercise could only be performed for the red spectra). It was found that for more than half the cases, the models that gave the highest ccp were identical for the different exposures of the same star. In the rest of the cases, the models picked were similar, and most importantly the effect on the radial velocities was well within the error margins previously mentioned (i.e. < 6 km/s). In 70% of the stars, the overall range of velocities yielded by the full range of models used was less than 6 km/s.

The maximum range observed was $\simeq$ 20 km/s (just for one star). However in this latter case the large range was caused by models that gave low ccp (well below 30%). From the above analysis it becomes clear that the use of models is necessary for the proper derivation of the velocity shifts, as the correct matching of the template to the programme star can be crucial. Therefore, just the use of a selection of a few galactic carbon stars as templates for the cross-correlation, which is the usual practice, may not be good enough.

Comparison between the Red and Blue spectra: The above analysis was based on the velocities derived from the red spectra. Generally, the "red" spectra (8335−8879 Å) had much higher signal-to-noise ratios than the "blue" spectra (4656−5785 Å), mostly due to the fact that carbon stars are much brighter in the red. This, coupled with the smaller pixel size (by a factor of 3 in km/s) of the red spectra and with the fact that in the red spectra there is a forest of strong but unsaturated lines, led to much more accurate velocities from the red spectra.

It is important, however, to compare the radial velocities derived from the two different wavelength regions. The results for the first run are discussed here. There is a small zero-point difference between the blue and red spectra velocities amounting to -6.2 ± 3.1 km/s, corresponding to less than 0.10 of the combined pixel size. The rms of the velocity difference between the red and blue spectra of the standard stars is 8.7 km/s, corresponding to 0.13 of the combined pixel size (the maximum difference being 17.4 km/s, corresponding to 0.26 of the combined pixel size). For the programme stars, the rms of the velocity difference between the two sets of velocities, for ccp higher than 30%, was 20.5 km/s corresponding to 0.31 of the combined pixel size, which is expected given the lower signal-to-noise of the blue spectra. This comparison between the velocities yielded by the red and blue spectra provides a check against gross errors caused by mis-identification of the ccp. No such instances were noted. In Table 1, we have adopted the velocities derived from the "red" spectra.

4. Discussion

The overall radial velocity histogram of the 70 SMC carbon stars of Table 1a is shown in Fig. 2. The LMC stars of Table 1b are too few to warrant further analysis. They are only used as a control sample, for this paper. The following discussion refers to the 70 SMC stars alone, unless clearly stated otherwise. The histogram of Fig. 2 shows no evidence of the peak bifurcation (corresponding to a separation of 30 km/s between the two main peaks) observed in some samples of young stars (see e.g. Torres & Carranza 1987). Similarly, no bifurcation was observed in the sample of carbon stars in the central region of the SMC studied by Hardy et al. (1989). Interestingly, the new high resolution measurements of HI in the SMC (Staveley-Smith et al. 1995, 1996), which presumably trace a young stellar population, also do not show bifurcation.

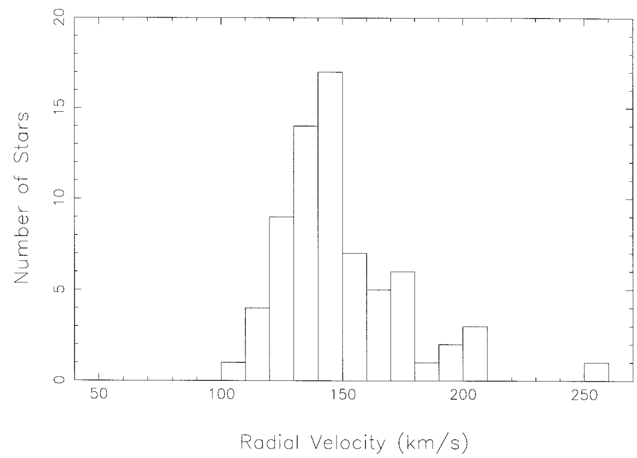

Fig. 2. The heliocentric radial velocity histogram of the sample of Table 1a

The mean radial velocity of the whole sample is 149.3 ± 3.0 km/s (LSR), with a dispersion of 25.2 ± 2.1 km/s. This value for the velocity dispersion was derived after having taken into account the contribution of the observational errors, as described in Da Costa et al. (1977). The radial velocities confirm that all of the stars in the sample are indeed members of the MCs, as expected from their locations and apparent magnitudes. There is one exception of a very high velocity star in the sample (star MH 928 with a velocity of 363 km/s). This star was not included in the calculations of the characteristics of the velocity distribution.

It is interesting to compare these values with the ones obtained for other samples of intermediate-age and old stars, mentioned in Sect. 1. Table 3 shows a summary of the previous results, along with the present ones. There is generally good agreement between the radial velocity dispersions, with the possible exception of the Hatzidimitriou et al. (1993) sample, which has an apparently higher dispersion. However, if the correlation between velocity and distance along the line of sight –which is present in that sample– is taken into account, the velocity dispersion drops to $\simeq$ 18 km/s. As far as the mean radial velocity of the SMC is concerned, there are about 2σ discrepancies between the different samples, which can be partly attributed to errors in the zero-point of the velocity calibrations, and –probably– partly to the different locations of the samples.

Although there are no multi-epoch observations for the carbon stars of Table 1, with the exception of 5 stars that were observed in both observing runs, it is important to try to evaluate the effect that binaries could have on the estimated velocity dispersion of our sample. As mentioned

Table 3. A summary of recent studies of the kinematics of relatively old stellar populations in the SMC, along with the results from the current study. *Column 1* gives the source, *Column 2* the type of stars studied in each case, *Column 3* the location of the sample, *Column 4* the sample size, and finally *Columns 5 & 6* the mean heliocentric (LSR) radial velocity and radial velocity dispersion with the associated errors, corresponding to each case

Study	Type	Region	n	<RV> (km/s)	RV dispersion (km/s)
Hatzidimitriou et al. 93	HB	NE outer	30	151 ± 6	33 ± 4
Suntzeff et al. 86	RGB	NW outer	12	123 ± 7	18 ± 5
Dopita et al. 85	PN	central	44	146 ± 4	25 ± 3
Hardy et al. 89	CS	central	131	148 ± 2	27 ± 2
Present	CS	whole sample	70	149.3 ± 3.0	25.2 ± 2.1
		no Outer Wing	62	145.5 ± 2.7	20.6 ± 1.9

earlier, it is possible that one of the five stars that were observed in both observing runs as well as one of the velocity standards, could be binaries. We have performed simulations of the effects of different proportions of binaries in the observed velocity dispersion.

This was done using a sample of 70 stars, and 1000 trials, with an initial normal distribution of velocities (with a standard deviation of 25 km/s). Onto this distribution, the effects of binaries were added, given a fraction of stars in binary systems, and an upper and lower limit to the binary orbital velocity of the carbon star. The orientation of the orbit was randomly distributed, and the orbit assumed circular (an elliptical orbit will result in the stars spending more time further apart, with lower orbital speed). Three cases were considered:

1) 20% of the stars in binaries with orbital velocities of 25 km/s.
2) 50% of the stars in binaries with orbital velocities uniformly distributed between 0 and 25 km/s.
3) 20% of stars in binaries with orbital velocities of 32.5 km/s.

The choice of the possible fractions of binary stars are based The choice of the maximum velocity limits is based on two basic assumptions:
First, that no mass transfer occurs, and second, that the companion star would contribute less than 10% to the light of the carbon stars. This second condition comes from the following argument: most observed carbon stars have C_2 bands which have essentially zero light in the band heads. This puts a limit on the light contribution from any possible companion (unless it is an eclipsing binary, with the companion behind the carbon star - in this case the orbital velocity at the time of the observation will be in the plane of the sky, and will not affect the observed radial velocity significantly).

The velocity dispersion increases from 25 km/s to 25.7 km/s in the first two cases and to 26.3 km/s in the third case (with an rms of 1 km/s in all cases). Therefore, the effect of such distributions of binaries would be that the measured velocity dispersion would be 1km higher than the actual. Therefore, we conclude that the measured velocity dispersion of 25.2 could be revised to 24.2 km/s if such a binary distribution is assumed to exist.

The sample of outer LMC carbon stars observed – located in the SW of the LMC, i.e. in the general direction of the SMC (Table 1b)– have a mean velocity of 227.4 ± 2.8 km/s and a velocity dispersion of 10.6 ± 1.9 km/s. If we excude the two lowest velocity stars in the sample (12 and 16), we get a mean velocity of 231.0 ± 1.4 km/s and a velocity dispersion of 4.8 ± 1.0 km/s. The velocity dispersion is remarkably low, however one should keep in mind the small size of the sample and its spatial distribution within a small area of the LMC halo.

The spatial distribution of stars of different velocities may offer some insights into the dynamics of the SMC. We have already seen that at least in some directions (e.g. in the NE sample of Hatzidimitriou et al. 1993, and in the Wing, from Hardy et al. 1989) there are streaming motions that affect the calculated overall mean velocities and velocity dispersions. In Fig. 1 we have marked with different symbols the different velocity groups (arbitrarily defined, for the sake of the presentation). There are three points that can be made:

(i) The stars that could be postulated as belonging to the outer Wing of the SMC and possibly to the intercloud region (although the distinction between the two is not clear), seem to have a systematically higher mean velocity. There are eight such stars in the sample (MH 1171, MH 1173, MH 1175, MH 1176, MH 1177, MH 1180, MH 1181, MH 1185). They have a mean heliocentric velocity of 179 ± 14 km/s (or 168 ± 8 km/s, removing the highest velocity star). The rest of the SMC stars then have a mean radial velocity of 145.5 ± 2.7 km/s and a velocity dispersion of 20.6 ± 1.9 km/s, which are more representative of the main body of the SMC. There is no apparent correlation of the velocities of the eight "Outer Wing" stars with projected distance from the SMC centre,

or with projected distance along the Wing axis. However, the number of stars in the "Outer Wing" sample is too low for further statistical analysis. It is important to note that with the exception of one star (MH 1173, with a velocity of 253.3 km/s, and radial projected distance from the centre of the SMC of 5.2 deg), all of these remote stars, some of which are very close to the outer regions of the LMC (in projection), have velocities too low to be LMC members. Star MH 1173, which has the highest velocity of 253.3 km/s, is close to the SMC centre and well within the SMC contours, therefore more likely to be an SMC star. It should be mentioned that at least two of the LMC stars, 12 and 16 may also be outer Wing/intercloud members.
(ii) Morgan & Hatzidimitriou (1995) noticed the presence of an elongated feature in the spatial distribution of carbon stars in the SMC, at the southernmost extremity of the galaxy. Six of the stars of Table 1a seem to belong to this feature (stars MH 1033, MH 1106, MH 1111, MH 1112, MH 1155, MH 1165). If they are removed from the sample of SMC stars, no change is observed in the mean velocity and velocity dispersion. There is no obvious kinematical signature of this group of southern stars. It is probably worth noting, however, that the southernmost star of this feature has a rather high velocity (195.5 km/s).
(iii) No convincing rotation was found around either the major or the minor axes of the SMC, or any other axis examined (i.e. all projected axes, every 20 deg). This is in agreement with the result of Hardy et al. (1989).

Dopita et al. (1985) and Hardy et al. (1989) have used their estimates of the velocity dispersion in the central regions of the SMC to calculate the mass of the SMC (within the central parts), by applying the virial theorem. Although the validity of this method is very questionable in the case of the SMC with its possibly disturbed dynamics, we shall attempt a similar calculation for the sake of comparison with the previous results, especially since our sample has a much larger radial extent. Using the result on the overall velocity dispersion (without the Wing region) of 21 km/s out to a radius of 6 kpc and assuming a simple spherical distribution of matter (which is certainly an over-simplification), we derive a total mass of $\simeq 1.2\ 10^9 M_\odot$, which lies in between the values estimated by Hindman (1967) from HI data, and by Dopita et al. (1985) and Hardy et al. (1989) from the kinematics of planetary nebulae and carbon stars respectively in the inner regions of the SMC.

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