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Radio Continuum of the Small Magellanic Cloud at Wavelengths 6 and 3·4 cm

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Abstract

The radio continuum at wavelength 6 cm has been surveyed in the direction of the Small Magellanic Cloud with a telescope beam of 4′·1 arc. Only 27 radio sources have been delineated in this galaxy, and details of their positions, flux densities and spectral indices are given. Some supporting observations were made of the stronger sources at 3·4 cm wavelength. The distribution of the 6 cm emission is compared with the distributions of the ionized gas and neutral hydrogen.

1. Introduction

The first observations of the radio continuum of the Small Magellanic Cloud (SMC) were reported by Mills (1955), who used a wavelength of 3·5 m and a telescope beamwidth of 50′ arc. Shain (1959) found that the galaxy could be seen at a wavelength of 15·2 m and that an extension towards the Large Cloud could be detected. The first evidence of individual sources within the SMC was obtained by Mathewson and Healey (1964) with the Parkes telescope at 73 cm and 21 cm. These authors remarked that the broad radio contours followed the bright optical 'bar' and the 'wing' of the SMC, but they scarcely discussed individual sources. In spite of the angular resolution of 7′·4 arc at 11 cm, Broten (1972) found relatively few individual sources and little evidence for the extended background radiation prominent at the longer wavelengths. This supported the surmise of Mathewson and Healey of a nonthermal background.

The present work consists of a survey made with the Parkes 64 m telescope of beamwidth 4′·1 arc at 6 cm, and a series of observations of the stronger sources at 3·4 cm. In the latter case the beamwidth was 2′·6 arc. Compared with the LMC the radio sources in the SMC are relatively few in number and there is very little background radiation at the shorter wavelengths.

2. Equipment and Method of Observation

The 6 cm cryogenically cooled receiver (Brooks and Sinclair 1972) had a bandwidth of 500 MHz about the operating frequency of 5009 MHz and a system temperature of 80 K. The input to the receiver was switched between the feed horn and a cold-load reference at 17 K.

The scale of flux density was based on measurements of Hydra A, assumed to have a (peak) flux density of 13·0 Jy.* Measurements of the beam shape using the

* 1 Jy (jansky) = $10^{-26}\ \mathrm{W\,m^{-2}\,Hz^{-1}}$.

Table 1. Catalogue of 3·4 and 6 cm sources in SMC

(1) Source number	(2) Position (1950·0) R.A. h m	(3) Dec. ° ′	(4) Henize HII regions	(5) Integrated flux densities* $S_{3\cdot4}$ (Jy)	(6) S_6 (Jy)	(7) S_{11} (Jy)	(8) S_{21} (Jy)	(9) S_{73} (Jy)	(10) Spectral index α
S1	00 12·1	−73 54·2			0·29±0·03	0·19P	0·63	0·77	−0·6
S2	00 19·6	−74 31·8			0·13±0·01			0·24	−0·3
S3	00 19·8	−74 45·8			0·37±0·04	0·51, 0·58B, 0·53P	1·75	2·2	−0·8
S4	00 21·5	−74 13·2			0·16±0·02	0·26B, 0·25P	0·82	1·42	−0·9
S5	00 40·5	−76 04·7			0·49±0·05	0·4P	1·19		−0·7
S6	00 43·8	−72 22·0			0·23±0·02				
S7	00 44·8	−72 57·2		<0·1	0·36±0·04				
S8	00 45·2	−72 24·0			0·18±0·02				
S9	00 45·7	−73 24·7	19 (1)	0·47±0·07	0·92±0·09	0·61, 0·63B, 0·94P	0·90	1·0MC, 1·18, 2·2MA	−0·2
S10	00 46·3	−73 32·7	{22 (2), 28 (2)}	} 0·45±0·07				0·40	
S11	00 46·6	−75 46·0			0·17±0·02	0·41P	0·48		−0·6
S12	00 46·7	−72 56·3		<0·1	0·19±0·02†				
S13	00 47·2	−73 24·0	30 (2)	<0·1	0·31±0·03†				
S14	00 47·9	−72 35·0			0·17±0·02				
S15	00 48·6	−73 08·2	36 (1)	<0·1	0·25±0·03†	0·21, 0·56B	0·71		(−0·3)
S16	00 49·3	−73 03·6	37 (1)	<0·1	0·23±0·02†				
S17	00 57·6	−72 26·0	66 (3)	2·64±0·40	{2·42±0·24, 2·66G±0·27}	1·32, 1·89B, 1·35P	} 3·1	{1·89, 2·9MA}	} −0·0
S18	01 01·0	−76 02·5		1·35±0·20	0·74±0·07	0·43P	0·71		Curved
S19	01 01·8	−72 19·0	76 (2)		0·35±0·04		} 0·90 (S19–S20)		
S20	01 02·4	−72 19·2	76A (2)	0·31±0·05	0·32±0·03	0·56, 0·50P		0·65	−0·1
S21	01 03·6	−72 15·8	78 (2)	<0·1	0·18±0·02	0·20	0·17	0·17MA	0·0
S22	01 06·2	−72 46·8							
S23	01 06·4	−72 16·5	80 (1)		0·10±0·01				
S24	01 08·4	−72 44·0							
S25	01 09·3	−73 30·0		0·4 ±0·06	0·32±0·03	0·70B, 0·42P	1·08	2·1	−0·6
S26	01 12·8	−73 34·0	{83 (2), 84 (2)}	} (0·6)	0·77±0·08	0·65, 0·38P	0·68	{0·47, 1·1MA}	} −0·1
S27	01 27·6	−73 48·8	90 (2)		0·25±0·03	0·18P		0·29, 0·49MA	−0·1

* See Section 3 of text for explanation of abbreviations used.

† Flux densities marked with a dagger in column 6 were calculated after a base level of 0·1 K brightness temperature was removed.

sources Hydra A, 1934–63 and 2134+004 showed the beam to be circular within 5%, with a half-power width of 4′·1 arc. The scale of flux density was converted to one of full-beam brightness temperature, assuming the beam to be gaussian with this half-width. In this conversion 1 K corresponds to 1·2 Jy.

The survey consisted of scans in declination at half-beamwidth intervals across the SMC between regions well outside the Cloud that were adopted as cold sky (0 K). The baselines for the declination scans were referenced to tie-down scans in right ascension across the cold regions. Data samples were recorded in an on-line computer at intervals one-tenth of a beamwidth apart. The data were smoothed digitally using the weighting function sinc x, where x is the ratio of the sample interval to the beamwidth. Corrections were applied on-line to the data for the zenith-dependent effects of spillover and aperture efficiency. At least two scans were made at each right ascension and the average was finally plotted with an on-line incremental plotter. Further editing of the data and contour plotting was carried out off-line.

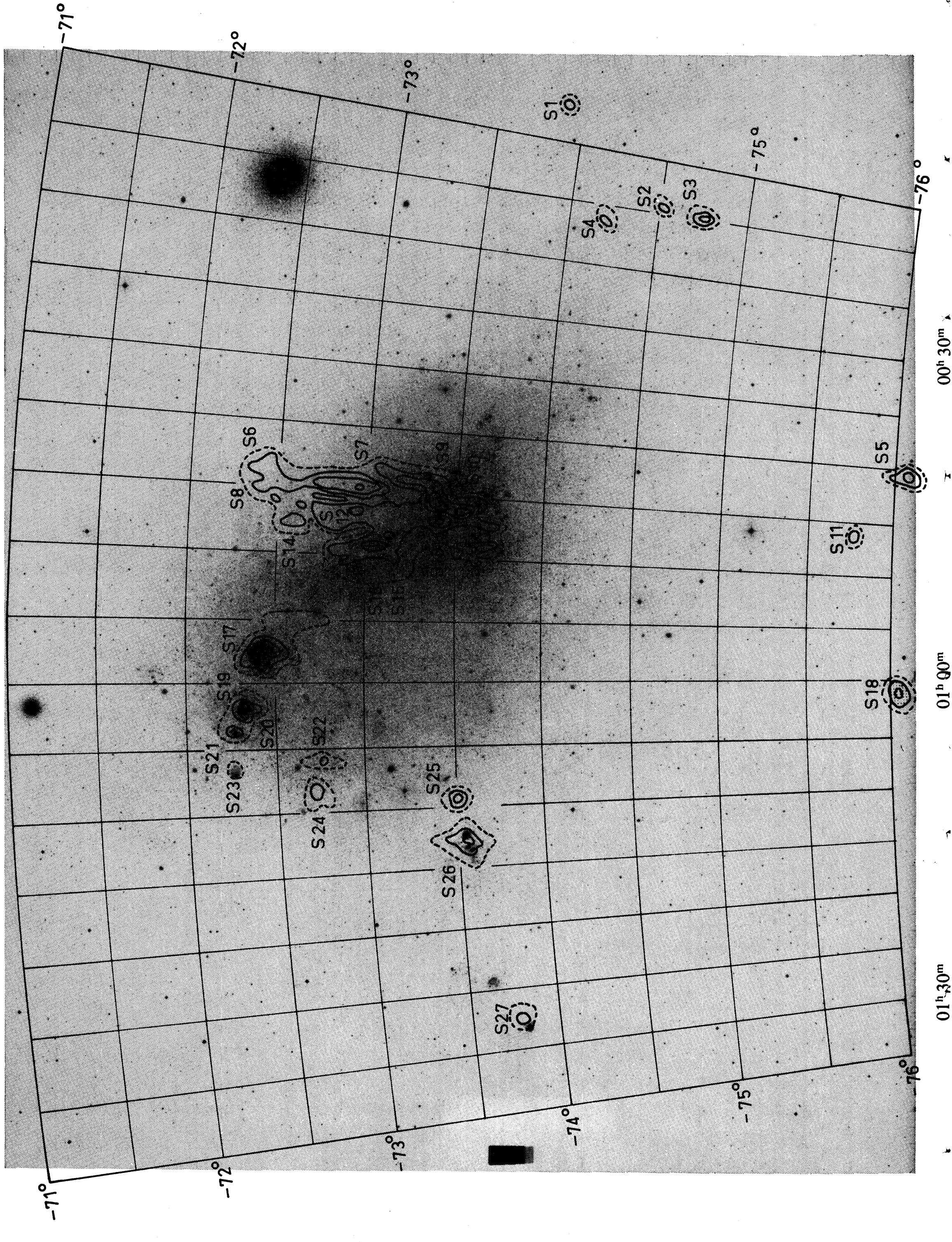
The operation and calibration of the 3·4 cm receiver have been described by McGee *et al.* (1975). In the present case the telescope beam was circular and of half-power width 2′·6 arc. The relation between full-beam brightness temperature and flux density was 1 K ≡ 1·57 Jy. The peak flux density for Hydra A was assumed to be 7·6 Jy.

Observations of the stronger sources from the 6 cm survey were made with the aid of an auto-scanning program for the measurement of source positions and flux densities. The program sampled the receiver output to record scans in right ascension and declination which were repeated and averaged until a satisfactory signal-to-noise ratio was achieved.

3. SMC Survey

The radio continuum map of the SMC at wavelength 6 cm is given in Fig. 1. The lowest level contours representing a full-beam brightness temperature of 0·05 K are shown as dashed lines. The full contours are spaced at intervals of 0·1 K full-beam brightness temperature. The radio continuum map has been superimposed on a reproduction from a superb plate of the galaxy taken by the U.K. Science Research Council on their 1·2 m Schmidt telescope at Siding Spring Observatory. The emulsion was an Eastman-Kodak IIIaJ with the bandwidth approximately 4000 to 5500 Å and therefore useful for highlighting the ionized gas regions as well as stars. The prominent globular clusters to the west and north of the SMC are 47 Tucanae and NGC 362 respectively. It can be seen in Fig. 1 that the high-frequency radio emission is restricted to three main regions within the SMC. More details of the 6 cm continuum contours in these three regions are given in Fig. 2, in which individual sources are labelled and their maximum brightness temperatures are marked.

The list of sources with their 1950 positions, estimated flux densities and spectral indices appears in Table 1. The estimated errors in position are: $\pm 0^{m}\cdot 3$ in R.A. (column 2) and $\pm 1'\cdot 2$ in Dec. (column 3). Column 4 contains Henize (1956) catalogue numbers of emission nebulae, together with (in parentheses) relative Hα intensities increasing on a scale of 1 to 5. The principal sources are clearly visible in Broten's (1972) 11 cm map of the SMC, and if the 6 and 11 cm maps are used as guides they can also be discerned in the 21 cm contours of Mathewson and Healey (1964). We have estimated the flux densities at 11 and 21 cm where possible from these maps.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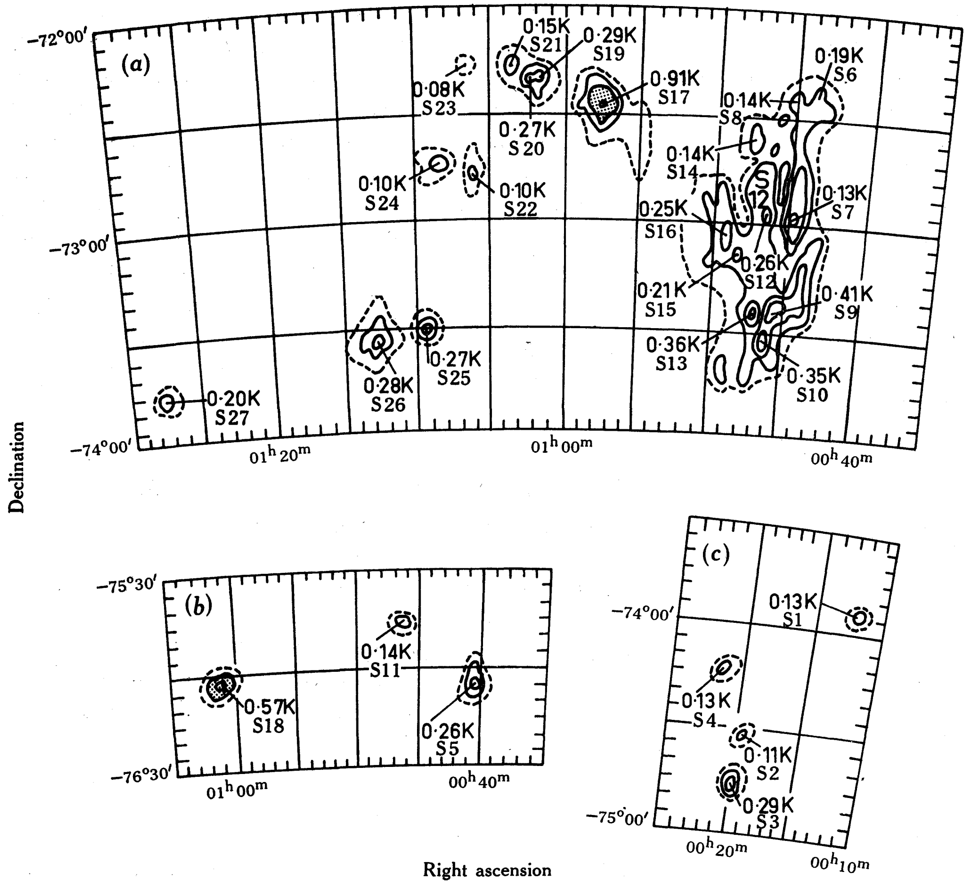

Fig. 2. Three contour maps of full-beam brightness temperature of the 6 cm radio continuum in the SMC on coordinates of R.A. and Dec. (epoch 1950·0):

(*a*) Sources in the main body of the SMC.

(*b*) Southern sources.

(*c*) Western sources.

The aerial beamwidth at half-power was 4′·1 arc. The contour interval is 0·1 K. The maximum full-beam brightness temperature is marked for each source.

Fig. 1 (*opposite*). Small Magellanic Cloud photographed on a IIIaJ plate with the SRC 1·2 m Schmidt telescope at Siding Spring Observatory (reproduced by courtesy of the U.K. Science Research Council). Superimposed is an R.A., Dec. (epoch 1950·0) grid and a contour map of the radio continuum at 6 cm wavelength. The contour interval is 0·1 K full-beam brightness temperature. The dashed contours are at 0·05 K. The catalogue number is marked for each source.

We also used the maps to calculate spectral indices for the sources in Table 1. The recent survey by Clarke *et al.* (1976) provided information at 73 cm for 11 of the sources. The abbreviations used in the table are: B, flux density derived from Broten's (1972) contours; G, flux density based on an assumed gaussian shape for the source; MA, flux density from Mills and Aller (1971); MC, flux density from Mathewson and Clarke (1972); P, flux density from Shimmins and Bolton (1972) and Bolton and Butler (1975). The unlabelled flux densities in columns 7 and 8 were derived by us from the contours of McGee (1972) at 11 cm and Mathewson and Healey (1964) at 21 cm, while the unlabelled flux densities in column 9 are from Clarke *et al.* (1976).

The stronger sources with flat spectra were observed at 3·4 cm wavelength. Estimated flux densities for sources S9, 10, 17, 18, 20, 25 and 26 are given in Table 1. Six of the sources were unresolved by the 2′·6 arc beam. The N66 nebula (S17) was considerably extended, and the 3·4 cm contours for this region are given in Fig. 3 below. Sources S7, 12, 13, 15, 16 and 21 were below a flux density level of 0·1 Jy.

Western sources

Sources S1 to S4 in Fig. 2*c* lie near R.A. $00^h 20^m$ and between Dec. $-73° 50'$ and $-74° 50'$. The close grouping suggests that they may be associated with the SMC. The group appears to have an elongated structure in Broten's (1972) 11 cm chart and to extend northwards to approximately declination $-73°$. Sources S1, 3 and 4 are nonthermal. The latter pair, together with S2, lie near the edge of one of the expanding gas shells (No. 2) proposed by Hindman (1967) in his analysis of neutral hydrogen data. If these sources are associated with the SMC the projected distance from the optical bar is some 2 kpc. However, Fig. 1 gives no indication of corresponding visible features. Clarke *et al.* (1976) did not regard them as members of the SMC.

Southern sources

Another group of three sources (Fig. 2*b*) lies to the south, and if they are members of the SMC they would be at about the same projected distance (2 kpc) from the bar. Sources S5 and S11 were relatively intense at 21 cm (Mathewson and Healey 1964) and exhibit nonthermal spectra. The source S18 is the second most intense source in the SMC area at 6 cm. Its spectrum from 21, 11 and 6 cm measurements suggested that it might be an HII region and searches were made for possible recombination line emission at 5 GHz (H109α) and 8·9 GHz (H90α). No evidence of recombination lines was found down to a line-to-continuum ratio of 3%. The plate in Fig. 1 obtained subsequent to the radio observations shows no sign of an HII region. The more recent 3·4 cm flux density estimate indicates a positive up-turn in the spectrum, which is a feature of some quasi-stellar objects.

The source S18 has been further investigated by Peterson *et al.* (1976). Their radio position is within 7″ arc of an 18^m stellar object at R.A. $01^h 00^m 55^s{\cdot}27$, Dec. $-76° 02' 56''{\cdot}1$ (1950·0). By means of two-colour photography (blue and ultraviolet) with an image tube camera at the Cassegrain focus of the 74 inch telescope at Mt Stromlo they found an ultraviolet excess—again a characteristic of quasars.

Sources in main body of SMC

In general the remaining sources (Fig. 2*a*) are found at either end of the optical bar of the SMC and in the so-called wing.

S9

The principal source in the south-west region is S9. The position of the maximum corresponds closely to that of the Henize (1956) nebula N19, the differences being 36″ arc in right ascension and 60″ arc in declination. Optically the nebula dominates the southern end of the SMC bar. The Henize catalogue gives its size as $5'\cdot2\times7'\cdot0$ arc, corresponding to linear dimensions of 96×126 pc. The surface brightness in Hα light is low, being 1 on the intensity scale of 1 to 5.

Recently Mathewson and Clarke (1972) have used a 'combination of radio and optical techniques ... to identify a supernova remnant in the emission region N19 ...'. They found a spectral index of $-0\cdot5$ which, as Milne (1970) has shown, would strongly support claims for an SNR. Their calculation is based on their own flux density of 1·0 Jy at 73 cm and a value at 11 cm privately communicated by N. W. Broten in 1965. (We infer the latter must have been 0·42 Jy.) However, from Broten's (1972) published 11 cm contours we deduce a flux density of 0·63 Jy, in agreement with our own value of 0·61 Jy (McGee 1972) and this, in combination with our 6 cm and 3·4 cm flux densities, gives a spectral index of $-0\cdot2$ and suggests that at the low centimetre wavelengths most of the radiation from S9 arises in an HII region. The principal difficulty in evaluating this source is that of deciding the level of background radiation and the consequent corrections for angular size. The uncorrected half-power width at 6 cm is $7'\cdot2\times5'\cdot6$ arc. The 3·4 cm observations suggest that its diameter is less than 2′·6 arc. Mathewson and Clarke (1972) gave a diameter of 22 pc ($\equiv$ 1′·2 arc) for their SNR at the western edge of N19.

That the radiation from this emission complex is largely thermal is supported by our observation of the H109α recombination line in the direction of S9. Although the integration time was limited, there is a good indication of a line with the following parameters:

Line	Frequency (MHz)	T_L (K)	$\Delta\nu$ (kHz)	ΔV (km s^{-1})	T_L/T_C (%)	ΔT_L (K)	V_R (w.r.t. Sun) (km s^{-1})
H109α	5008·923	0·015	612	36·9	3·9	$\pm$0·01	+137·9

The values of half-width and line-to-continuum ratio are typical of galactic and LMC recombination lines in HII regions. Inspection of the radial velocity diagrams in the Hindman and Balnaves (1967) atlas shows that a strong concentration of neutral hydrogen of radial velocity $+138\cdot3$ km s^{-1} is present in the same direction and presumably close to this source. Smith and Weedman (1973), using a Fabry–Perot interferometer with spectral resolution 11 km s^{-1}, found a radial velocity of $+142\cdot3$ km s^{-1} on the eastern side of the nebula. Hence there are at least two lines of evidence pointing to the presence of both thermal and nonthermal sources in the large complex S9—as seemed to be the case with some complexes in the LMC (McGee and Newton 1972).

Other South-west Sources

The source S10 corresponds closely with Henize HII regions 22 and 28. The source S13 is probably the radio counterpart of Henize 30 and 30A. The western extension of the 6 cm continuum from S9 includes Henize regions 12A and 12B. In all, 25 Henize nebulae are to be found in the southern part of the SMC bar, but our angular resolution is insufficient to allow more than a few to be identified with individual radio sources.

Sources in the Mid Bar

A group of minor radio sources is found in the direction of part of the optical bar of the SMC. On Broten's (1972) map the 11 cm radio picture shows a large irregular source with two points of maximum intensity. The 6 cm survey has resolved six separate sources, and other low-level sources are evidently present in view of the shape of the contours. The larger Henize HII regions N36 and 37 are close to sources S15 and S16 respectively but smaller nebulae do not have corresponding radio features. The comparatively strong Henize N46, of dimensions $19'' \times 16''$ arc and Hα intensity 3, does not have either a 6 or 11 cm counterpart. The low-intensity radio sources S6, 8 and 14 appear to be outside the main body of the bar.

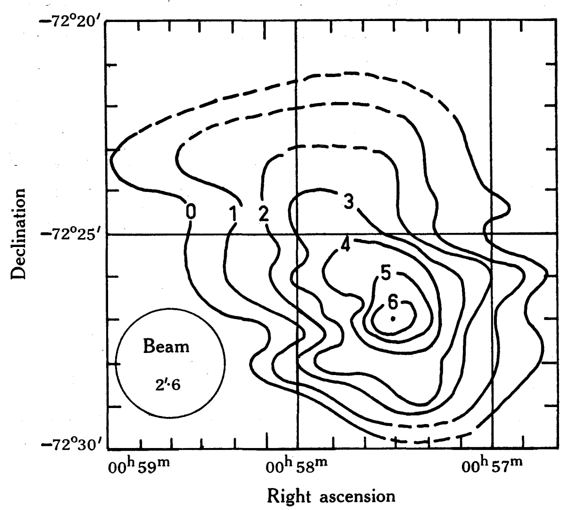

Fig. 3. Contour map of the 3·4 cm continuum of source S17. The values on the contours may be converted to full-beam brightness temperature T_b by multiplying by 0·18 K. The T_b at the maximum was 1·2 K. The circle indicates the half-power beamwidth of the telescope.

Sources at North-east End of Bar

The source S17 is the strongest 6 cm source in the SMC by a factor of more than two in beam brightness temperature. Included in the area of its contours are the nebulae NGC 346, or N66A, B, C and D, and N70. As can be seen from Table 1, the spectrum of S17 is typically thermal. The detection of a hydrogen recombination line with the parameters shown below supports this result. However, the line-to-continuum ratio is much lower than normal, being 2% as compared with 5% in strong galactic sources.

Line	Frequency (MHz)	T_L (K)	$\Delta\nu$ (kHz)	ΔV (km s^{-1})	T_L/T_C (%)	ΔT_L (K)	V_R (w.r.t. Sun) (km s^{-1})
H109α	5008·923	0·018	788	47·2	2	±0·006	+162·2

The radial velocity is in close agreement with optical Hα results. Bok *et al.* (1964), using a nebula spectrograph on the 74 inch Mt Stromlo telescope, reported values of $+159 \pm 7$, $+165 \pm 6$ and $+152 \pm 8$ km s^{-1} for N66, while Feast (1970) found $+163$ km s^{-1}. Hindman and Balnaves (1967) found double-peaked neutral hydrogen lines in this direction, of radial velocities $+130$ and $+170\ \mathrm{km\,s^{-1}}$ approximately. The 3·4 cm map of S17 in Fig. 3 shows that almost all of the background radiation present at 6 cm has disappeared but that the central part of the source is more complex than would have been expected from the 4′ arc resolution of the 6 cm map. The shape of the 3·4 cm contours is similar to that of the visible nebulosity.

S19, 20, 21 and 23

These sources correspond fairly closely with gaseous nebulae (see Fig. 1). Sources S19 and 20 correspond to Henize N76, 76A, 76B and 76C while the area S21 includes the positions of Henize N78, 78A, B, C and D. The radio estimates in Table 1 indicate that this group of sources is thermal. On the radial velocity information from Smith and Weedman (1973) it would seem that these sources are well separated along the line of sight from S17. Their measurements are

$$V_{\mathrm{R}}(\mathrm{N76A}) = +184\cdot6\ \mathrm{km\,s^{-1}}, \qquad V_{\mathrm{R}}(\mathrm{N76B}) = +189\cdot5\ \mathrm{km\,s^{-1}}\ \ (\mathrm{S19, 20});$$

$$V_{\mathrm{R}}(\mathrm{N78A+B}) = +196\cdot9\ \mathrm{km\,s^{-1}}\ \ (\mathrm{S21}); \qquad V_{\mathrm{R}}(\mathrm{N80A}) = +178\cdot4\ \mathrm{km\,s^{-1}}\ \ (\mathrm{S23}).$$

Sources in the 'Wing'

The longer wavelength surveys show the whole region of the 'wing' covered by radio emission. Only seven sources trace out the wing at wavelength 6 cm. The sources S22 and 24 possibly correspond to a large one-contour source found at 21 cm by Mathewson and Healey (1964). Both of these sources would appear to have nonthermal spectral indices.

S25 and S26

Table 1 shows that S25 is strongly nonthermal. The source S26 covers a comparatively large area of sky and probably includes contributions from Henize HII regions N83, N84, N85 and N86. The spectral index is $-0\cdot1$. The brightest known star in the SMC, HD7583, is found in the direction of S26. It is possible that the sources S25 and 26 are another example of the thermal–nonthermal pairs found in the LMC (McGee and Newton 1972). No 6 cm continuum source was found at R.A. $01^{\mathrm{h}}15^{\mathrm{m}}\cdot0$, Dec. $-73°41'\cdot4$ (1950), the position given for the X-ray source 2UR 0115–73 in the UHURU catalogue (Giacconi *et al.* 1972).

S27

This source is very close to Henize N90. It is possible that our measurement of right ascension is in error. Clarke *et al.* (1976) found the right ascension for S27 to be the same as that for N90 ($01^{\mathrm{h}}28^{\mathrm{m}}\cdot3$).

4. Comparisons with Other Distributions in SMC

HII activity

Contours of Hα excess distribution published by Schmidt (1972) have been superimposed on the 6 cm map and are shown in Fig. 4. The main region of Hα emission is seen to correspond closely with the sources at the north-east end of the bar. The other two concentrations correspond well with the thermal sources in the south-west bar and the southern part of the wing. The individual correspondences of HII nebulae and 6 cm thermal sources have been discussed in the previous section. After

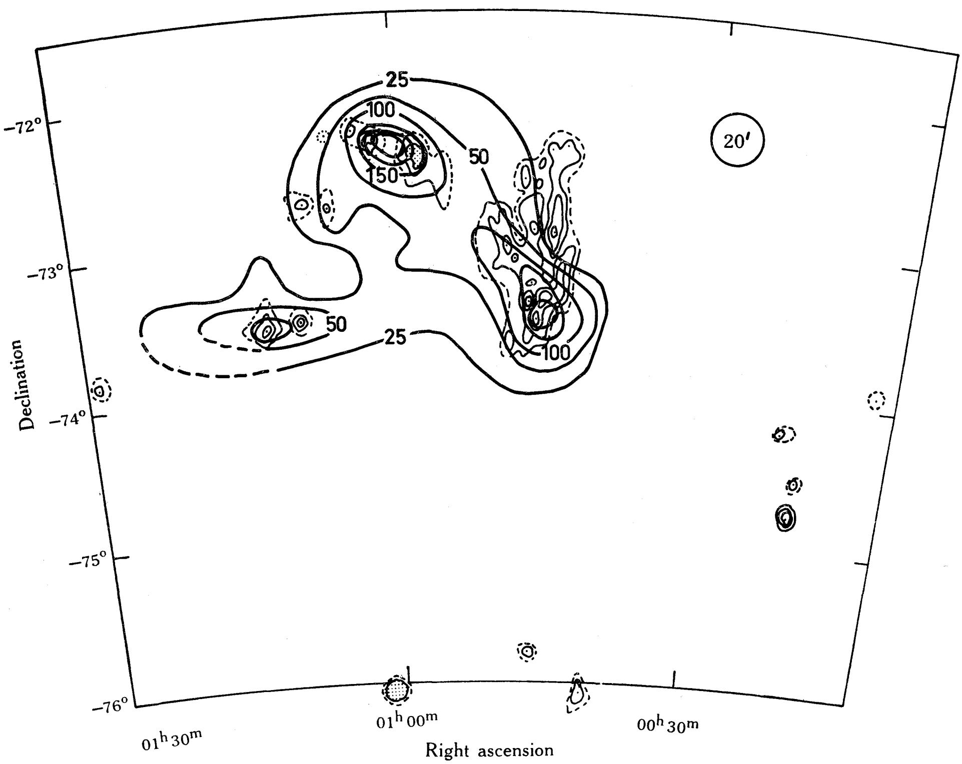

Fig. 4. Contours of Hα excess distribution sketched from Fig. 3 of Schmidt (1972) and superimposed on the 6 cm full-beam brightness temperature distribution of the SMC. The circle is Schmidt's 'focal diaphragm' 20′ arc. The contour interval of the Hα excess is 50 units after contour 50. The epoch is 1950·0.

cataloguing and classifying the nebulae, Henize (1956) wrote 'when the Large and Small Clouds are compared one striking difference ... is evident; whereas type 1 nebulae (irregular with intensities 4, 5) are abundant in the Large Cloud, they are almost entirely lacking in the Small Cloud. This is in contrast to the fact that the frequency of nebulae per unit area, irrespective of their type, is at least as great in the Small Cloud as in the Large. Thus it appears that nebulosity is as abundant in the Small Cloud as in the Large but that the surface brightnesses of the Small Cloud nebulae are not so great as those nebulae of the Large Cloud'. Only 27 sources have been delineated at 6 cm compared with 95 sources in the Large Cloud. The integrated flux density of all sources in the SMC area is 12·7 Jy, while in the LMC it is 80·7 Jy, or 55·6 Jy, if 30 Doradus is excluded from the LMC comparison. Excluding the quasar S18, two SMC sources have $T_b > 0 \cdot 4$ K, while 24 LMC sources have $T_b > 0 \cdot 4$ K. The mass of the SMC is only about 0·3 times the mass of the LMC.

Fifteen of the Henize HII regions have been identified with 6 cm radio sources on the basis that the centres have a difference of $\leqslant 1' \cdot 4$ arc. With one exception (N76A) they all have large dimensions, the average size being $4' \cdot 1 \times 3' \cdot 8$ arc or 75×70 pc at the accepted distance of 63 kpc for the SMC. Four other large nebulae listed by Henize (1956), N12, N12A, N12B and N50, correspond to spurs of 6 cm emission not listed as sources in Table 1. No correspondence has been found for

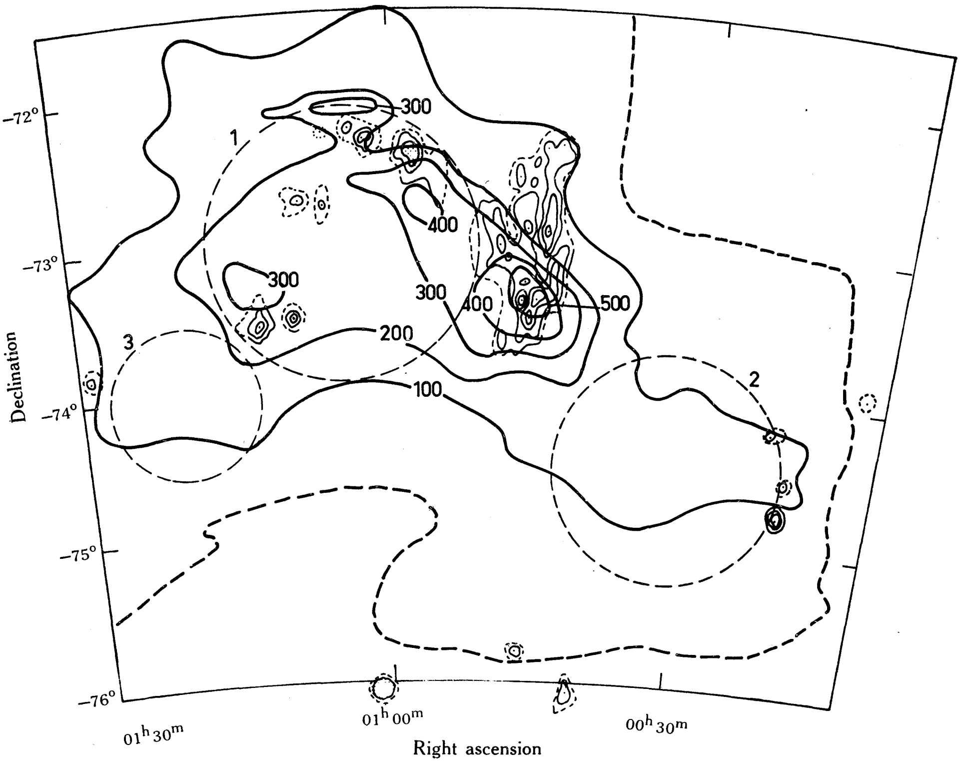

Fig. 5. Contours of integrated brightness of the neutral hydrogen 21 cm line sketched from Fig. 11 of Hindman (1967) and superimposed on the 6 cm full-beam brightness temperature distribution of the SMC. The dashed circles indicate the positions of the three 'expanding gas shells'. The contour interval for the H line is $3\cdot5\times10^{-15}$ W m^{-2} sr^{-1}. The epoch is 1950·0.

the two remaining large nebulae: N17, 3′·2 × 1′·4 arc, Hα strength 1 at R.A. $00^h 44^m\cdot9$, Dec. −73° 48′; and N89, 4′·3 × 4′·7 arc, Hα strength 1 at R.A. $01^h 24^m\cdot5$, Dec. −73° 38′. Nine HII regions of Hα strength 3 closely grouped around an average size of 26″·5 × 19″·6 arc were not expected to be detected as individual sources because in projected area they occupied only the fraction 0·009 of the telescope beam.

Henize regions N10 to N34 (with the exception of N17) occurring in an area bounded by R.A. $00^h 43^m$ and $00^h 48^m$ and Dec. −73° 05′ and −73° 43′ correspond to a general area of 6 cm radiation where individual 6 cm sources have not been resolved. The source N46 (R.A. $00^h 50^m\cdot1$, Dec. −73° 07′) of dimensions 19″ × 16″ arc and Hα strength 3 lies in the direction of extended 6 cm radiation.

HI distribution

The distribution of neutral hydrogen in the SMC, represented by contours of the brightness of the 21 cm line integrated over the profile (Hindman 1967), has been superimposed on the 6 cm continuum contours in Fig. 5. The region of maximum HI intensity covers the south-west portion of the bar. The centre of the 500 contour ($\equiv 500\times3\cdot5\times10^{-7}$ W m^{-2} sr^{-1}) is shifted to the north by about 8′ arc with respect to the Hα excess maximum in Fig. 3. Similar displacements are evident for the HI maximum at the north-east end of the bar where the 300 contour is north of sources

S19, 20, 21 and 23, and in the wing where the 300 contour is north of the thermal source S26. This curious 'displacement' of the integrated HI contours was noted by Schmidt (1972). The large thermal source S17, for example, lies close to a depression in the HI. This phenomenon is in direct contrast to conditions found by McGee (1964) in the LMC where the HII regions, the radio continuum contours and HI contours were markedly coincident. Schmidt (1972) mentioned that the displaced HI (with respect to HII) maxima in the north-east bar and in the wing region are located near the rim of shell No. 1 (Hindman 1967), where double-peaked 21 cm line profiles were interpreted as indicating an expanding shell of expansion velocity 23 $km\,s^{-1}$. The shells are shown as dashed circles in Fig. 5. In the present case sources S17, 19, 20, 23, 25 and 26 are close to the rim of shell No. 1; sources S1, 3 and 4 are on the rim of shell No. 2 and sources S26 and 27 are near the rim of shell No. 3.

Other radio continua

Previous observers (Mathewson and Healey (1964) at 21 cm; and Broten (1972) at 11 cm) have delineated radio sources in their surveys of the SMC but have not published catalogues of the positions and parameters.

21 cm

All 27 sources in Table 1 can be seen on the 21 cm contour map (Mathewson and Healey 1964). Where possible we have used the 6 cm positions to assist in extracting the estimates of flux density at 21 cm given in column 9 of Table 1. In the area of sky bounded approximately by R.A. $00^h 10^m$ and $01^h 30^m$ and Dec. $-70° 00'$ and $-76° 10'$, there are 20 sources of low intensity on the 21 cm map surrounding the main body of the SMC which have not been detected at 6 cm. These could well be background objects and their presumed nonthermal spectra would render their detection difficult at shorter wavelengths.

11 cm

Agreement in position is good for the important sources at 6 and 11 cm (Broten 1972). The effect of improved resolution in the present survey is seen when two large sources at 11 cm break up into sources S9, 10 and 13 in one case and into S19, 20 and 21 in another. Sources S6, 8, 14 and 23 do not correspond to 11 cm features and S27 was possibly outside the area surveyed by Broten. Some low-level sources at 11 cm do not have 6 cm counterparts.

73 cm

Eleven of the sources in Table 1 appear in the Molonglo radio source catalogue 4 (Clarke *et al.* 1976). The data on positions and flux densities are particularly useful since the beam size at 73 cm, $\sim 3'$ arc, compares well with the beam sizes at 3·4 and 6 cm. The agreement in positions between the 73 cm survey and the present is within the experimental errors (except in the R.A. of S27, mentioned above); the mean difference in right ascension is $-4 \cdot 4$ s and in declination $+0' \cdot 2$. The 73 cm survey did not extend further south than $-75°$, so that no information is available for S5, 11 and 18. Presumably no attempt was made to delineate the low intensity sources S6, 7, 8, 12, 13, 14, 15 and 16 in the main body of the SMC.

5. Conclusions

The 6 cm continuum radiation from the SMC, as observed with a telescope of moderately good resolution (4′·1 arc), is scarcely spectacular: there is no general galactic background and there are only 27 sources, all of which are below 1 K full-beam brightness temperature. The contrast between the radio and stellar distributions in Fig. 1 is most striking. Very little continuum was detected in the central parts of the stellar bar and none at all in the extensive stellar region between the bar and the wing of the SMC. Good agreement was found between the 6 cm continuum and the ionized nebula. The positions and spectra of the stronger sources were confirmed by observations at 3·4 cm. The displacement of the neutral hydrogen distribution with respect to the ionized gas (reported by Hindman 1967) is confirmed by the 6 cm survey.

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