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A radio continuum study of the Magellanic Clouds

VI. Discrete sources common to radio and X-ray surveys of the Magellanic Clouds^{*}

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Abstract. By comparing Parkes telescope radio surveys with the X-ray ROSAT All-Sky Survey (RASS) we have found 71 discrete sources of both radio and X-ray emission in the Large Magellanic Cloud (LMC). These 71 sources are mainly supernova remnants (SNRs) and SNR candidates (36), and background sources (27). For six of the sources we have no proposed identification and the other two are H II regions. A source-intensity comparison of the radio and X-ray sources shows very little correlation, but we note that the strongest SNRs at both radio and X-ray frequencies are young SNRs from Population I. Six new LMC SNR candidates are proposed. From the radio flux density of the SNRs we have estimated the SNR birth rate to be one every 100 (± 20) yr and the star-formation rate (SFR) to be 0.7 (± 0.2) M_{\odot} yr⁻¹.

A similar comparison was undertaken for the Small Magellanic Cloud (SMC), but instead of the RASS we used a roster of pointed observations made with the ROSAT Position Sensitive Proportional Counter (PSPC). This comparison resulted in 27 sources in common between the Parkes radio and ROSAT PSPC surveys. Two new SMC sources are proposed for SNR candidates. The SMC SNR birth rate was estimated to be one every 350 (\pm 70) yr and the SFR was estimated to be 0.15 (\pm 0.05) M_{\odot} yr⁻¹.

Key words: galaxies: Magellanic Clouds — radio continuum: galaxies — X-rays: galaxies — ISM: supernova remnants (SNRs) — ISM: H II regions

1. Introduction

The Magellanic Clouds (MCs) are excellent laboratories for studying discrete sources owing to their proximity to our own Galaxy. Most discrete radio sources in spiral and irregular galaxies are SNRs and H II regions. SNRs are usually observed as strong X-ray sources, whereas H II regions are generally weak X-ray emitters. It is well known that SNRs and X-ray binaries often occur in large H II regions and hence H II regions sometimes appear in X-ray surveys.

The first high-frequency radio detection of discrete sources in the MCs was made by McGee & Milton (1966) at 1.4 GHz, which opened a new era in extra galactic research. Pioneering X-ray surveys of the LMC have been

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^{*} Tables 2 and 3 are also available electronically at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

presented in Long et al. (1981) (LHG catalogue) and in Wang et al. (1991) (W catalogue). The SMC X-ray surveys can be found in Seward & Mitchell (1981) (1E catalogue), Inoue et al. (1983) (IKT catalogue), Bruhweiler et al. (1987) and in Wang & Wu (1992). All these surveys are based on observations made with the Einstein satellite.

Almost half of the X-ray sources in the LMC field catalogued by Wang et al. (1991) were confirmed as SNRs, H II regions or X-ray binaries. The other half are foreground stars or background objects (e.g. clusters of galaxies, radio galaxies, quasars). In the Wang & Wu (1992) survey, 24 out of 70 sources towards the SMC are intrinsic to the SMC.

These earlier studies provided a good basis for a new generation of radio and X-ray surveys of the MCs. Recent Parkes radio surveys of the MCs are now available: Haynes et al. (1991), Filipović et al. (1995; hereafter Paper IV), Filipović et al. (1996, hereafter Paper IVa), Filipović et al. (1997a, hereafter Paper V) and Filipović (1996). At X-ray frequencies, Pietsch et al. (in preparation) have prepared a list of sources towards the LMC from the X-ray ROSAT All-Sky Survey (RASS; Pietsch & Kahabka 1993) and Kahabka et al. (in preparation) presented a list of sources towards the SMC from the ROSAT Position Sensitive Proportional Counter (PSPC).

There are several other high-resolution surveys of the MCs in progress. At radio frequencies, a neutral-hydrogen survey at 1.4 GHz and continuum surveys at 1.4 and 2.3 GHz have been made with the Compact Array of the Australia Telescope National Facility (Staveley-Smith et al. 1997). At X-ray frequencies there are the ROSAT PSPC and HRI pointed observations (Snowden & Petre 1994) and the ASCA X-ray observations of some MCs SNRs (Hughes et al. 1995).

In this paper we compare sources common to the available radio and X-ray surveys using primarily the radio data of Papers IV, IVa and V and X-ray data of Pietsch et al. (in preparation) and Kahabka et al. (in preparation). We classify each source as either SNR, HII region, X-ray binary, background object or foreground star. In Sect. 2 we briefly discuss discrete radio and X-ray sources. In Sects. 3 and 4 we analyse and discuss all discrete sources common to the radio surveys and the ROSAT X-ray surveys. Finally, in Sect. 5 we discuss the radio-to-X-ray source-intensity relationships for all sources in common towards the MCs, with special emphasis on the LMC SNRs.

2. Discrete sources towards the MCs

2.1. Discrete radio sources towards the LMC

Catalogues of discrete radio sources towards the LMC at six radio frequencies are presented in Papers IV and IVa of this series and in Filipović (1996). The total number of catalogued radio sources is 483: 192 at 1.40 GHz, 119 at 2.30 GHz, 338 at 2.45 GHz, 373 at 4.75 GHz, 332 at 4.85 GHz and 212 at 8.55 GHz. As clear radio detections, we listed only radio sources that are stronger than 5σ or seen at two or more frequencies.

2.2. Discrete X-ray sources towards the LMC

A catalogue of RASS X-ray sources towards the LMC is published in Pietsch et al. (in preparation). In addition to this catalogue we compared Parkes radio and RASS images and found eight additional X-ray sources which are not catalogued in Pietsch et al. (in preparation). These eight sources are listed in Table 1 which follows the format of the table in Pietsch et al. (in preparation). Source positions, RA and Dec, are given in J2000 coordinates in Col. 2 and Col. 3, respectively. Positional error is given in Col. 4 and the exposure time in Col. 5. The definitions of likelihood existence (LH) (Col. 6), count rate (Col. 7), hardness ratios (HR1) and (HR2) (Cols. 8 and 9, respectively) are the same as in Pietsch et al. (in preparation). Count rates of the sources have been derived for the five standard energy bands: "broad" (0.11 - 2.4 keV), "soft" (0.11-0.41 keV), "hard" (0.52-2.01 keV), "hard1" (0.52 - 0.90 keV) and "hard2" (0.91 - 2.01 keV). HR1 is defined as HR1 = (hard - soft)/(hard + soft) and HR2 is defined as HR2 = (hard2 - hard1)/(hard2 + hard1). LH is the maximum likelihood of source existence and may be converted into probabilities via $P \sim 1 - e^{(-LH)}$. That means that LH = 9.7 corresponds to about four Gaussian sigma significance. All sources have $LH \ge 8$.

We believe that a number of other radio sources could have X-ray counterparts, but because most of these sources belong to confused regions, we could not resolve them in the RASS. We expect that these "confused" sources will be resolved in the ROSAT-pointed observations (PSPC) which have better resolution.

We use the common area of the radio and X-ray surveys defined in Paper IV of ~100 square degrees between RA (B1950) = $04^{h}23^{m}$ to $06^{h}14^{m}$ and Dec (B1950) = -74° to -64° . In this area we expect about eight sources to have positional coincidence by chance alignment, based on the number of sources at each frequency and 2.5' search criterion for coincidence. Also, we have checked this number of chance coincidences by simulation. We shifted one set of positions in either coordinate by 5 to 30' and found the number of spurious coincidences to be 9 ± 3 over repeated trials.

We now have 325 RASS sources towards the LMC field defined by the radio surveys (see Sect. 2.1) and we compare these with 483 radio sources in the same field.

2.3. Discrete radio sources towards the SMC

The new catalogues of radio sources in the SMC at five radio frequencies: 1.42 GHz (86 sources), 2.45 GHz (107 sources), 4.75 GHz (99 sources), 4.85 GHz (187 sources) and 8.55 GHz (41 sources) are given in Paper V and in

Table 1. Additional LMC RASS sources found after comparison with Parkes radio data (Paper IV) and not listed in Pietsch et al. (in preparation). Entries in this table follow the format of Pietsch et al. (in preparation)

(1) No.	(2) RA (2000) h m s	$ \overset{(3)}{\underset{\circ}{\rm Dec}} \overset{(2000)}{_{\prime \ \prime \prime$	(4) $P_{\rm e}$ (")	(5) Exposure (s)	(6) LH	(7) Count Rate $(\operatorname{cts} \operatorname{ks}^{-1})$	(8) HR1	(9) HR2	(10) Other Names
9001 9002 9003 9004	$\begin{array}{c} 04 \ 28 \ 36.7 \\ 04 \ 46 \ 09.0 \\ 04 \ 54 \ 21.3 \\ 05 \ 13 \ 42 \ 2 \end{array}$	-67 49 10 -72 04 53 -68 00 11 -67 24 19	$19 \\ 40 \\ 30 \\ 29$	$ 1420 \\ 1019 \\ 2028 \\ 2293 $	$ \begin{array}{r} 13 \\ 10 \\ 8 \\ 8 \end{array} $	$4.8 \pm 2.5 \\12.1 \pm 4.9 \\7.2 \pm 2.8 \\3.2 \pm 2.1$	1.00 ± 0.00 0.81 ± 0.35 0.35 ± 0.35 1.00 ± 0.00	1.00 ± 0.00 0.68 ± 0.29 0.38 ± 0.36 1.00 ± 0.00	PKS B0428 - 679 N 30: DEM L112
9005 9006 9007	05 24 10.0 05 28 49.3 05 34 59.3	$-66\ 20\ 54$ $-65\ 39\ 41$ $-64\ 38\ 27$	$20 \\ 21 \\ 26 \\ 47$	2110 3250 1827	11 8 9	3.2 ± 2.4 4.5 ± 2.4 2.2 ± 1.4 6.9 ± 3.4	1.00 ± 0.00 1.00 ± 0.00 0.61 ± 0.38	1.00 ± 0.00 1.00 ± 0.00 0.32 ± 0.43 0.89 ± 0.35	N 46; DEM L162
9008	05 38 34.7	$-69\ 06\ 06$	37	2199	19	27.4 ± 6.8	1.00 ± 0.00	0.32 ± 0.20	30 Dor; N 157A

Filipović (1996). There is a total of 224 radio sources towards the SMC. As clear radio detections, again we listed only radio sources that are stronger than 5σ or seen in at least two frequencies.

2.4. Discrete X-ray sources towards the SMC

A catalogue of the ROSAT PSPC sources in the field of the SMC is published in Kahabka et al. (in preparation) and combines the results of nine pointed observations. These observations (exposure corrected) of the SMC were carried out with the ROSAT PSPC detector in the energy range 0.1 - 0.4 keV and 0.4 - 2.4 keV.

Using the common area of the radio and X-ray surveys (~ 12 square degrees between RA (B1950) = $00^{h}30^{m}$ to $01^{h}20^{m}$ and Dec (B1950) = $-71^{\circ}18'$ to $-74^{\circ}32'$) and the search criterion, we expect about nine sources to have positional coincidence by chance alignment. In this area, there are 86 radio sources from our Parkes radio surveys and they are compared with 248 X-ray PSPC sources from Kahabka et al. (in preparation).

3. Source identification

The comparison of the Parkes radio and the ROSAT X-ray surveys of the LMC resulted in the discovery of 71 sources common to both surveys. A similar comparison was undertaken for the SMC field and resulted in the discovery of 27 sources common to both surveys. Each source lies within 2.5' of its counterpart; this is the basic criterion for positive source identification. This criterion was chosen according to the upper limit of positional uncertainties at our 1.4 GHz survey which is $\sim 2'$ at the 1σ level (Paper IV). The most accurate radio positions available are from the highest radio-frequency survey in which the sources appear. These positions were compared with X-ray positions from Pietsch et al. (in preparation) and Kahabka et al. (in preparation).

In Table 2, we present data for the 71 sources in common towards the LMC and in Table 3 we list the 27 sources in common towards the SMC. Columns 2 and 3 of Tables 2 and 3 give the radio-source and X-ray source names respectively. Column 4 lists the source radio flux density at 4.75 GHz (4.85 GHz for the SMC). For eight LMC and five SMC sources the flux density at 4.75 GHz (4.85 GHz for the SMC) was estimated by interpolation from other radio frequencies; these sources are flagged in Col. 4. The X-ray information, count rate and HR2, are listed for each source in Col. 5 and Col. 7 respectively.

Column 6 lists the source radio spectral index (α) and error ($\Delta \alpha$) as defined by the relationship $S_{\nu} \sim \nu^{\alpha}$, where S_{ν} is flux density and ν is frequency. In order to extend the radio frequency coverage and to obtain more accurate radio spectral indices we have also used some flux densities from other radio catalogues; Clarke et al. (1976) at 0.408 GHz, Mills et al. (1984) at 0.843 GHz and Milne et al. (1980) at 14.7 GHz. Spectral indices are not given for 10 LMC and six SMC sources which were detected at only one radio frequency or for which radio data are only available at two close frequencies (4.75 GHz and 4.85 GHz).

Column 8 of Tables 2 and 3 gives the "radio source type" based on published references (Col. 9); these sources are marked with capital letters BG (background sources), H II regions and SNR. In the case of SNRs, where applicable, we have divided the sources into one of five different types: SNR1 to SNR5 respectively (type 1 – evolved SNRs, type 2 – Oxygen-rich SNRs, type 3 – Balmerdominated SNRs, type 4 – Crab-like SNRs and type 5 – possible type III SNRs). This follows the classification of Mathewson et al. (1983a). Note that capitals (BG, SNR and H II) were used for classifications from previous works and lower case (bg and snr) for sources classified here. The question-mark indicates probable but not certain



Fig. 1. a) The differences between radio and X-ray source positions for the LMC. Asterisks represents SNRs; filled diamonds – SNRs embedded in HII regions; open circles – background sources; filled square – HII regions and triangles – unclassified sources. Further details are given in Sect. 3.1. The dashed circle is 1' radius. b) The number of sources as a function of radio – X-ray source separation towards the LMC per unit area of the radial bin (per arcmin²)

classification. The criteria by which we classify these sources are discussed in Sect. 4.1.

A cross-check of all 71 sources towards the LMC and 27 sources towards the SMC has been made with a wide range of catalogues that contain discrete sources towards the MCs (Col. 10). The catalogues used are given as a footnote to Tables 2 and 3. Some comments regarding the discrete sources are given in Col. 11.

3.1. Positional differences for sources in common towards the LMC

The results of the position comparison for all sources common to the Parkes radio and RASS X-ray surveys of the LMC are shown in Figs. 1a and 1b. For the 71 sources, the mean difference in right ascension (RA) is $22'' \pm 6''$ (radio – X-ray) with standard deviation (SD) of 52''. The difference in declination (Dec) is $0'' \pm 5''$ (SD = 43''). Figure 1b shows that there is an excess in the number of sources with small radio – X-ray differences, as expected, well above the number resulting from random coincidence.

Dividing this sample into (i) SNRs, (ii) SNRs embedded in H II regions and (iii) background sources, and again comparing radio – X-ray source positions we obtain: $\Delta RA = +5'' \pm 8''$ and $\Delta Dec = -1'' \pm 5''$ for 19 SNRs; $\Delta RA = +63'' \pm 13''$ and $\Delta Dec = -3'' \pm 15''$ for 17 SNRs embedded in H II regions, and $\Delta RA = +12'' \pm 10''$ and



Fig. 2. The differences between radio and X-ray source positions for the SMC. Asterisks represents SNRs; open circles – background sources; filled square – HII regions and triangles – unclassified sources. The dashed circle is 1' radius

Table 2. Catalogue of the LMC radio sources identified in the RASS. The X-ray source name (Col. 3) is taken from Pietsch et al. (in preparation). More details are given in Sect. 3

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
No.	Radio	X-Rav	S4 75	Count Rate	$\alpha \pm \Delta \alpha$	HR 2	Type	$References^{\dagger}$
	Source Name	Source Name	(Jv)	$cts ks^{-1}$			51	
			(-0)					
1	LMCB0428 - 6755	LMC RASS 9001	0.240	4.8	-0.62 ± 0.04	1.00	BG	7; 25
2	LMCB0438 - 7316	LMC RASS 66	0.108	27.4	-0.90 ± 0.05	0.07	bg	
3	LMCB0441 = 6957	LMC RASS 75	0.258	5.2	-0.07 ± 0.21	0.51	bg	
4	LMC B0442 = 0824 LMC B0445 = 6458	LMC RASS 78	0.047	1.1 50.6	0.23 ± 0.00	0.28	bg	
5	LMC B0445 - 0458	LMC RASS 64	0.085	59.0	-0.02 ± 0.21	0.07	bg -	
6	LMCB0446 - 7210	LMC RASS 9002	0.091	12.1	-0.65 ± 0.04	0.68	bg	~~~~~
7	LMCB0453 - 6834	LMC RASS 100	0.140	410.1	-0.40 ± 0.09	-0.30	SNR	20; 22; 27
8	LMCB0454 = 6030	LMC RASS 103	0.060	23.7	-0.49 ± 0.05	-1.00	SINK	5; 13; 20; 22; 27; 28
10	LMCB0454 = 0718 LMCB0454 = 6806	LMC RASS 102	0.058	31.4 79		-0.33	2 2	4
10	LIVIC D0454 - 0800	LMC RASS 5005	0.000	1.4	0 15 1 0 01	0.38	: CNID	F 0 00 00 0F 00
11	LMCB0455 = 6843	LMC RASS 104	0.141	16.4	-0.45 ± 0.04	-0.07	SNR	5; 8; 20; 22; 27; 28
12	LMCB0450 = 6803	LMC RASS 100	0.022	0.4	2.11 ± 0.11	0.03	PC	
14	LMCB0502 = 0038 LMCB0506 = 6806	LMC RASS 125	0.033	926 7	-2.11 ± 0.11 -0.58 ± 0.06	-0.20	SNR	
15	LMCB0500 - 6829	LMC RASS 141	0.220 0.245	5.0	-0.63 ± 0.04	-0.61	SNR?	8
16	LMC D0507 7020	LMCDASS 120	0.146	97.1	0.72 + 0.05	0.52	CND2	8
10	LMCB0507 = 7029	LMC RASS 159	0.140	27.1	-0.72 ± 0.03 0.56 \pm 0.21	0.52	br	8
18	LMCB0508 = 0450 LMCB0509 = 6848	LMC RASS 140	0.529	1322.7	-0.57 ± 0.21	0.14	SNR4	13. 14. 20.
10	LINE BOOD 0010	1010101000110	0.020	1022.1	0.01 ± 0.11	0.22	511111	22; 27; 28
19	$\rm LMCB0513-6729$	$\rm LMCRASS9004$	0.186	3.2	-0.48 ± 0.03	1.00	?	, ,
20	$\rm LMCB0513-6915$	LMCRASS166	0.264	8.7	-0.45 ± 0.16	-0.27	SNR1	23
21	LMCB0519 - 6905	LMC RASS 183	0.072^{f}	1273.1	-0.47 ± 0.14	0.03	SNR3	13; 14; 20; 22; 27; 35
22	LMCB0519 - 6941	LMC RASS 180	0.866	16.2	-0.35 ± 0.04	-0.32	SNR	1; 13; 19; 20;
								22; 27; 28; 30
22	I MC P0520 6028	I MC DASS 185	0 111	91 0	0.22 ± 0.05	0.14	SND	22. 27
23 24	LMCB0520 = 0928 LMCB0522 = 6757	LMC RASS 185	0.111	80.3	-0.32 ± 0.03 -0.02 ± 0.08	-0.05	SNR	22, 21 6: 13: 20: 26: 28: 54
21	ENIC BOOLE 0101	1110 10100 102	0.200	00.0	0.02 ± 0.00	0.00	51110	0, 10, 20, 20, 20, 01
25	$\rm LMCB0523-6623$	$\rm LMCRASS9005$	0.100	4.5	0.26 ± 0.26	1.00	?	
26	$\rm LMCB0524-6443$	LMC RASS 202	0.043	7.7	-0.78 ± 0.11	0.49	bg	
27	LMCB0525 - 6601	LMC RASS 205	0.390	1010.3	-0.60 ± 0.12	-0.04	SNR5	15; 20; 22; 27; 28; 29
28	LMCB0525 - 6607	LMC RASS 207	1.009	1487.8	-0.51 ± 0.06	0.02	SNR5	1; 5; 9; 13; 15;
29	LMCB0525 - 6941	LMC RASS 203	2.251	8764.9	-0.58 ± 0.03	0.02	SNR2	22; 27; 28; 50; 50 1; 13; 14; 17;
								20; 22; 27; 28
30	LMCB0528 - 6542	LMCRASS9006	0.035	2.2		0.32	?	
31	LMCB0528 - 6551	LMCRASS213	0.108	12.3	-0.32 ± 0.04	-0.24	SNR	8; 22; 27
32	LMCB0528 - 6838	LMCRASS214	0.210	18.8		-0.13	snr ?	
33	LMCB0528 - 6914	LMC RASS 210	0.075	14.2	-0.44 ± 0.03	-0.05	SNR1	27; 42
34	LMC B0530 - 6655	LMCRASS220	0.100	15.0	-0.82 ± 0.11	-0.55	$\operatorname{snr}?$	
35	LMC B0531 - 6518	LMC RASS 223	0.041	31.3	0.00 ± 0.11	0.44	bg?	
36	$\rm LMCB0532-6734$	LMC RASS 229	0.093	69.0	-0.56 ± 0.12	-0.35	SNR?	23; 37
37	LMCB0532 - 7102	LMCRASS225	0.382^{f}	49.6	-0.31 ± 0.02	-0.50	SNR	20; 22; 27
38	$\rm LMCB0534-6438$	LMCRASS9007	0.058	6.9	-0.59 ± 0.11	0.89	bg	
39	LMCB0534 - 6957	LMC RASS 237	0.054	194.7	-0.48 ± 0.05	-0.28	SNR1	20; 22; 27
40	LMC B0534 - 7035	LMC RASS 239	0.067	31.3	-0.44 ± 0.03	0.06	SNR	20; 22; 24; 27
41	LMCB0534 - 7204	LMC RASS 236	0.103	5.4	-0.32 ± 0.04	-0.89	snr?	
42	LMC B0535 - 6603	LMC RASS 245	0.701	5508.2	-0.57 ± 0.05	0.02	SNR4	1; 9; 10; 13; 15;
12	I MC D0526 6452	IMCDASS 250	0.050	25.2	0.77 ± 0.21	0.12	he	22; 27; 28; 33; 39
40 11	LMCB0536 = 6725	LMCRASS 200	0.030	20.2 10.8	-0.77 ± 0.21 -0.38 ± 0.12	0.13	SNR1	23
44	LMCB0536 = 7040	LMC RASS 247	0.135	49.8	-0.38 ± 0.12 -0.61 ± 0.05	0.37	SNR	25
-10	ENIC 10000 - 1040	1010 10100 240	0.020	00.4	0.01 ± 0.00	0.40	SILL	20, 22, 27, 21
46	LMC B0537 - 6506	LMC BASS 252	0.035	30.8		0.50	hg?	
47	LMC B0538 = 6911	LMC RASS 253	3.571	142.9	-0.15 ± 0.05	0.55	SNR4	5: 9: 11: 13:
					<u>1</u> 0.00	0.00		20; 22; 27; 28
48	$\rm LMCB0539-6907$	LMCRASS9008	35.787	27.4	-0.11 ± 0.02	0.32	Hii	1; 2; 3; 25; 31;
								33; 46; 47; 54
49	$\rm LMCB0540-6921$	LMC RASS 265	0.980	579.7	-0.37 ± 0.07	0.54	SNR2	20; 21; 22; 27;
FO	IMCIDOF 40 40.40	IMODACCAC	4.100	7000 5	0.17 - 0.01	0.70	TT ··	28; 34; 54
90	ымС В0540 – 6946	LMU KASS 264	4.180	7080.5	-0.17 ± 0.01	0.76	н 11	1; 2; 3; 10; 18; 25, 31, 30, 52, 52
								20, 01, 09, 02, 00

(1)	(10)	(11)
No.	Other Names [‡]	Comments
1 2 3 4	MC 2; MC4(0428-679); PMN J0428 - 6749; PKS B0428 - 679 MC4(0439-732A,B); PMN J0438 - 7310 MC 6; PMN J0440 - 6952 PMN J0442 - 6818	S_5 from 48 used instead of $S_{\rm 4.75}$
5		
6 7 8	MC4(0446 - 721); PMN J0446 - 7205 MC4(0453 - 685); LHG 1 (W2); PMN J0453 - 6829 N11L; DEM L34a	Pop II? Pop I; S_5 from 28 used instead of $S_{4.75}$
10	PMN J0454-6800	
11	N OG MGA(OAFG COZ) DEN LOO LUG O (NO) DANI IOAFF CODO	
11	N 80; $MC4(0450 - 687)$; DEM L33; LHG 2 (W3); PMN J0455 - 6838	Pop II!
$12 \\ 13 \\ 14 \\ 15$	QSO B0502-665 MC4(0506-680); LHG 11 (W10) N 100; DEM L76; PMN J0506 - 6824	Pop I?
16	DEM L80: NGC 1845: PMN 10506 - 7026: LH26	
17	DEM 100, NGC 1040, 1 MIN 30000 1020, 11120	
18	N 103A,B; MC 22; MC4(0509 - 687A,B); DEM L84(85);	Pop I; SNR embedded in H ii region;
	LHG 13 (W11); NGC1850; PMN J0508 – 6844; IJL 34	Poor positional agreement
19	N 30; MC 25; MC4 $(0514 - 676)$; DEM L112 (106) ; NGC 1871;	MC position shifted in RA by 5' and in DEC by $10'$;
20	PMN J0513 - 6724; LH38; IJL 41	Star HD 34632 in the field
20	N 112; $MC4(0513 - 692A)$; DEM L109; IJL 39	Pop1
$\frac{21}{22}$	LHG 26 (W24) N 120A,B,C; MC 31; MC4(0519 $-$ 696A,B,C); DEM L134; NGC 1918; LHG 23 (W21); IJL 47; LH42;	Pop II Pop I; $S_{8.55}$ includes LMC B0518 – 6937; SNR embedded in H ii region;
00	CO 17; PMN J0519 – 6938; PKS B0519 – 696	Extended complex of radio sources
23	MC4(0520 - 695); LHG 27 (W25); PMN J0519 - 6926; Sa 113	Pop II?; Poor positional agreement
24	N 441; $MC4(0522 - 079C)$; DEM L150; LHG 51 (W29); LH48	Blonded with Hij region N 44B C (IMC B0522 – 6800)
25	N 46: MC 36: DEM L162: NGC 1941: LIL 56	S5 from 48 used instead of $S_{4.75}$
20	MG4(0504 _ C47)	55 from to used instead of 54.75
26	MC4(0524 - 647) N 40P, MC 42, MC4(0525 - 660P), DEM 1181, 1HC 24 (W27)	Pop I
28	N 495, MC 42, MC4(0525 $-$ 661A); DEM L181, LHG 54 (W57)	PopI
20	LHG 36 (W39): PMN J0526 $-$ 6604: PKS B0525 $-$ 661	ropr
29	N 132D; MC 39; MC4($0525 - 696$); DEM L186; LHG 35 (W38);	Pop I;
	PMN J0525 $- 6938$; PKS B0525 $- 696$	SNR embedded in H ii region
30		Star HD 271294 in the field
31	MC 48; MC4(0528 $-$ 658); DEM L204;	Pop II?; Radio extended;
	LHG 39; PMN J0528 – 6550	Poor positional agreement
32	W46	Star GSC 9162.0555 is in the field
55	LHG 40 ($W42$); FMIN $J0527 = 0911$	one on soft hand (star) and SNR on hard hands
34		one on sole band (star) and pivit on hard bands
35		Poor positional agreement
36	N 56: MC4(0532 - 675): LHG 48 (W53): NGC 2011: LH75	Poor positional agreement
37	N 206; MC4(0532 – 710B); LHG 47 (W54)	Pop I; SNR embedded in H ii region
38		• ,
39	LHG 53 (W60)	Pop I?
40	MC b; $MC4(0534 - 706)$; DEM L238; LHG 54 (W61);	Pop II?
	NGC 2038; PMN J0534 – 7034	
41	MC4(0534 - 720); PMN J0534 - 7202	Poor positional agreement
42	N 63A; MC 63; MC4(0535 $-$ 660); DEM L243; LHG 59 (W65);	Pop I; SNP embedded in Hii region
13	NGC 2050, F MIN 50555 = 0001, L1185, F K5D0555 = 000, 15L 75	Star CSC 8887 04000 in the field
44	N 59B: MC4(0536 – 675B): DEM L241: LHG 60 (W67): LH88	Poor positional agreement
45	MC d; MC4 $(0536 - 706)$; DEM L249;	Pop II?
	LHG 61 (W70); NGC 2056; PMN J0535 – 7038	•
46		AGN: X-var: Galaxy
47	N 157B; MC4(0538-691);	Pop I;
	LHG 67 (W73); NGC 2060; LH99	SNR embedded in H ii region
48	30 Dor; N 157A; MC 74; MC4(0539 – 691); DEM L263; NGC 2070;	SG(X)
40	LHG 72(W72(76,78)); PMN J0538 $-$ 6905; LH100; PKS B0539 $-$ 691	PopI
49	N 130A, NO (6; NO 4(0340 - 033); DEM L209; LHG (9 (W87); NGC 2081; PSR $B0540 = 69$; LH104; PKS $B0540 = 693$	горт
50	N 159A; MC 77; MC4(0540 $-$ 697A); DEM L271; LHG 78 (W84):	LMC X-1; He iii region; X-var; SNR?
	NGC 2079; PMN J0539 – 6944; LH105; CO 33; PKS B0540 – 697; IJL 82	X-ray position in \overrightarrow{RA} shifted by $1.5'$

(1) No.	(2) Radio Source Name	(3) X-Ray Source Name	(4) $S_{4.75}$ (Jy)	(5) Count Rate $cts ks^{-1}$	$\begin{array}{c} (6) \\ \alpha \pm \Delta \alpha \end{array}$	(7) HR 2	(8) Type	(9) References [†]
51 52 53	$\begin{array}{l} {\rm LMCB0542-6702} \\ {\rm LMCB0543-7333} \\ {\rm LMCB0544-6910} \end{array}$	LMC RASS 275 LMC RASS 276 LMC RASS 282	$\begin{array}{c} 0.126\\ 0.815\end{array}$	$6.1 \\ 8.1 \\ 9.2$	$\begin{array}{c} 0.30 \pm 0.18 \\ -0.59 \pm 0.06 \end{array}$	-0.57 1.00 -0.95	snr? BG snr?	1; 25
$54 \\ 55$	$ \begin{array}{l} {\rm LMCB0544-7030} \\ {\rm LMCB0546-6416} \end{array} \\$	${\rm LMCRASS283}\\ {\rm LMCRASS292}$	0.232^{f}	$9.4 \\ 231.9$	0.28 ± 0.15	$-0.05 \\ 0.16$	snr? bg	
56 57 58	LMC B0547 - 6729 LMC B0547 - 6746 LMC B0547 - 6942	LMC RASS 299 LMC RASS 297 LMC RASS 296	$\begin{array}{c} 0.087 \\ 0.063 \\ 0.565 \end{array}$	$15.9 \\ 5.7 \\ 36.6$	$0.42 \pm 0.07 \\ -0.58 \pm 0.05 \\ -0.61 \pm 0.09$	$ \begin{array}{c} 0.35 \\ 0.42 \\ 0.24 \end{array} $	bg? BG SNR2	12 1: 5: 13: 20:
59 60	LMC B0548 - 7025 LMC B0550 - 6823	LMC RASS 298 LMC RASS 309	$0.046 \\ 0.388$	$116.0 \\ 10.9$	-0.55 ± 0.06 -0.37 ± 0.06	$-0.12 \\ -0.29$	SNR3 SNR?	22; 27; 28; 51 20; 22; 27; 35 1; 25; 32
61 62	LMC B0552 - 6402 LMC B0552 - 6948	LMC RASS 318 LMC RASS 320	0.154^{f} 0.040	$127.3 \\ 32.9 \\ 2.4$	$\begin{array}{c} 0.16 \pm 0.21 \\ -1.00 \pm 0.04 \end{array}$	$0.15 \\ 0.36 \\ 0.54$	bg bg?	, ,
$63 \\ 64 \\ 65$	$ LMC B0553 = 6704 \\ LMC B0557 = 6854 \\ LMC B0602 = 6443 $	LMC RASS 322 LMC RASS 343 LMC RASS 378	$0.056 \\ 0.299$	$2.4 \\ 5.0 \\ 3.7$	$\begin{array}{c} -0.06 \pm 0.08 \\ -1.15 \pm 0.06 \end{array}$	$0.54 \\ 0.10 \\ 0.01$	bg : ? BG	25; 32
66 67 68	LMC B0602 - 6830 LMC B0605 - 6625 LMC B0606 - 7041	LMC RASS 379 LMC RASS 390	$0.060 \\ 0.065^{f} \\ 0.052^{f}$	3.5 3.2	0.14 ± 0.22 -0.81 ± 0.17 0.02 ± 0.21	0.01 0.14 0.51	bg bg bg	
69 70	$ LMC B0608 - 7041 \\ LMC B0608 - 6510 \\ LMC B0611 - 6623 $	LMC RASS 409 LMC RASS 430	0.052° 0.061^{f} 0.210	18.5 17.4 166.4	-0.88 ± 0.06 -0.69 ± 0.07	$0.51 \\ 0.10 \\ 0.18$	bg BG	38
71	$\rm LMCB0611-6734$	$\rm LMCRASS429$		6.6		0.23	bg	

[†]References used in Table 2 (Col. 9), Table 4 (Col. 6) and Table 5 (Col. 7).



 $\Delta Dec = +9'' \pm 8''$ for 27 background sources. There are two H II regions and six unclassified sources.

Clearly, there is a large RA positional difference for SNRs embedded in H II, regions and the nature of this difference is the subject of further investigation. Excluding the embedded SNRs and source LMC B0540 – 6946 (LMC X-1; see Sect. 4.6), the positional alignment of the Parkes radio and RASS surveys is good with differences of $\Delta RA = +9'' \pm 6''$, $\Delta Dec = +1'' \pm 5''$ (radio -X - ray), with standard deviations in the differences of 44'' and 37'' respectively.

This uncertainty is consistent with the combined positional uncertainties for the radio and the X-ray sources, and retrospectively justifies the initial identification criteria of 2.5' (which is equivalent to 3.4σ in RA and 4.1σ in Dec).

3.2. Positional differences for sources in common towards the SMC

We have compared the positions for all 27 sources common to radio and X-ray surveys of the SMC. We used the same criterion for source identification as that used for the LMC survey, i.e., the source must lie within 2.5' of its counterpart. This criterion was chosen according to the upper limit of positional uncertainties at our 1.42 GHz survey. These positions were compared with X-ray positions from Kahabka et al. (in preparation).

The results of this comparison are shown in Fig. 2. For the 27 sources, the mean difference in RA is $0'' \pm 15''$ (SD = 76'') and in Dec is $-6'' \pm 13''$ (SD = 66''). Thus, we have found no significant positional bias between our radio positions and those from the ROSAT PSPC surveys.

(1)	(10)	(11)
No.	Other $Names^{\ddagger}$	Comments
51		Poor positional agreement
52	MC 83; MC4(0543 $-$ 735); PKS B0542 $-$ 736	AGN
53		
54		$\mathbf{Y} = 1 \mathbf{E} \mathbf{G} 0 \mathbf{f} 4 \mathbf{G} = \mathbf{G} 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 0 1 0 0 1 0 0 0 0 0 0 0 0$
55		A-var; $1ES 0540 - 642$; 1 wo Galaxies ?
56	NGC 2117; PMN J0547 – 6728	
57	MC4(0547 - 677); W 98; PMN J0547 - 6745 N 125, MC 80, MC4(0547 - 607), DEM I 216, LHC 88 (W07).	Den II. Desition for N 125 is not given in Hening (1056).
59	PMN 10547 = 6942; CO 39; PKS $R0547 = 697$;	For it; Fosition for N 155 is not given in Henize (1950); Milne et al. (1980) and Long et al. (1981) identified as N 135.
59	LHG 89 (W99): CO 40	Pop II
60	MC 92; MC4(0550 - 683); DEM L328; PMN J0550 - 6822; PKS B0550 - 683	Extended radio source; Poor positional agreement
61	MC4(0550 - 641A); PKS B0551 - 640	
62	MC4(0552 - 698); LHG 93 (W102); PMN J0552 - 6947	
63		
64		
65	MC 94; MC4(0602 - 647); PMN J0602 - 6443; PKS $B0602 - 647$	Double Galaxy; $S_{8.4}$ from 32 used instead of $S_{8.55}$
66	PMN J0602 - 6830	Star GSC 9164.1193 in the field
67	MC4(0605 - 664)	
68		X-ext; Star GSC 9168.1191 in the field; Galaxy
69 70	MC4(0611 - 662), DKS D0611 - 662	S- from 28 used instead of S Colour
10	W104(0011 - 003), rAS $D0011 - 003$	55 from 56 used instead of 54.75; Galaxy
71		

[‡]Abbreviations used in Col. 10.

Ν	$H\alpha$ catalogue of emission nebulae (Henize 1956),
MC	Radio catalogue (5.00 GHz) (McGee et al. 1972a),
MC4	Radio catalogue (0.408 GHz) (Clarke et al. 1976),
DEM L	$H\alpha$ catalogue of emission nebulae (Davies et al. 1976),
NGC	NGC 2000 catalogue (optical) (Sinnott 1988),
LHG	Einstein X-ray catalogue (Long et al. 1981),
W	Einstein X-ray catalogue (Wang et al. 1991),
PSR	Catalogue of pulsars (Taylor et al. 1993),
PMN	Radio catalogue (4.85 GHz) (Wright et al. 1994),
PKS	PKSCAT-90 radio catalogue (Otrupcek & Wright 1991
\mathbf{Sa}	Catalogue of planetary nebula (Sanduleak et al. 1978;

Sanduleak 1984),

COCatalogue of CO molecular clouds (Cohen et al. 1988),

IJL Catalogue of CO molecular clouds (Israel et al. 1993) and

LH Catalogue of stellar associations (Lucke & Hodge 1970)

4. Classification and analysis of discrete sources in common

Out of the 71 sources common to the Parkes radio and RASS surveys of the LMC, 38 have been previously classified (see Table 2, Col. 8). Most are SNRs (30, including four SNR candidates) and background sources (six). Only two X-ray sources from the radio surveys are listed as HII regions. One of them is a chance coincidence with the X-ray binary LMC X-1 (Sect. 4.6) and the other is 30 Doradus.

Out of the 27 sources common to the Parkes radio and the ROSAT PSPC surveys of the SMC, 23 have been previously classified (see Table 3, Col. 8). There are 12 SNRs, seven background sources and three HII regions. One source (SMC B0035 - 7228) appears to be a chance coincidence with the SMC X-ray super-soft source (Sect. 4.3).

Of 52 confirmed radio HII regions in the LMC (Filipović et al. 1997b, hereafter Paper VII), seven sources appear on the Einstein X-ray lists of Helfand et al. (1991), Wang & Helfand (1991b) and Wang et al. (1991). The small number of X-ray emitting HII regions in the RASS LMC point-source list relative to the number seen with the Einstein survey may result from several causes. Some of the Einstein sources are not found as they are below the RASS detection threshold, and others are too extended to be identified as point sources or are located in confused areas. Another possibility is that the improved RASS source positions may exclude the proposed H II regions as the origin of the X-ray source.

H II regions are excellent SN birth places and we expect a number of SNR X-ray sources to be associated with HII regions (Chu & Low 1990). Another process that could explain the appearance of H_{II} regions in X-ray surveys is shock heating by stellar winds inside the HII regions, but Chu et al. (1995b) argue that stellar winds alone could not produce enough X-ray emission. The most extreme example of this is 30 Doradus which is a bright H II region at both radio and X-ray frequencies with no confirmed SNRs (Dickel et al. 1994). We believe, however, that stellar winds, together with embedded SNRs, could be

Table 3. Catalogue of the SMC radio source	identified in the ROSAT PSPC.	The X-ray source name	(Col. 3) is taken from
Kahabka et al. (in prepration). More details a	are given in Sect. 3		

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
No.	Radio	X-Ray	$S_{4.85}$	Count Rate	$\alpha \pm \Delta \alpha$	HR 2	Type	References [†]
	Source Name	Source Name	(Jy)	$\rm cts~ks^{-1}$				
1	$\rm SMCB0034-7155$	RX J0036.9 - 7138	0.078^{f}	24.60		0.38		20
2	SMC B0035 - 7228	RX J0037.3 - 7214		503.55		-0.95	bg?	15, 20
3	$\mathrm{SMC}\mathrm{B0037}-7327$	RX J0038.6 - 7310	0.058	31.70	$-0.14{\pm}0.20$	0.39	BG	18, 20
4	$\operatorname{SMC}B0039 - 7353$	RX J0041.0 - 7336	0.102	9.65	$0.11 {\pm} 0.14$	-0.14	SNR	18, 20
5	SMC B0040 - 7323	RX J0041.9 - 7308	0.083	5.85	$-0.68 {\pm} 0.17$	0.59	BG	18, 20
6	$\mathrm{SMC}\mathrm{B0043}-7321$	RX J0045.1 - 7303	0.090	2.92	$0.03 {\pm} 0.11$	-0.19	Hii	2, 20
7	SMC B0043 - 7330	RX J0045.6 - 7313	0.039	4.19		0.13	$\operatorname{snr}?$	20
8	SMCB0045 - 7255	RX J0047.2 - 7239	0.020	2.11	0.15 1.0.10	1.00	BG?	15, 20
10	SMC B0045 - 7324	RX J0047.6 - 7309	0.932	35.10	-0.15 ± 0.18	0.21	SNR	2, 7, 9, 10, 12, 15, 18, 20
10	SMC B0040 - 7333	KA J0048.3 - 7319	0.204	3.87	0.11 ± 0.13	0.41	SNR	2, 7, 9, 10, 12, 20
11	SMC B0047 - 7324	RX J0048.9 - 7306	0.099	1.61	-0.14 ± 0.03	-0.21	Hii	2, 20
12	SMC B0047 - 7332	RX J0049.0 - 7314	0.070^{J}	12.5	0.25 ± 0.06	0.11	SNR	8, 10, 15, 18, 20
13	SMC B0047 - 7343	RX J0049.8 - 7324	0.046	1.40	0.70 ± 0.04	0.68	BG	18, 20
14	SMC B0049 - 7338	RX J0051.0 - 7321	0.046	118.10	-0.06 ± 0.36	-0.26	SNR	7, 8, 10, 15, 18, 20
15	SMCB0049 - 7356	RX J0050.8 - 7341	0.197^{j}	4.77	0.18 ± 0.20	0.41	BG	18, 20
16	SMC B0051 - 7254	RX J0053.0 - 7239	0.196	0.96	$-0.40 {\pm} 0.21$	-0.50	SNR	8, 10, 12, 15, 18, 20
17	SMC B0053 - 7227	RX J0055.4 - 7210	0.057	24.70	-0.44 ± 0.12	0.36	BG	15, 18, 20
18	SMC B0054 - 7235	RX J0056.6 - 7220	0.035	1.95	0.49 ± 0.12	0.55	snr?	20
19	SMCB0057 - 7226	RA J0059.5 - 7210	1.033	220.50	-0.15 ± 0.06	-0.08	SNR	2, 3, 9, 13, 15, 15, 18, 10, 20
20	$\rm SMCB0058-7149$	RX J0100.3 - 7133	0.146	7.91	$-0.41 {\pm} 0.14$	-0.34	SNR	8, 10, 18; 20
21	SMCB0058 - 7228	RX J0100.7 - 7211		23.97		0.33		15, 20
22	SMCB0101 - 7226	RX J0103.2 - 7209	0.125	9.05	$-0.09 {\pm} 0.02$	0.35	SNR	7, 9, 10, 17, 15, 18, 20
23	$\mathrm{SMC}\mathrm{B}0102-7218$	RX J0103.9 - 7202	0.411	506.03	$-0.33 {\pm} 0.19$	-0.11	SNR	1, 2, 4, 7,
								9, 10, 15, 18, 20
24	SMC B0103 - 7239	RX J0105.0 - 7223	0.052	42.60	-0.47 ± 0.29	-0.32	SNR	7, 9, 10, 15, 18, 20
25	SMC B0104 - 7226	RX J0105.3 - 7210	0.212^{f}	18.80		0.07	SNR	20
26	$\rm SMCB0110-7318$	$\rm RXJ0111.5-7302$	0.088	3.03	$0.04 {\pm} 0.15$	0.32	\mathbf{BG}	18, 20
27	$\rm SMCB0113-7334$	RX J0114.2 - 7319	0.328^{f}	2.96	$0.28{\pm}0.06$	0.71	Hii	2, 18, 20

[†]References used in Table 3 (Col. 9)

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Amy (1994)
                            Caplan et al. (1996)
1]
                          2
  Hodge & Snow (1975)
                          6
                            Jones & McAdam(1992)
                         [10] Mills et al. (1984)
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Mills et al. (1982)
9]
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[13] Rosado et al. (1993b) [17] Ye et al. (1995)

[14] Savage et al. (1977) [18] Ye (1988)

Davies et al. (1976) Mathewson et al. (1983) 7 Mountfort et al. (1987) 11 Wang & Wu (1992) [15][19] Ye et al. (1991)

4] Dopita et al. (1981) 8 Mathewson et al. (1984)

Rosado et al. (1994) 12

16 White et al. (1991)

Kahabka et al. (in preparation). [20]

sufficient for X-ray emission from large H II regions. Arthur & Henney (1996) proposed a model in which an SNR evolves inside an extremely diffuse stellar-wind bubble (formed by the OB association stars) but the density in the SNR is augmented through hydrodynamic ablation of cool, dense clumps by the post-blast SNR flow.

Most SNRs in the MCs are embedded in HII regions; 16 such objects have been found. Chu & Kennicutt (1988b) predicted that more embedded SNRs will be identified in future radio surveys of higher angular resolution and sensitivity. These SNRs are rather weak emitters of very small size (<5'') and are obscured within much stronger HII regions such that their detection is difficult with the present radio survey data.

By comparison, the discovery of further young and luminous SNRs in the MCs isolated from HII regions in significant numbers is not likely (Clarke 1976). This conjec-

ture is supported by our Log N - Log S study (Paper VII) where we predict that only a small fraction of our unclassified sources can be SNRs.

4.1. Source classification criteria

To establish a criterion for the classification of the 33 "unknown" LMC and five "unknown" SMC sources and to check the "known" sources, we plot in Figs. 3a and 3b the source radio spectral index against the X-ray HR2. These colour-colour diagrams show several important trends.

First, all known background sources have positive HR2, with mean value for the ones towards the LMC of $HR2_{mean} = 0.31$ and SD = 0.22 (see Fig. 4b), compared to the HR2 for the LMC SNRs (see Fig. 4a), which have a much wider distribution (-1.00 < HR2 < 0.55). All sources with negative HR2 are SNRs or SNR candidates.

((1) (10)	(11)
N	Vo. Other Names [‡]	Comments
_	1 2 1E0035.4-7230; WW 13	X-ray binary candidate 124" from SMC X-ray Binary; X ray super soft source
	3 PMN J0038 – 7310 4 PMN J0040 – 7337; DEM S5; LI-SMC 10 5 MC4 B0040 – 733A; PMN J0042 – 7306	X-ray binary candidate
	6 N 12B; NGC 249; DEM S18; LI-SMC 30 7 N 10; PMN J0044 – 7313; DEM S11 (14); LI-SMC 28 8 PMN J0047 – 7239; WW 19; LI-SMC 40	BG in X-ray classification
	9 N 19; S9; MC4 B0045 – 734; PMN J0047 – 7308; NGC 261; DEM S32; IKT 2; LI-SMC 43; WW 16; BKGS 1A 10 N 22 (20, 21, 23, 28, 28A); S10; MC4 B0046-735; DEM S37 (36); LI-SMC 45 (42)	SNR embeded in H ii region SNR embeded in H ii region
с	 N 30; S13; DEMS45 DEMS49; IKT 5; WW 22; BKGS 2; LI-SMC 54 N 31 (33); PMN J0049 - 7326; DEMS44; LI-SMC 57 (56) PMN J0051-7321; 1E0049.4 - 7339; IKT 6; WW 24; LI-SMC 68 	
	15	
	 16 N 50; DEM S68; PMN J0053 - 7238; WW 30; BKGS 5 17 MC4 B0053 - 724; PMN J0055 - 7210; NGC 306; WW 36 18 N 58 (57); PMN J0056 - 7219; DEM S86; LI-SMC 110 (109) 	Two sources in MOST
	 N 66 (66Å,B,C,D); S17; PKS B0057 – 724; MC4 B0057 – 724; PMN J0059 – 7210; NGC 346; DEM S103; 1E0057.6 – 7228; IKT 18; LI-SMC 131; WW 44 MC4 B0058 – 718B: PMN J0100 – 7133: DEM S108 	SNR embbedded in H ii region; Emission nebula
	21 1E0059.0 - 7228; IKT 19; WW 45 22 N 76C: 1E0101.5 - 7226: IKT 21: WW 50: LI-SMC 160	X-ray binary candidate
	 23 N 76 (76A); S20; PKS B0102 - 723; MC4 B0102 - 723; PMN J0103 - 7202; DEM S124 (123); 1E0102.2 - 7219; IKT 22; WW 51; BKGS 12; LI-SMC 162 (161) 24 DEM S125; 1E0103.3 - 7240; IKT 23; WW 52; BKGS 13; LI-SMC 169 25 DEM S128; IKT 24; WW 53; BKGS 14; LI-SMC 170 	SNR embeded in Hii region; An Oxygen-Rich Young SNR
	 26 PMN J0111-7302 27 N 84; S26; PKS B0113 - 735; MC4 B0112 - 736; NGC 456; PMN J0114 - 7318; DEM S150 (152); LI-SMC 202 (201) 	Vicinity of BG source

[‡]Abbreviations used in Col. 10.

Ν	$H\alpha$ catalogue of emission nebulae (Henize 1956),
S	Radio catalogue (McGee et al. 1976),
MC4	Radio catalogue (408 MHz) (Clarke et al. 1976),
MRC	Radio catalogue (408 MHz) (Large et al. 1981),
DEMS	$H\alpha$ catalogue of emission nebulae (Davies et al. 1976),
NGC	NGC 2000 catalogue (optical) (Sinnott 1988),
PMN	Radio catalogue (4.85 GHz) (Wright et al. 1994),
PKS	PKSCAT-90 radio catalogue (Otrupcek & Wright 1991),
1E	X-ray catalogue (Seward & Mitchell 1981),
IKT	X-ray catalogue (Inoue et al. 1983),
LI - SMC	IR catalogue (Schwering & Israel 1991; Israel et al. 1993),
WW	X-ray catalogue (Wang & Wu 1992) and
BKGS	X-ray catalogue (Bruhweiler et al. (1987).

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Second, the LMC SNRs have a narrower range of radio spectral index ($\alpha_{\text{mean}} = -0.44$, SD = 0.20; see Fig. 5a) than background sources in the field of the LMC ($\alpha_{\text{mean}} =$ -0.39, SD = 0.60; see Fig. 5b).

Third, the background sources have two peaks of spectral index: one with very steep radio spectra consisting of 12 sources with $\alpha_{\text{mean}} = -0.77$ and SD = 0.19, and another with flat and inverted spectra (10 sources) with $\alpha_{\rm mean} = 0.19$ and SD = 0.24.

Because of the overlap in radio spectral index (Paper VII), spectral index alone is not sufficient to distinguish SNRs, HII regions and background sources. As an additional help in source classification, we will treat all sources outside the region de-

fined by $RA(B1950) = 04^{h}45^{m}$ to $RA(B1950) = 06^{h}00^{m}$ and $Dec(B1950) = -65^{\circ}$ to $Dec(B1950) = -72^{\circ}30'$ as background sources. Also, all sources outside the area of the SMC defined by $RA(B1950) = 00^{h}30^{m}$ to $RA(B1950) = 01^{h}30^{m}$ and $Dec(B1950) = -71^{\circ}40'$ to $Dec(B1950) = -74^{\circ}00'$ will be treated as background. No radio sources in these surrounding areas are known to belong to either the LMC or the SMC.

Because of the small number of HII regions observed in previous X-ray surveys (4 out of 174, Paper VII), we do not believe that any of the previously unclassified (both radio and X-ray) sources in the field of the MCs are compact HII regions.





Fig. 3. The distribution of radio spectral index (α) and X-ray hardness ratio 2 (HR2) for different classes of sources towards a) the LMC and b) the SMC. Asterisks represents SNRs; filled square – HII regions; open circles – background sources and triangles – unclassified sources. All background sources have HR2 > 0

4.2. Background sources in the field of the LMC

A list of background sources towards the LMC is presented in Paper VII. From this list, six known background sources have been confirmed as X-ray emitters: LMC B0428-6755, LMC B0502-6638, LMC B0543-7333, LMC B0547 - 6746, LMC B0602 - 6443 and LMC B0611 - 6623 (see in Table 2, Col. 8 marked with "BG").

There are 16 sources outside the LMC area defined in Sect. 4.1. All of the sources (LMC B0438-7316, LMC B0441-6957, LMC B0442-6824, LMC B0445-6458, LMC B0446-7210, LMC B0508-6436, LMC B0524-6443, LMC B0534-6438, LMC B0536-6452, LMC B0546-6416, LMC B0552-6402, LMC B0602-6830, LMC B0605-6625, LMC B0606 - 7041, LMC B0608 - 6510 and LMC B0611 - 6734) have a positive HR2 and radio spectrum typical of background sources. Here we suggest that all of these sources are background objects (see Table 2, Col. 8 marked with "bg").

Another five sources within the LMC area (LMC B0531-6518, LMC B0537-6506, LMC B0547-6729, LMC B0552-6948 and LMC B0553-6704) are classified as probable background sources because of their positive hardness ratios and/or radio spectra. This classification is strongly based on the HR2 because, as the radio spectra could not be estimated for some of these sources, they were detected at only one radio frequency. These sources are marked in Table 2, Col. 8, with "bg?".

To conclude, 27 out of 71 sources in common towards the LMC appear to be background (or candidates for background) sources. This is consistent with the number expected from Log N – Log S studies of such objects (Paper VII).

4.3. Background sources in the field of the SMC

A catalogue of background radio sources towards the SMC can be found in Paper VII. From this list we found six radio sources (SMC B0037-7327; SMC B0040-7323; SMC B0047-7343; SMC B0049-7356; SMC B0053-7227 and SMC B0110-7318) that are common to the ROSAT PSPC list of sources (Kahabka et al. in preparation). These sources were marked with "BG" in Table 3, Col. 8.

Another radio source (SMC B0045-7255) listed in Paper VII as a background candidate (see in Table 3, Col. 8 marked with "BG?") was found in the ROSAT PSPC X-ray surveys (RX J0047.2 - 7239). This source, with positive HR2, will be treated as a definite background object in future studies.

The X-ray super-soft source RX J0037.3 - 7214 lies 126" from the radio source SMC B0035 - 7228 and therefore they are most probably a chance coincidence. We believe that the radio source is likely to be a background object.

In total, 8 out of 27 sources in common towards the SMC appear to be background objects. Seven of them

Fig. 5a.

have an X-ray counterpart and one is probably a chance coincidence.

4.4. Supernova remnants in the LMC

Previous studies investigated 56 SNRs in the LMC, from which 37 are confirmed and 18 are candidates (Mathewson et al. 1983, 1984, 1985; Mills et al. 1984; Chu & Kennicutt 1988a, b, 1994; Chu et al. 1993, 1995a, b, 1997;



Fig. 4. Distribution of HR2 for a) the LMC SNRs, and b) background sources towards the LMC



Fig. 5. Distribution of radio spectral index for a) the LMC SNRs, and b) background sources towards the LMC common to the RASS

Smith et al. 1994; Dickel et al. 1993, 1994; Dickel & Milne 1995). All are detected at radio frequencies. Three confirmed SNRs (B0505 - 679, B0509 - 675 and B0543 - 689) listed in Mathewson et al. (1983a), Mills et al. (1984) and Tuohy et al. (1982) could not be detected in any of the six Parkes radio surveys (their emission is below our detection limits). They were, however, detected at 843 MHz with the Molonglo Observatory Synthesis Telescope (MOST) (Mills et al. 1984). Positive X-ray detection of these three

SNRs has been reported by Wang et al. (1991) and Pietsch et al. (in preparation). Another SNR discovered by Chu et al. (1997) is associated with H II region N159 and we discuss this source in Sect. 4.6.

We have detected 26 SNRs and four SNR candidates in both the X-ray and our Parkes radio surveys. All 30 sources: namely LMC B0453-6834, LMC B0454-6630, LMC B0454-6718, LMC B0455-6843, LMC B0506-6806, LMC B0507-6829, LMC B0507-7029, LMC B0509-6848, LMC B0513-6915, LMC B0519-6905, LMC B0519-6941, LMC B0520-6928, LMC B0522-6757, LMC B0525-6601, LMC B0525-6607, LMC B0525-6941, LMC B0528-6551, LMC B0528-6914, LMC B0530-6734, LMC B0532-7102, LMC B0534-6957, LMC B0534-7035, LMC B0535-6603, LMC B0536-6735, LMC B0536-7040, LMC B0538-6911, LMC B0540-6921, LMC B0547-6942, LMC B0548-7025 and LMC B0550-6823, show strong evidence for being SNRs based on radio spectral index or X-ray HR2, or both. These sources are marked in Table 2, Col. 8 with "SNR" or "SNR?".

Two previously unclassified radio sources (LMCB0530 - 6655 and LMCB0534 - 7204) are strong candidates for being SNRs because of a negative HR2 and steep radio spectral index.

There are another four previously unclassified radio sources (LMC B0528 - 6838, LMC B0542 - 6702, LMC B0544 - 6910, LMC B0544 - 7030) which have a negative HR2, but we have no radio spectral index data, since they are observed only at one radio frequency. These are more likely to be SNRs than background sources and therefore we consider them as SNR candidates (see in Table 2, Col. 8 marked with "snr?").

Thirty SNRs and six new SNR candidates from this study have been classified out of the total number of 71 sources. This increases the total number of SNR candidates known in the LMC from 18 to 24.

4.4.1. Statistics of the LMC supernova remnants

Wang et al. (1991) detected 28 X-ray SNRs from the Einstein survey of the LMC and Smith et al. (1994) and Chu et al. (1995a, 1997) found another seven SNRs from the ROSAT PSPC survey. Here we confirm the existence at X-ray frequencies of an additional five previously known radio SNRs and suggest a further six new SNR candidates. This brings the total number of X-ray SNRs and SNR candidates in the LMC to 46. As the total number of known SNRs and SNR candidates in the LMC to 46. As the total number of known SNRs and SNR candidates in the LMC to 46. As the total number of known SNRs and SNR candidates in the LMC is 62, 74% are now confirmed as X-ray sources.

There are four known SNRs and 12 SNR candidates in our Parkes radio surveys for which there are no X-ray counterparts (Table 4). Table 4 contains SNRs drawn from different age populations. There are both strong and weak radio SNRs in Table 4 and so the nondetections in X-rays are not simply because the SNRs are radio weak. The speculation by Aschenbach (1995) for the existence of X-ray quiet SNRs is supported.

It is interesting to note that 33% (60 out of 182), or 48% (89 out of 182 if 29 SNR candidates are included) of the radio SNRs in our Galaxy have been seen in X-ray surveys (Aschenbach 1995). These percentages for our Galaxy are far smaller than for the LMC. The reason may be that soft X-ray emission from some of the Galactic SNRs may be absorbed by H I in the Galactic Plane, whereas X-ray emission from the LMC is less absorbed because of lower column-depths towards the MCs.

4.4.2. An estimate of the supernova rate in the LMC

An estimate of the rate of supernova formation can be obtained if the age of the individual SNRs can be determined. To estimate the age of individual SNRs in the MCs, we follow the method of Van Buren & Greenhouse (1994) and adopt the relationship between age and radio flux density at 4.75 GHz ($S_{4.75}$). For calibration, we have scaled the flux density of Cas A ($S_{4.75} = 650$ Jy) at its distance of 3 kpc, and age of 340 years (Whithfield 1957), to the distance of the LMC (50 kpc; Westerlund 1993) to give the relationship:

$S_{4.75} = 3887 \times T^{-1.3}$

where T is the SNR age in years and $S_{4.75}$ is in Jansky (Jy).

Assuming the $S_{4.75}$ flux densities to be complete down to ~ 0.1 Jy (which corresponds to a SNR age of 3400 yr), we have computed the age of 38 SNRs and SNR candidates. It has been assumed that the flux densities are not seriously affected by any confusing HII regions. A comparison of our estimates of the individual SNR ages with diameters taken from various optical and high-resolution radio images shows little correlation and, therefore, we assign little confidence to the individual ages. The mean period between successive SNR occurrences is $100 (\pm 20)$ vr. This figure does not agree with the estimate of Chu & Kennicutt (1988b) who give the birth-rate in the LMC of one SNR per 500 yr. However, Chu & Kennicutt (1988b) predict that their estimate of the rate will change with the discovery of new SNRs hidden in HII regions and superbubbles.

Using the radio supernova rate and the relation between star-formation rate (SFR) and supernova rate (Condon 1992; Eq. (20)) it is possible to determine the SFR in the LMC. We obtain an SFR of $0.7(\pm 0.2) \ M_{\odot} \,\mathrm{yr}^{-1}$. This result is consistant, albeit slightly higher than the upper limit of ~ $0.6 \ M_{\odot} \,\mathrm{yr}^{-1}$ suggested by Kennicutt (1991).

Our estimate of supernova birth-rate in the LMC seems large in comparison to the rate in our Galaxy (one every 30 - 50 yr). Probably, the problem lies in the Van Buren & Greenhouse (1994) relationship which is too simplistic given the poor correlation between ages and flux for

(1) Radio	(2) $S_{4,75}$	$\begin{array}{c} (3) \\ \alpha \pm \Delta \alpha \end{array}$	(4) Type	(5) Reference	(6) Comments
Source Name	(Jy)		51		
$\rm LMCB0450-6927$	0.267	-0.68 ± 0.16	SNR?	8; 31	He III region
$\rm LMCB0450-7055$	0.496	-0.36 ± 0.08	SNR1	23; 25	Pop II?
$\rm LMCB0454-7005$	0.166	-0.67 ± 0.09	SNR?	8; 20	
$\rm LMCB0459-6612$			SNR?	8	Seen only at 2.45 GHz
$\rm LMCB0505-6548$	0.046	-1.27 ± 0.21	SNR?	8	
$\rm LMCB0520-6531$	0.505	-0.37 ± 0.15	SNR?	8; 49	X-ray – Superbubble
$\rm LMCB0521-6545$	0.141	-0.33 ± 0.03	SNR?	8; 20	
$\rm LMCB0523-7138$	0.176	-0.86 ± 0.05	SNR?	8; 20	Superbubble
$\rm LMCB0524-6627$	0.050^{f}	-0.33 ± 0.06	SNR1	20; 23	Pop I; SNR embedded in H II region
$\rm LMCB0524-7121$	0.104	-0.48 ± 0.14	SNR?	8	
$\rm LMCB0528-6716$	0.149	-0.79 ± 0.15	SNR	23	
$\rm LMCB0528-7038$	0.244	0.00 ± 0.02	SNR?	8	
$\rm LMCB0529-6702$	0.208	-0.93 ± 0.06	SNR?	34	Vicinity of Pulsar PSR $B0529 - 66$
$\rm LMCB0537-6641$	0.442	-0.01 ± 0.12	SNR?	8	
$\rm LMCB0538-6922$	1.012	0.03 ± 0.10	SNR	27; 42	Pop I; SNR embedded in H _{II} region
$\rm LMCB0544-6621$	0.092	-1.34 ± 0.33	SNR?	8	

Table 4. Radio SNRs and SNR candidates in the LMC that are not detected with X-ray surveys (RASS or Einstein survey). The references in Col. 5 are the same as in Table 2

well-known SNRs. Also, Condon's (1992) relation between SFR (in $M_{\odot} \text{ yr}^{-1}$) and SN rate assumes some kind of universal initial mass function (IMF), while we have strong indications for bimodal mass function in the MCs, with the large star masses (hence SNs) strongly favoured in clusters and associations (Massey et al. 1995).

4.5. Supernova remnants in the SMC

From the list of 20 SMC SNRs and SNR candidates (Ye 1988), 12 were found in our Parkes radio surveys (Paper VII). Five well-known SNRs and three SNRs candidates could not be detected in any of our radio surveys but they can all be detected with the MOST radio telescope and are also in the ROSAT PSPC surveys.

All 12 radio SMC SNRs from the Parkes surveys have counterparts in the ROSAT PSPC survey. These 12 sources are: SMC B0039-7353, SMC B0045-7324, SMC B0046-7333, SMC B0047-7332, SMC B0049-7338, SMC B0051-7254, SMC B0057-7226, SMC B0058-7149, SMC B0101-7226, SMC B0102-7218, SMC B0103-7239 and SMC B0104-7226. They show typical SNR characteristics and here we confirm their SNR nature.

Radio sources SMC B0043-7330 and SMC B0054-7235 have not been classified before and we found counterparts in X-ray sources RX J0045.6 - 7313 and RX J0056.6 - 7220. These sources were also detected in $H\alpha$ and IR surveys and therefore we believe that they could be good SNR candidates. However, neither of these sources has a conclusive radio spectral index or HR2.

4.5.1. An estimate of the supernova rate in the SMC

Using the same method as for the LMC, we estimate the birth-rate of SNRs and the SFR in the SMC. From 12 SMC SNRs, 10 have radio flux at 4.85 GHz greater than 0.1 Jy, which is our completeness level. Using an estimated age of these 10 SMC SNRs, we find that the birth-rate of the SNRs in the SMC is one every 350 (\pm 70) yr. As for the LMC, this figure does not agree with the previously published estimate of Mathewson et al. (1983) who give the birth-rate in the SMC of one SNR per 800 yr.

Using this birth-rate we obtain an SFR for the SMC of 0.15 (± 0.05) M_{\odot} yr⁻¹. This result is also consistent with the upper limit of ~ 0.1 M_{\odot} yr⁻¹ suggested by Kennicutt (1991).

4.6. Other MCs sources found in this study

Only five radio H II regions (LMC B0539-6907 = 30 Dor, LMC B0540-6946, SMC B0043-7321; SMC B0047-7324 and SMC B0113-7334) are correlated with X-ray sources in this study. The X-ray emission from the well-known radio H II region(s) LMC B0540 - 6946 (N 159; Hunt & Whiteoak 1994) is caused by the X-ray binary (LMC X - 1) and is therefore not associated with the H II region. Chu et al. (1997) found X-ray emission from N 159A (2' east of LMC X-1) in the ROSAT HRI image, which they interpret as being coused by an SNR. However, Hunt & Whiteoak (1994) did not find any evidence of such

Table 5. Sources in the field of the LMC detected at radio and X-ray frequencies but not listed in Table 2. These sources are either in the X-ray surveys (RASS, PSPC or Einstein) but not in the Parkes surveys, or in the Parkes surveys but not in the RASS

(1) Radio Source Name	(2) X-ray Source Name	$\begin{array}{c} (3)\\ \alpha\pm\Delta\alpha \end{array}$	(4) Type	(5) Reference [†]	(6) Comments
$\frac{\rm LMCB0453-6700}{\rm LMCB0500-7014}$	RX J04531 - 6655 LHG 7; W 7	$\begin{array}{c} -0.55 \pm 0.08 \\ -0.73 \pm 0.19 \end{array}$	SNR SNR1	4 15; 20; 27; 28: 40: 41	Pop I; SNR embedded
$\begin{array}{l} {\rm LMCB0501-6629} \\ {\rm B0505-679} \end{array}$	RX J0502 - 6624 LMC RASS 135;	$-1.27 \pm 0.08 \\ -0.50$	SNR? SNR3	28; 40; 41 28 22; 27; 35	Vicinity of PSR B0502 – 66?
B0509 - 675	LMC RASS 152; LHG 14; W 12	-0.48	SNR3	27; 35	
$ \begin{array}{l} {\rm LMCB0509-6720} \\ {\rm LMCB0517-7151} \\ \\ {\rm LMCB0517-7151} \end{array} \end{array} $	RX J0509 - 6717 W 18	-0.76 ± 0.04 -0.38 ± 0.07	SNR? BG	7; 17 1; 12	
LMC B0522 - 6800	W 30	-0.48 ± 0.08 -0.04 ± 0.06	HII	2; 3; 6; 13; 26; 28; 31 2: 3: 6: 13: 26: 28	Near a non-thermal source; He III region
LMC B0526 - 6731	W 40	-0.27 ± 0.10	HII	2; 3; 0, 10, 20, 20	SB(X)
$\begin{array}{l} {\rm LMCB0532-6743} \\ {\rm LMCB0535-6948} \\ {\rm LMCB0536-6914} \end{array}$	W 51 LHG 56; W 63 LHG 62; W 71; DX 105262 6011	$\begin{array}{c} -0.01 \pm 0.18 \\ 0.12 \pm 0.05 \\ 0.05 \pm 0.05 \end{array}$	H II H II SNR	2; 3; 28; 43; 44; 54 3; 37; 54 5; 27	Curved radio spectrum; Diffuse emission Pop I; SB(X); SNR embedded
LMC B0536 - 6920 LMC B0539 - 6606	RX J05362 - 6911 W 66 LHG 75	-0.73 ± 0.21	SNR	45	Seen only at 8.55 GHz
LMC B0540 - 6927 B0543 - 689	$\begin{array}{l} {\rm RXJ05402-6928} \\ {\rm LMCRASS278;} \\ {\rm LHG82;W91} \end{array}$	-0.29	SNR	27	Seen only at 8.55 GHz

[†]The numbers in this column refer to references given at the end of Table 2.

an SNR in the high-resoulution (${\sim}10^{\prime\prime})$ ATCA radio observations.

There are sixsources towards the LMC (LMC B0456-6803, LMC B0454-6806, LMC B0513-6729, LMC B0523 - 6623, LMC B0528 - 6542 and LMC B0557 - 6854) and two towards the SMC (SMC B0034-7155 and SMC B0058-7228) that could be either SNR candidates or background objects with flat radio spectra and positive HR2 close to zero. The classification of these sources, however, remains ambiguous.

There are four foreground stars in the field of the RASS (Pietsch et al. in preparation) that coincide with our radio sources (LMC B0513-6729, LMC B0528-6542, LMC B0528-6838 and LMC B0536-6452). We believe that source LMC B0536-6452 is a background source (Sect. 4.2). We classified the source LMC B0528-6838 as an SNR candidate (Sect. 4.4) and the classification of the remaining two sources (LMC B0513-6729 and LMC B0528-6542) is ambiguous. All of these sources belong to the group of expected random coincidences (see Sect. 3).

4.7. Radio and X-ray sources towards the LMC common to other surveys

So far we have discussed sources detected in the Parkes radio surveys (Papers IV, IVa and V) and the ROSAT X-ray surveys (Pietsch et al. in preparation; Kahabka et al. in preparation). However, there are other sources towards the LMC detected in both radio and X-ray from other surveys which are not listed in Table 2. There are no such sources in the field of the SMC.

In Table 5 we list an additional 14 sources towards the LMC which have been catalogued in Papers IV and IVa but which have not been detected in the RASS. These sources have been detected at X-ray wavelengths by the Einstein surveys by Long et al. (1981) and Wang et al. (1991), and with the ROSAT PSPC by Trümper et al. (1991). Also, we add three confirmed radio SNRs (B0505 - 679, B0509 - 675 and B0543 - 689 detected with the MOST and discussed in Sect. 4.4) which are listed in the RASS but not seen in our radio surveys (Table 5).



Fig. 6. The distribution of X-ray count rate and radio flux density at 4.75 GHz for different classes of sources in the LMC. Asterisks represents SNRs; filled squares – HII regions; open circles – background sources and open triangles – unclassified sources. The dashed lines represent the approximate threshold in radio and X-ray surveys. Sources below the dashed lines represent non-detections

All abbreviations and lists of references in Table 5 are based on the nomenclature used in Table 2, with the exception of the X-ray information (count rate and HR2).

Of these 17 sources, nine are known SNRs, five are HII regions and one is a known background source (see Table 5, Col. 4). The classification of sources LMC B0539 - 6606 and LMC B0540 - 6927 is ambiguous but they are likely to be SNR candidates.

5. Radio to X-ray source intensity comparison

In Fig. 6 we have compared the X-ray source intensity (count rate, Table 2, Col. 5) from the RASS with the radio flux density from the 4.75 GHz LMC survey (Table 2, Col. 4). A similar comparison for the SMC is shown in Fig. 7 where we compared the source radio flux from 4.85 GHz survey (Table 3, Col. 4) with the X-ray source intensity (count rate, Table 3, Col. 5) from the ROSAT SMC PSPC surveys.

Most of the radio sources in the field of the LMC (412 out of 483; 85%) fall below the sensitivity limit of the RASS survey (shown in Fig. 6 below 0.002 counts s^{-1}) while most of the X-ray sources (254 out of 325; 78%) fall below the sensitivity limit of the radio survey (shown

below 0.2 Jy). Many strong radio sources and strong X-ray sources have not been detected at X-ray and radio frequencies, respectively. For the SNRs embedded in H II regions, a small component of the radio flux will be caused by the H II regions but this will not significantly affect the radio-to-X-ray flux correlation.

There is very little correlation between radio and X-ray source intensities shown in Fig. 6. Of the sources observed at both radio and X-ray frequencies, the strongest at both frequencies tend to be SNRs. Breaking the sample of 483 radio sources into those above the X-ray threshold of 0.002 counts s⁻¹(71 sources) and those below (412 sources), the fraction of SNRs is 51% (36 out of 71) and 6% (26 out of 412), respectively.

Similar results can be seen in Fig. 7 where we compared the 27 sources in common towards the SMC. Seventeen of the SMC sources (SNRs and HII regions) are stronger emitters in both radio and X-ray frequencies than eight background and two unclassified sources.

We followed the classification of Chu & Kennicutt (1988b) for SNRs in the LMC as Population I or Population II, to consider the difference in X-ray and radio properties of the two types. In Fig. 8 the X-ray Count Rate is plotted against the radio flux density (at 4.75 GHz) for



Fig. 7. The distribution of X-ray count rate and radio flux density at 4.85 GHz for different classes of sources in the SMC. Asterisks represent SNRs; filled squares – H II regions regions; open circles – background sources and open triangles – unclassified sources

32 SNRs distinguished by type. Nine SNRs are plotted as "unknown" types. The interpolated 4.75 GHz flux densities were estimated from other radio data for eight sources (flagged in Table 2, Col. 4) where no 4.75 GHz flux densities are available. There is a large scatter in the ratio of X-ray count rate to radio flux density. The ratio varies by three orders of magnitude from 0.019 to 18 counts s⁻¹ Jy⁻¹ with median 0.38 counts s⁻¹ Jy⁻¹ for the SNRs detected both at radio and X-ray. If we consider SNRs detected at radio but not in X-ray, the range of X-ray-toradio ratio is even larger, with an upper limit as low as 5 10⁻⁴ counts s⁻¹ Jy⁻¹. However, there is a tendency for SNRs which are strong in the radio to be also strong in X-rays.

Figure 8 shows that young SNRs from Population I appear in the top right-hand corner with strong X-ray and radio intensities. Dividing this sample at arbitrary values of 0.1 Jy and 0.1 counts s^{-1} , we note that the quadrant with strong radio and X-ray intensities is dominated by SNRs of Population I. Here 89% (8 out of 9) are Population I while in the other quadrants the fraction is 19% (6 out of 32) for the quadrant of strong radio and weak X-ray (including the sources below the X-ray threshold), 19% (3 out of 16) for weak radio, weak X-ray

(including the sources below both thresholds) and 20% (1 out of 5) for weak radio, strong X-ray (including the sources below the radio threshold).

Population I SNRs are young and usually occur within large H II regions. This could be one reason for the occasional detection of X-ray emission from H II regions. Young Population II SNRs in the LMC are usually Balmerdominated and occur in regions not interacting with other sources. They are, therefore, relatively weak X-ray and radio emitters. This could be a significant fact in SNR evolution; however, we can not rule out selection effects or a bias resulting from the small number of classified SNRs.

6. Conclusions

From a comparison of radio and X-ray surveys of the MCs we find 71 sources in common towards the LMC and 27 sources in common towards the SMC. The sources in common towards the LMC are mainly SNRs and SNR candidates (36) and background sources (27). Out of 27 sources in common in the field of the SMC, 14 are SNRs, three are H II regions and eight are background sources.

We used the X-ray hardness ratio 2 (HR2) to help classify radio sources as SNRs or background sources using the



Fig. 8. The distribution of X-ray count rate and radio flux density at 4.75 GHz for different population of LMC SNRs. Asterisks represent Population I SNRs; open diamonds – Population II SNRs; and filled triangles SNRs of unknown population. Population I SNRs tend to be strong in both radio and X-ray surveys. The sample of sources with both strong radio and X-ray intensities is dominated by Population I SNRs

fact that the previously known background sources have positive HR2.

Based on this classification we propose six new radio and X-ray sources as SNR candidates in the LMC (LMC B0530-6655, LMC B0534-7204, LMC B0542-6702, B0528-6838, LMC LMC B0544 -6910, LMC B0544-7030). Two SMC sources (SMC B0043-7330 and SMC B0054-7235) show characteristics typical for SNRs and therefore we classified them as SNR candidates.

From the number and radio flux densities of the LMC SNRs we derive an SNR birth-rate of one every $100(\pm 20)$ yr and an SFR of 0.7 (± 0.2) M_{\odot} yr⁻¹ for the LMC. Similarly, for the SMC SNRs we find a birth-rate of one every 350 (± 70) yr and an SFR of 0.15 (± 0.05) M_{\odot} yr⁻¹.

Comparing the intensities (radio and X-ray) for the sources in common towards the MCs, we found very little correlation between radio and X-ray intensities densities but note that the strongest SNRs from this sample are young SNRs from Population I.

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