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THE 100 STRONGEST RADIO POINT SOURCES IN THE FIELD OF THE LARGE MAGELLANIC CLOUD AT 1.4 GHz

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SUMMARY: We present the 100 strongest 1.4 GHz point sources from a new mosaic image in the direction of the Large Magellanic Cloud (LMC). The observations making up the mosaic were made using Australia Telescope Compact Array (ATCA) over a ten year period and were combined with Parkes single dish data at 1.4 GHz to complete the image for short spacing. An initial list of co-identifications within $10''$ at 0.843, 4.8 and 8.6 GHz consisted of 2682 sources. Elimination of extended objects and artifact noise allowed the creation of a refined list containing 1988 point sources. Most of these are presumed to be background objects seen through the LMC; a small portion may represent compact H II regions, young SNRs and radio planetary nebulae. For the 1988 point sources we find a preliminary average spectral index (α) of –0.53 and present a 1.4 GHz image showing source location in the direction of the LMC.

Key words. Radio Continuum: galaxies – Magellanic Clouds – Catalogs

1. INTRODUCTION

The Large Magellanic Cloud (LMC) is a galaxy that, from our vantage point, appears as a nearly face-on spiral. It is an ideal location to study and to develop our understanding of radio sources such as supernova remnants (SNRs), H II regions, planetary nebulae, and X-ray binaries and their interactions. More distant radio sources that include active galaxies can also be seen in the direction of the LMC. These sources, that are not in the LMC, must also be identified and distinguished from those within the LMC.

We present a description and analysis of our data in Section 2, and the results in Section 3. Concluding remarks with a brief discussion are presented in Section 4.

2. OBSERVATIONS AND ANALYSIS

During October 1994 and February 1995, the LMC was surveyed in mosaic mode, centred at 1.4 GHz (bandwidth 128 MHz), using the Australia Telescope Compact Array (ATCA). This survey divided the LMC into 12 regions, each containing 112 pointing centres. Each pointing centre was observed approximately 115 times (ranging from 95 to 140) for 15 s. The data were reduced using the MIRIAD software suite (Sault and Killeen 2006). Data from the

64-m Parkes radio telescope (Filipović et al. 1995) of the same region at 1.401 GHz (λ=21 cm) were used to fill in the missing short spacing allowing large-scale structure to be resolved. The Parkes data were obtained in the 1990's with beamwidth of 16.6′ and rms noise of 30 mJy beam^{-1}. As described in Hughes et al. (2006, 2007), the resulting combined 21-cm mosaic image of the LMC has a resolution of $\sim 40''$ and a sensitivity of ~ 0.3 mJy beam^{-1}. Hughes at al. (2007) developed a pioneering technique for the more efficient cleaning of the side-lobes which are mainly created by strong sources such as 30 Doradus.

Similar ATCA/Parkes mosiac images have been created from observations at 4.8 and 8.6 GHz (λ=6 and 3 cm) during the period between 2001 and 2003 by Dickel et al. (2005). Their 4.8 GHz image has a FWHM of 33″ while the 8.6 GHz image has a FWHM of 20″. Our analysis of these images shows a rms noise of 0.36 and 0.55 mJy beam^{-1} at 4.8 and 8.6 GHz, respectively. The original data were also re-processed by A. Hughes using the same technique as discussed in Hughes et al. (2007).

In our analysis, we also make use of radio surveys at 843 MHz made with the Molonglo Observatory Synthesis Telescope (MOST). This survey of the Magellanic Clouds has an angular resolution of 45″ and a sensitivity of 0.7 mJy beam^{-1}. Since this image covers the largest portion of sky second only to the 1.4 GHz image, its area represents the boundary limits for our catalogue. For more details, see Turtle and Amy (1991).

The above radio images were analyzed one by one using the IMSAD task, which is part of the MIRIAD software suite. We initially selected all 1.4 GHz point sources with gaussian peak fluxes greater than 5σ (1.5 mJy beam^{-1}). The resulting list from IMSAD were compared to those obtained using the 843 MHz, 4.8 and 8.6 GHz images with their respective 3σ cutoff values. A preliminary point source catalogue was obtained for those 1.4 GHz sources having at least one co-identification within 10″ at another frequency. The extent of the catalogue limited by the MOST observation region is RA (J2000)=$06^h11^m00^s$ to $04^h29^m00^s$ and DEC(J2000)=– $64^0 59' 00''$ to –$72^0 49' 30''$. This initial list contained 2682 objects.

Each source was numbered and labeled using Karma's KVIS tool, which allowed for individual inspection. Sources that were extended at 1.4 GHz were excluded as well as those sources that appeared to be noise artefacts. The search area included the central portion of the LMC, although most sources there were extended, not appearing to be consistent with being point sources.

Using these latest images of the LMC we have found co-identifications with 56 previously identified radio SNRs from Filipović et al. (1998) and an additional 20 candidate SNRs based on location, radio intensity, size and morphology. More details about the LMC SNRs study will be presented in the follow-up papers.

3. RESULTS

Using the methods described above, we were able to create a refined list containing 1988 sources. 1.4 GHz flux densities (based on peak flux) range from 1.5 mJy to 1.5 Jy. Using available flux densities (S_ν) at all frequencies (ν), individual spectral indices ($S_\nu \propto \nu^\alpha$) for each source were determined. From these we determined an average spectral index (α) of -0.53 (SD= 0.93). Further analysis will most likely narrow this range as this list is compared to other known sources within the LMC.

In Fig. 1, we show a histogram of the spectral indices for the strongest 100 point sources in our catalog. For these sources we see a symmetric curve indicating that the majority of them have indices between –0.8 and –1.0. The values range between indices of 0.2 and –2.2 and compare reasonably to a similar histogram of background objects in the direction of the SMC as shown in Fig. 1 of Payne et al. (2004).

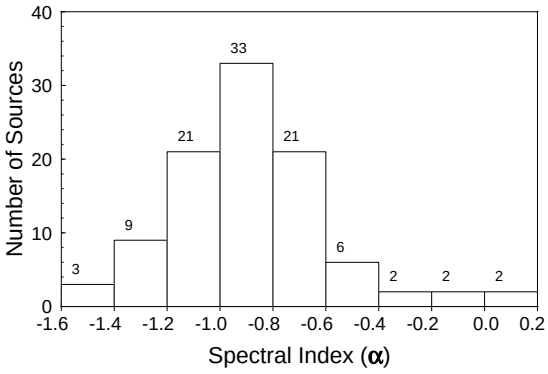

Fig. 1. *Histogram of spectral indices for the strongest 100 point radio sources in the field of the LMC. Only one object is outside of this graph range at α=– 2.2.*

Table 1 gives source position (J2000; given in R.A. and Dec.), flux densities at 1.4 GHz, 843 MHz, 4.8 GHz and 8.6 GHz (given in Jy) and corresponding radio spectral index for the strongest 100 objects in the field of the LMC at 1.4 GHz. We show their positions in Fig. 2 (crosses). As expected, these sources cover the transparent region of the LMC evenly.

The expected background integral source count at 1.4 GHz was obtained by interpolating polynominial fits (log N – log S) given by Wall (1994). These fits give the predicted number of background sources in the observed field. For 1.4 GHz, given a 5σ cut-off of 1.5 mJy and a sky coverage of ~ 32 square degrees[1], we expect to find 1960 background sources. This compares well to the 1988 sources reported here, especially since further comparisons with catalogs at other wavelengths will most likely eliminate a few more sources.

[1]This represents the transparent region of the 843 MHz map in the direction of the LMC.

Table 1. Catalogue of the strongest 100 point sources in the field of the LMC at 1.4 GHz.

R.A. (J2000.0)	Dec. (J2000.0)	1.4 GHz (Jy)	843 MHz (Jy)	4.8 GHz (Jy)	8.6 GHz (Jy)	Spectral Index (α)
05:15:37.55	-67:21:28.1	1.477	2.27	0.5502	0.3548	–0.80
06:00:05.11	-70:38:34.0	0.4854	0.9202	–	–	–1.26
05:45:54.05	-64:53:34.8	0.4593	0.6791	–	–	–0.77
05:28:10.63	-65:03:52.8	0.4487	0.6484	–	–	–0.73
05:16:41.55	-71:49:05.3	0.3528	0.4766	0.1591	0.1144	–0.62
04:49:03.04	-70:52:04.6	0.3395	0.5204	0.1342	0.09757	–0.73
05:32:54.25	-72:31:54.7	0.3013	0.4891	–	–	–0.96
05:15:24.12	-65:58:41.1	0.2962	0.5108	0.07576	0.03643	–1.13
06:01:11.33	-70:36:08.3	0.2347	0.3005	–	–	–0.49
05:29:30.11	-72:45:28.6	0.2294	0.262	–	–	–0.26
05:16:37.78	-72:37:07.6	0.2224	0.323	–	–	–0.74
05:52:05.93	-68:14:41.3	0.2219	0.3716	0.06859	0.04017	–0.96
05:29:51.49	-67:49:33.2	0.2121	0.3251	–	0.04381	–0.86
05:44:27.14	-71:55:26.7	0.209	0.3359	0.05635	0.02649	–1.10
04:46:11.45	-72:05:11.7	0.1865	0.2755	–	–	–0.77
06:00:02.78	-71:42:06.2	0.1825	0.3193	–	–	–1.10
06:01:35.23	-69:55:45.2	0.1788	0.2933	–	–	–0.98
05:05:01.10	-66:45:18.2	0.1751	0.3338	0.04099	0.01991	–1.21
05:43:15.13	-68:06:52.0	0.1686	0.3298	0.03978	0.02182	–1.17
05:33:44.77	-72:16:24.4	0.1554	0.1701	–	–	–0.18
05:52:34.69	-66:40:41.6	0.1456	0.2902	–	–	–1.40
04:49:38.98	-65:05:02.0	0.1436	0.2409	–	–	–1.02
05:12:13.41	-72:32:47.4	0.1414	0.4356	–	–	–2.20
05:55:16.04	-67:20:51.1	0.1388	0.2429	–	–	–1.10
04:37:44.59	-72:27:50.0	0.1354	0.1933	–	–	–0.70
05:22:29.45	-70:37:55.0	0.1336	0.2112	0.04991	0.03348	–0.79
04:37:04.43	-71:48:19.6	0.1321	0.2365	–	–	–1.15
04:59:40.36	-69:55:03.7	0.1268	0.2037	0.03978	0.01401	–1.11
05:59:57.73	-71:20:36.0	0.1258	0.2581	–	–	–1.42
04:36:55.13	-69:30:33.1	0.1256	0.1943	–	–	–0.86
04:56:08.72	-70:14:33.8	0.1256	0.1903	0.1527	0.1294	–0.09
04:58:45.37	-72:50:24.7	0.1229	0.157	–	–	–0.48
05:44:38.33	-65:34:54.2	0.1201	0.218	–	–	–1.18
04:44:51.16	-67:46:36.2	0.1198	0.1967	–	–	–0.98
04:45:12.98	-65:47:07.9	0.1148	0.1737	–	–	–0.82
05:56:32.25	-71:29:06.0	0.1109	0.1804	0.03382	0.02142	–0.93
05:01:39.04	-66:25:25.4	0.1094	0.1045	0.04726	0.02491	–0.63
05:18:40.68	-65:36:14.8	0.1087	0.2151	–	–	–1.35
04:44:16.21	-68:42:11.8	0.1081	0.1571	–	–	–0.74
05:51:30.41	-69:16:31.0	0.1063	0.1736	0.03496	0.02236	–0.89
04:38:51.46	-68:22:58.5	0.1049	0.1641	–	–	–0.88
05:05:51.39	-69:51:17.4	0.1012	0.1487	0.05908	0.04966	–0.46
06:00:35.26	-70:12:18.4	0.09992	0.1434	–	–	–0.71
05:08:31.35	-67:06:16.4	0.09891	0.1666	0.03379	0.02128	–0.88
05:47:45.43	-67:45:06.2	0.0956	0.1548	0.05575	0.03996	–0.55
05:05:36.10	-70:05:14.8	0.09407	0.1571	0.02918	0.01682	–0.96
05:00:36.49	-72:06:23.5	0.09076	0.1406	0.03057	0.01716	–0.90
06:04:36.08	-71:02:23.6	0.09023	0.1273	–	–	–0.68
05:05:31.12	-65:55:15.7	0.08999	0.1409	0.03114	0.01756	–0.89
05:04:02.36	-72:03:45.5	0.08952	0.132	0.03226	0.01587	–0.90

Table 1. Catalogue of the strongest 100 point sources at 1.4 GHz (Continued).

R.A. (J2000.0)	Dec. (J2000.0)	1.4 GHz (Jy)	843 MHz (Jy)	4.8 GHz (Jy)	8.6 GHz (Jy)	Spectral Index (α)
05:05:39.65	-71:07:40.2	0.08849	0.138	0.03396	0.01994	–0.82
05:51:40.46	-68:43:09.5	0.08817	0.1457	0.02994	0.02247	–0.82
06:01:41.28	-72:38:32.5	0.0864	0.1225	–	–	–0.69
05:43:17.55	-66:26:55.6	0.08633	0.05501	0.09289	0.09518	0.19
04:40:08.66	-71:57:18.2	0.08249	0.1083	–	–	–0.54
04:53:37.89	-68:29:27.8	0.08134	0.1089	0.05749	0.05211	–0.31
04:43:18.45	-66:52:04.9	0.07911	0.1038	–	–	–0.54
05:21:27.37	-65:21:40.3	0.0778	0.126	–	–	–0.95
04:43:15.50	-66:02:48.5	0.07735	0.1349	–	–	–1.10
04:51:19.90	-72:21:07.4	0.07439	0.1242	–	–	–1.01
05:41:32.78	-67:06:15.7	0.07283	0.1241	0.0225	0.01355	–0.95
05:56:13.83	-69:23:31.7	0.07255	0.1179	–	–	–0.96
05:07:10.63	-71:44:04.8	0.07184	0.1414	0.009675	–	–1.56
05:36:36.32	-67:07:35.0	0.07069	0.1199	0.02514	–	–0.89
05:54:22.23	-67:54:50.8	0.06796	0.1138	–	–	–1.02
04:55:51.47	-69:02:10.4	0.06759	0.07879	–	0.09049	0.09
05:09:31.11	-67:31:16.0	0.06748	0.09819	0.02745	0.02201	–0.66
04:58:46.33	-67:05:38.5	0.06663	0.1061	0.02556	0.01788	–0.77
05:48:45.09	-65:53:49.6	0.06527	0.1097	0.01753	0.007036	–1.16
05:31:24.31	-65:16:34.0	0.06496	0.1088	–	–	–1.02
04:42:11.81	-68:10:03.9	0.0645	0.08777	–	–	–0.61
05:46:44.39	-66:41:14.2	0.06351	0.1038	0.02143	0.01385	–0.87
05:46:36.81	-72:05:54.8	0.06315	0.08177	0.03052	0.01494	–0.70
05:32:53.02	-67:09:42.0	0.06214	0.099	0.02105	0.0115	–0.92
05:07:35.95	-71:52:34.6	0.06178	0.1044	0.01883	0.01067	–0.98
05:19:28.01	-65:27:03.6	0.06149	0.1033	–	–	–1.02
05:49:01.77	-71:20:11.4	0.0607	0.09022	0.02295	0.01599	–0.75
05:07:17.62	-66:56:46.8	0.06061	0.1001	0.0193	0.01044	–0.96
04:53:33.06	-70:40:27.2	0.05927	0.1036	0.02467	0.01444	–0.82
05:55:01.85	-69:51:46.5	0.05892	0.1053	0.01232	–	–1.24
05:52:08.74	-70:31:30.2	0.05886	0.1049	0.01428	0.007234	–1.15
04:52:56.95	-65:28:13.7	0.05784	0.09686	–	–	–1.02
05:42:41.91	-66:02:57.5	0.0578	0.08926	0.02161	0.01046	–0.90
05:06:34.32	-67:56:43.7	0.05736	0.09587	0.01923	0.01353	–0.85
05:55:11.20	-69:47:51.4	0.05732	0.09435	0.01808	0.009905	–0.96
05:41:27.27	-67:39:52.5	0.05719	0.1076	0.01316	–	–1.21
05:02:27.66	-65:57:11.7	0.05633	0.09523	0.01758	0.007245	–1.07
05:14:07.63	-70:40:58.1	0.05559	0.09152	0.0139	0.004549	–1.26
05:21:27.62	-67:07:23.3	0.05531	0.08736	0.02026	0.01078	–0.88
05:56:53.22	-68:22:28.4	0.0546	0.1028	–	–	–1.25
05:20:22.04	-72:44:44.7	0.05448	0.09054	–	–	–1.00
05:12:30.38	-68:28:05.8	0.05408	0.07479	0.02454	0.01354	–0.72
05:10:27.20	-69:32:09.1	0.05404	0.08677	0.01762	0.01143	–0.88
05:18:13.26	-71:38:07.3	0.05333	0.07372	0.02262	0.01212	–0.76
05:46:59.84	-65:35:00.9	0.05322	0.09416	–	–	–1.12
05:51:05.04	-71:06:10.2	0.05313	0.09359	0.01655	0.01005	–0.96
05:10:57.94	-65:29:34.2	0.05311	0.0727	–	–	–0.62
06:03:47.39	-69:29:43.2	0.05301	0.08889	–	–	–1.02
04:58:37.24	-67:12:44.2	0.0523	0.9973	0.01316	0.003353	–1.39
05:04:09.69	-67:01:10.8	0.05176	0.1005	0.0117	0.00481	–1.29

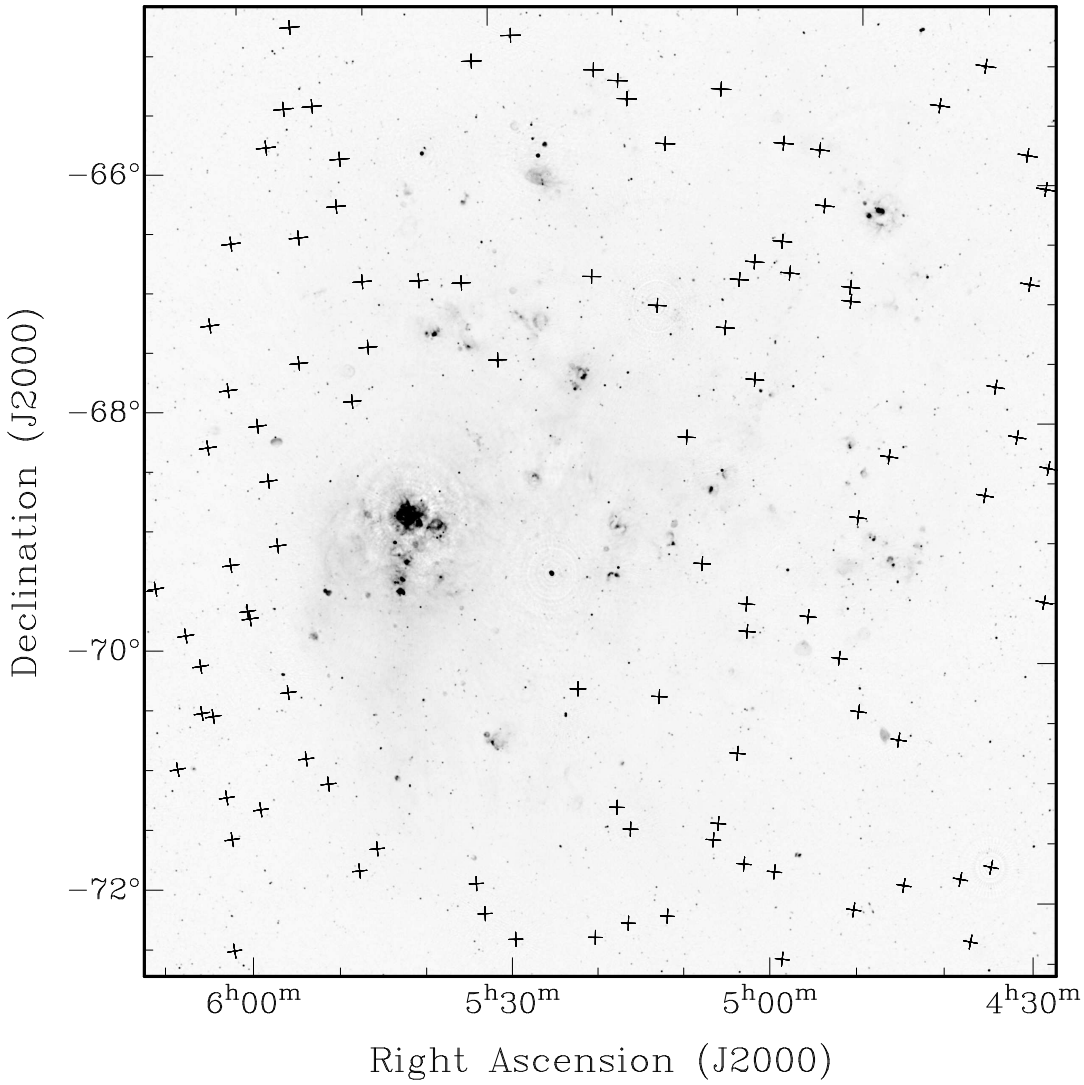

Fig. 2. *Strongest 100 radio point sources (crosses) overlying the 1.4 GHz radio image of the LMC. This image has a sensitivity of* ~ 0.3 *mJy beam*$^{-1}$ *and a resolution of 40″.*

4. CONCLUDING REMARKS AND SUMMARY

As the LMC is relatively transparent in radio, background radio galaxies and quasars are seen throughout except for the densest regions. Most likely, some of these objects may alternatively represent compact H II regions, microquasars, small SNRs and radio planetary nebulae. Comparisons with catalogues including these objects will be necessary before the completion of the final catalogue.

We present here the strongest 100 sources from a preliminary analysis of a 1.4 GHz ATCA/Parkes mosiac image created by Hughes et al. (2007). The refined list contains 1988 point objects having an average spectral index of –0.53; this list will be the subject of a future more comprehensive paper.

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100 НАЈСНАЖНИЈИХ ТАЧКАСТИХ РАДИО-ИЗВОРА У ВЕЛИКОМ МАГЕЛАНОВОМ ОБЛАКУ НА 1.4 GHz

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Стручни чланак

У овој студији представљамо 100 најснажнијих тачкастих радио-извора са наше нове мозаик слике Великог Магелановог Облака (ВМО) на фреквенцији од 1.4 GHz. Посматрања коришћена у овој студији сакупљена су у последњих 10 година на ATCA телескопу, а такође су допуњена са подацима добијеним са Паркс 64-м телескопа. Иницијална листа објеката у кругу од $10''$ на фреквенцијама од 0.843, 4.8 и 8.6 GHz састоји се од 2682 радио-извора. Елиминацијом нетачкастих објеката и артефаката шума дошло се до редукованог каталога од 1988 тачкастих радио-објеката. Већина ових објеката су највероватније позадински објекти, као што су квазари или активна галактичка језгра, која се виде кроз прозрачне делове ВМО. Веома мали проценат ових објеката представља објекте у самом ВМО као што су HII региони, млади остаци супернових и радио-планетарне маглине. Нашли смо да је средњи спектрални индекс за ових 100 најснажнијих радио-извора $\alpha = -0.53$. Такође представљамо и расподелу ових 100 објеката у пољу ВМО на 1.4 GHz.