with the Clouds. However, it may be worth while for optical astronomers to investigate the regions to the south of the Small Cloud where a cluster of sources with thermal-type spectral indices has been found.

Bok: Have you made a search for sources by methods comparable to those used for the Large and Small Clouds for one or more comparison fields well outside either Cloud, but still in the same part of the sky? It would be of great interest to have a survey of a similar region.

Mathewson: We have surveyed the region between the Clouds at 1410 and 408 Mc/s. An interesting point is that no "thermal" sources, i.e. sources with flat spectral indices, were found. Mr. Milne and Mr. Price have made a survey at 1410 and 408 Mc/s of the South Polar Cap region (south of $-76°$) and when their analysis has been completed it should be very interesting to compare the two surveys as you suggest.

Bolton: We have surveyed a large portion of the sky. North of the SMC and over to the LMC there is a larger concentration of nonthermal sources than anywhere else.

de Vaucouleurs: Have you checked whether a nonthermal source on the north side of the LMC coincides with the peculiar galaxy NGC 1947 which is optically reminiscent of NGC 1316 or NGC 5128?

Westerlund: If I may answer that question, I asked Dr. Mathewson to look for this object, but he did not detect it.

Hindman: I would like to point out that a large proportion of the thermal regions marked on Mathewson's map lie within the HI isophotes; thus it is possible that these are developing HII regions not yet identified optically.

Westerlund: Henize N49 in the LMC has [OI] $\lambda 6300$ in emission. This supports its classification as a possible supernova remnant.

Mathewson: It is interesting to note that Henize 63A which we have identified with a nonthermal radio source has [OI] in emission.

62. NEUTRAL HYDROGEN IN THE LARGE MAGELLANIC CLOUD

R. X. McGee and Janice A. Milton
CSIRO Radiophysics Laboratory, Sydney

I. Introduction

The neutral hydrogen gas in the Large Magellanic Cloud has been observed with the 14′.5 beam of the Parkes 210-foot telescope and the 48-channel H-line receiver. We wish to present a progress report based on computer reductions of integrated brightness and median radial velocities for some 4200 profiles. The survey is incomplete for some of the southern regions below dec. $-73°$. Assisting in the observations were our colleagues, M. W. Sinclair, C. J. Ohlston, and G. H. Trent and the staff at ANRAO, Parkes.

In the previous HI survey of the Large Cloud made with the same receiver and a 2°.2 aerial beam, the intensity contours were quite smooth and were centred on a fairly broad maximum near 30 Doradus. The blurring effect of including regions of 2 kpc diameter in an aerial beam of this size was seen in a consistent profile average halfwidth of 50 km/sec.

The present method of observation was to track the aerial along lines of constant declination at a rate in right ascension equivalent to 3′ of arc per min of time. Thus two H-line profiles were recorded per beamwidth — one profile in each 2 min of time.

The time constant was 1 min. Declination spacing was 12′ from $-65°$ to $-73°$ between R.A. 04^h30^m and 06^h10^m approximately and 6′ from $-68°30'$ to $-71°00'$ between R.A. 05^h30^m and 05^h55^m.

II. The HI Distribution

The enormous improvement in angular resolution can be appreciated from the details visible in the intensity contours of neutral hydrogen in Figure 1. The contours are of relative integrated brightness.

$$\text{Integrated brightness} \propto \int_0^\infty T(v)\,\mathrm{d}V$$

where $T(v)$ is the brightness temperature of the gas and V is the radial velocity.

The aerial temperature is accurately known but the brightness temperature determination is still under consideration and only an approximate figure can be placed on it at this time. Fifty units of integrated brightness $\approx 10^{20}$ H atom cm^{-2} in a line-of-sight column if the H-line profile is not saturated.

The HI radiation from the LMC lies in the radial velocity range $+240$ to $+310$ km/sec (with respect to the Sun) and is easily distinguished from the weak foreground galactic radiation near 0 km/sec.

The distribution is rather "clumpy" in appearance with a large main concentration and a number of outlying individual clouds. A general background of 0–50 units of relative integrated brightness extends over the whole galaxy.

(i) The concentration of HI in the region bound in R.A. coordinates by 05^h36^m and 05^h50^m approx., and in dec. by $-68°48'$ and $-71°24'$ approx., dominates the entire distribution.

The eastern part, enclosed by the dotted outline, is characterized by complex profiles. Two main peaks are in evidence at separations of 25 to 70 km/sec — the mean separation is 45 km/sec. A possible inference is the presence of an "arm" of HI extending outwards from the LMC plane.

In the north the gas in the direction of 30 Doradus ($05^h38\overset{m}{.}5$, $-69°06'$) is observed as single-peaked profiles of median radial velocity $+279$ km/sec. The integrated brightness contours have a deficiency of 20% of the surrounding intensity over a diameter of 12′ of arc around the position of the nebula.

(ii) Large complexes of gas stretch to the west and north of the main concentration. Seven of the more intense clouds are listed in Table 1. The concentration number, right ascension, declination, typical H-line profile half-width, radial velocity with respect to the Sun, dimensions in parsecs, average density, estimated mass, and coinciding HII regions as catalogued by Henize (1956)* are given.

The profiles are single-peaked except those in the south of Concentration No. 5. The average observed halfwidth of 25 km/sec is in the same range of values as those measured in galactic complexes as close to the Sun. However, the linear dimensions are enormous by comparison. The mean dimension is 800 pc. The estimated average density is 2 H atoms cm^{-3} or about half the density of complexes in the solar neighbourhood.

* Henize, K. G. (1956).—*Ap. J.* Suppl. **2**: 315–44.

Fig. 1.—Contours of relative integrated brightness of neutral hydrogen in the Large Magellanic Cloud.

https://doi.org/10.1017/S0074180900052748 Published online by Cambridge University Press

The northern region of Concentration No. 5 is of interest in view of the work reported by Bok (this volume, paper 68) on the young stellar association NGC 1929–37. When the maximum intensities of the single-peaked profiles are plotted, closed contours are formed of half-density width 30′ of arc or 500 pc centred exactly on 05^h22^m, $-68°00′$ — the position of the association. The maximum aerial temperature is 66 °K [$T_b \approx 100$ °K]. An estimate of the mass of the clouds is $3\times10^6 M_\odot$. After allowing for instrumental effects the dispersion σ is ±9 km/sec. The central median radial velocity is +295 km/sec.

TABLE 1

OUTER CONCENTRATIONS OF NEUTRAL HYDROGEN EMISSION IN THE LMC

No.	R.A. 1960 h m	Dec. 1960 deg min	Typical Halfwidth (km sec^{-1})	Median Radial Velocity (w.r.t. $\odot$) (km sec^{-1})	Linear Dimensions (at distance 57 kpc) (pc)	$\bar{n}_H$ (H atoms cm^{-3})	Estimated Mass $10^7 M_\odot$	Corresponding HII Region (Henize Catalogue)
1	04 50	−69 13	23	+270 N. +260 at max. +250 S.	1750 × 1050	0·7	3	N79, N77, N94
2	04 52	−67 00	26	+290	500 × 450	2·0	0·8	N4, 5
3	04 57	−66 24	30	+293	500 × 1000	2·4	2	N10
4	05 22·5	−69 48	20	+260	650 × 850	1·4	2	N120
5	05 22·5	−68 09	22 N. 53 S.	+300 N. +270 S.	850 × 900	1·4	3·4	N44
6	05 26·2	−66 12	25	+308	350 × 1250	2·5	1·7	N48
7	05 36	−66 00	28	+300	400 × 800	1·8	0·9	N61

(iii) The conspicuous optical bar of approx. 1° width about a line from 04^h55^m, $-68\frac{1}{2}°$ to 05^h45^m, $-70\frac{1}{2}°$ has scarcely any corresponding HI feature. Two gas concentrations in its vicinity, Concentration No. 4 and the very intense complex forming part of the main concentration at 05^h40^m, $-69°54′$, both coincide with what appear to be areas of optical absorption.

III. Comparison of HI, HII, and the Radio Continuum

Mathewson and Healey (this volume, paper 61) have drawn attention to the good agreement between HII regions and the sources of continuum radio emission in the Large Magellanic Cloud. Marked similarities exist between the HI and the 1410 Mc/s continuum distributions. Firstly, the boundary of an area including the main concentration of neutral hydrogen and Concentration Nos. 4 and 5 on the HI diagram corresponds approximately to the "6" contour which encloses the more intense

https://doi.org/10.1017/S0074180900052748 Published online by Cambridge University Press

contributions of continuum emission. Again, not only does each of the remaining outer concentrations of Table 1 and other less intense HI clouds correspond approximately in position to a continuum source but the resemblance in shape and orientation is most striking.

IV. Median Radial Velocities

A general agreement with previous results has been found, with values of +240 km/sec in the south-west regions increasing to +310 km/sec in the north-east.

Discussion

Bok: It is wonderful to have HII and HI regions mapped on a scale which is useful for optical work. This beautiful work has one striking aspect — it shows that the total mass of HI is very large, even for regions where OB stars prevail. The ratio of HI to HII is surprisingly high.

Oort: Isn't the large ratio common?

Bok: The point is that the HI masses for regions of comparable dimensions are about 100 times as great as the HII masses, even for regions rich in OB stars.

Kerr: The average dimensions of the outer HI concentrations are of the same order as those of the density fluctuations along galactic spiral arms, and also Dr. Weaver's regions of systematic velocity deviations in the Galaxy. Perhaps they are analogous formations, somewhat connected in the Galaxy, but appearing as individuals in the Clouds.

On the question of relative masses of neutral and ionized hydrogen in these concentrations, we do know that overall there is relatively much more neutral gas in the Clouds than in the Galaxy.

Aller: Are data available for HI clouds lying in the inner regions, i.e. closer to the bar?

McGee: The data presented are all that I have calculated to date.

Feast: A preliminary comparison shows good agreement between radial velocities from the new 21-cm observations and from the Radcliffe coudé spectra in the vicinity of the individual Henize HII regions.

Walraven: Considering the large amount of hydrogen in the Magellanic Clouds, it is remarkable that the dust content seems so low.

Bolton: The sizes of the Cloud regions are comparable to those in our Galaxy but the masses are much higher.

McGee: This is because the estimated densities are two or three times higher.

Ambartsumian: Is there any feature in the distribution of HI corresponding to the blue cluster NGC 1866?

McGee: I haven't made any comparisons except for Dr. Gascoigne's region around the 6^h15^m edge, where there is not much correspondence.

Ambartsumian: I understand that in the region of 30 Doradus you have observed the absorption in 21 cm. Do you think that your large feature is in front of the 30 Doradus complex or do you prefer to suppose that the 30 Doradus complex is situated inside this large HI feature?

McGee: Since only about 20% absorption is present, it appears possible that 30 Doradus is in the centre of the concentration.

Robinson: In relation to Dr. Ambartsumian's first question, we are embarking on a search for neutral hydrogen in blue clusters like NGC 1866. The only observations made so far are of the reddish cluster NGC 1466, well between the Clouds. This cluster contains no hydrogen, but a very dense HI cloud was found only 1° away.

Gascoigne: There are at least five blue globular clusters east of the main HI mass of the Large Cloud, well outside its sharp eastern ridge. There is no obvious nearby concentration of hydrogen with which these clusters can be associated. It will be of interest to see if the clusters themselves show any hydrogen content.

Burke: The remark was made that the LMC concentrations appeared comparable to those in the Galaxy. In McGee's study of the cloud complexes in our own Galazy, he presented two hierachies of complexes, one ranging around 100–200 pc, and the second being 1500 pc typically. The list of sizes presented here for the LMC looks more or less like a geometric mean of these values. I don't think one can say yet that these hydrogen associations are comparable.

McGee: Some clouds in the Galaxy at $R_0 = 9$–10 kpc are of the same general order in the z dimension but are extended in an approximately 2 to 1 ratio along the arms. The analogy is not complete.

Westerhout: Indeed, we should congratulate Mr. McGee and collaborators on these fine observations. But I do not agree with Dr. Bok that the scale of the radio maps is already useful for comparison with optical data. The resolving power is still of the order of 300 pc. If we see regions 300–800 pc in diameter, we do not know at all what their composition is. A fair proportion of the regions agrees not only in position, but also in size with the HII regions. One cannot of course have neutral and ionized hydrogen in the same place. Therefore, we might think of a model where, as in our Galaxy, the hydrogen in such large aggregates occurs in the form of rather dense knots with empty regions in between. In such a region there are apparently OB stars, which ionize some of the hydrogen knots. But it will take a resolution of 1 minute of arc or so before we can solve the question of the distribution of the gas over HI and HII regions.

The interesting new information in this paper is the breaking up of the formerly smooth hydrogen distribution into large separate regions. But let us not call these large regions clouds! They most likely form a very complicated structure.

63. PHOTOELECTRIC SPECTROPHOTOMETRY OF EMISSION NEBULOSITIES IN THE MAGELLANIC CLOUDS

H. R. DICKEL, University of Michigan; L. H. ALLER,* University of California, Los Angeles; D. J. FAULKNER, Mount Stromlo Observatory

I. Emission Nebulosities in the Large Magellanic Cloud

Photometric measurements of the emission nebulosities in the LMC are not numerous. Doherty, Henize, and Aller (1956) microphotometered both widened and unwidened objective-prism photographs covering a narrow wavelength range near $H\alpha$ to obtain cross-sectional "intensity profiles" for certain nebulosities in the Large Cloud. These intensities were converted to surface brightnesses by tracing the widened spectra of stars of known magnitude and colour and using the method of Ambartsumian (1933). Peak intensities for each scan across a nebulosity are given in erg cm^{-2} sec^{-1} steradian^{-1}.

Many of the emission nebulosities in the LMC are filamentary in structure. The classic example is 30 Doradus but other objects such as Henize 144, 159, and 160 show a pronounced fine structure. (See Figs. 1, 2, 3, and 4.) This inhomogeneity must be taken into account when we convert surface brightness into electron densities. Densities in the filaments may appreciably exceed those found from averages taken over the volume occupied by the nebula. Spectrophotometry of the emission nebulosities in the LMC was undertaken mostly at Mount Bingar with the Michigan photoelectric scanner. Throughout, we used the D slots which sufficed to

* Senior National Science Foundation (USA) post-doctoral Fellow at Australian National University, 1960–61.