RADIAL VELOCITIES ASSOCIATED WITH SELECTED EMISSION NEBULAE IN THE SMALL MAGELLANIC CLOUD

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Summary

Radial velocities for nine bright emission nebulae in the bar of the Small Cloud of Magellan are presented together with the corresponding profiles of 21-cm line emission from neutral hydrogen.

Introduction

A study of the radial velocities of certain bright emission nebulosities in the Small Magellanic Cloud has been undertaken at Mount Stromlo Observatory, using the new Nebular Spectrograph attached to the 74-in. reflector. This program is being carried out in conjunction with a 21-cm hydrogen line investigation of the same regions by J. V. Hindman of the Radiophysics Laboratory of CSIRO with the 210-ft radio telescope of the Australian National Radio Astronomy Observatory, Parkes, N.S.W. Both the radio and the optical investigations are still at the preliminary stage, so that in the present paper no attempt is made to analyse the rather complex picture which seems to be emerging. We merely reproduce the 21-cm line profiles for selected regions of nebulosity, with the optical radial velocities superposed. The regions chosen are shown on Plate 1.

Although a number of velocity measures of emission nebulae are available for the Large Magellanic Cloud, the only published velocity in the Small Cloud is that of IC 1644 (Moore 1932). Two nebulosities, N 9 and N 81 (IC 1644) in Henize's catalogue of Hα emission regions in the Magellanic Clouds (Henize 1956) have been measured by Feast (1964).

Equipment and Measurements

The 21-cm measurements were made with a 48-channel line receiver in conjunction with the Parkes 210-ft radio telescope, the angular resolution of which is about 14′. The receiver frequency resolution is equivalent to a velocity resolution of 7 km/s. The H I profiles are reproduced in Figure 2. The receiver time-constant was approximately 1 min and the noise fluctuations have been further reduced by averaging six observed profiles at each position. This gives a final r.m.s. fluctuation of less than $\pm\frac{1}{2}$°K. All of the profiles concerned exhibit the multiple peaked structure reported earlier by Hindman (1964).

Between August and December 1963, 17 spectrograms were obtained at Mount Stromlo Observatory by Bok, Gollnow, and Mowat, using a 3-in. $f/1\cdot2$ Schmidt camera on the Nebular Spectrograph. With a grating of 400 grooves/mm

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blazed for the second-order blue region, the dispersion was 140 Å/mm over the full spectral range. All spectra were taken with a slit width of 100 μ, which is reduced to about 20 μ in the focal plane. This slit width corresponds to approximately 2.″25 and the slit length used (2 mm) to 45″. Figure 1 shows a sample spectrum. In the

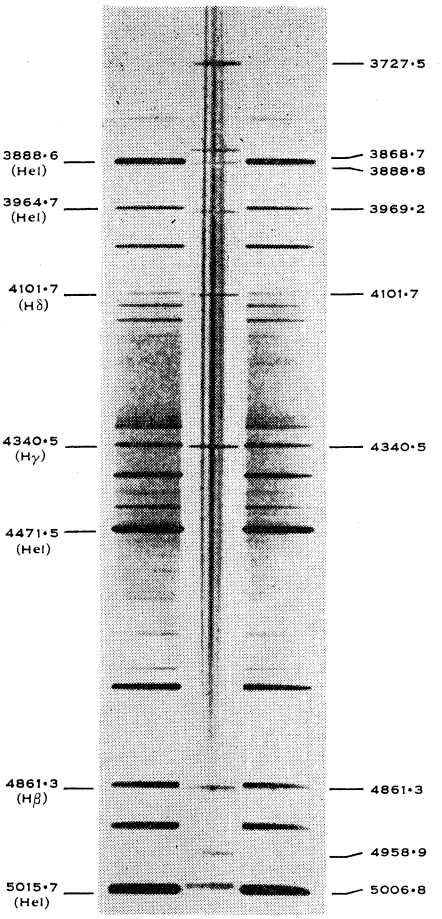

Fig. 1.—Spectrum of the centre of N 66. The three continuous spectra across the emission lines are produced by stars. For the comparison spectra a helium tube, also containing hydrogen, was used.

spectral region used (λ 3727–5007 Å), the following lines were measurable although not on all plates:

3727·535 Å	O II	4101·737	Hδ
3797·900	H_{10}	4340·468	Hγ
3835·386	H_9	4363·21	O III
3868·74	Ne III	4471·507	He I
3888·849	He I, Hζ	4861·332	Hβ
3969·22	Ne III, Hε		

The emission regions were selected from Henize's catalogue of emission nebulae in the Magellanic Clouds (Henize 1956). We chose nebulae of greatest relative brightness on Henize's intensity scale and have attempted to obtain a fairly even distribution of objects along the bar of the Small Cloud (see Plate 1). Spectra of nebulae in the wing of the Small Cloud are being taken at Mount Stromlo by B. E. Westerlund.

Since the Nebular Spectrograph was being used for the first time, it was decided to obtain spectra of an emission nebula for which published velocities were available, in order to compare the Stromlo radial velocities with velocities measured elsewhere. The region "Feast AB" in 30 Doradus was chosen from Feast's paper on the 30

TABLE 1

RADIAL VELOCITIES OBTAINED AT MOUNT STROMLO

Emission Nebula	R.A. 1963 h	m	Dec. °	′	No. of Spectra	Quality of Spectrum	Lines	Velocity (km/s)
N 9	00	42·1	−73	15	2	fair	7	+165±12
						good	11	+137±4
N 12A	00	45·2	−73	19	2	fair	6	+118±15
						fair	7	+116±3
N 12B	00	44·1	−73	17	2	faint	4	+101±8
						rather poor	6	+78±11
N 25	00	46·9	−73	27	1	weak	5	+104±9
N 36	00	49·3	−73	05	1	rather weak	5	+120±7
N 50	00	51·6	−72	51	2	fair	4	+182±8
						weak	3	+153±3
N 63	00	57·0	−72	51	2	good	6	+150±4
						rather poor	5	+156±6
N 64A	00	57·2	−72	52	2	good	7	+186±3
						good	7	+193±3
N 66	00	58·0	−72	23	3	good	7	+159±7
						good	8	+165±6
						good	7	+152±8
Feast AB	05	39·7	−69	00	4	good	13	+256±5
						good	13	+263±4
						good	13	+247±5
						good	13	+249±3

Doradus nebula (Feast 1961), the reason being that spectrograms of this particular nebulosity had been obtained at Radcliffe Observatory with three different cameras and the final velocity was therefore given a high weight by Feast. Also "Feast AB" is a narrow ribbon of nebulosity, making the orientation and positioning of the slit of the Nebular Spectrograph both easy and reproducible. Four spectrograms of the region were obtained at Mount Stromlo on three different nights, yielding the following radial velocities (corrected to the Sun) together with their probable errors: +256±5, +263±4, +247±5, +249±3 km/s. The mean of these observations, +254 km/s, is in good agreement with Feast's mean velocity of +249 km/s.

The spectrograms were measured with an Abbe comparator fitted with a photoelectric setting device (Gollnow 1962). The measuring accuracy of this system is, for one setting on a spectral line, of the order of ± 5 km/s at the dispersion used.

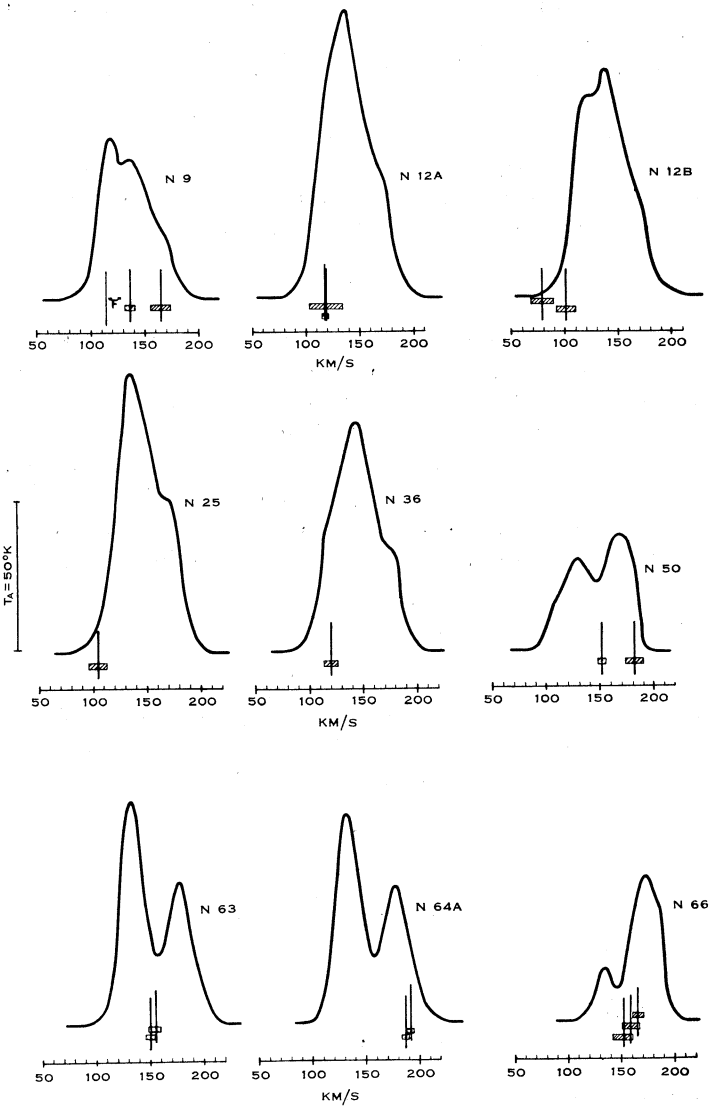

Fig. 2.—Neutral hydrogen profiles measured in the directions of nine of the Henize emission regions with the 210-ft telescope and 48-channel receiver at ANRAO. The optical radial velocities obtained at Mount Stromlo Observatory are represented by vertical lines on each profile. Horizontal shading indicates the probable error of the optical measurements. The vertical line marked "F" on the N 9 profile is the Feast velocity for this nebula.

We note that for our $f/1 \cdot 2$ camera, the resolution on the spectrum is of the order of $8\,\mu$, which means that the spectral features can be studied with a resolution of

approximately 80 km/s. This compares rather unfavourably with the 7 km/s resolution associated with the neutral hydrogen survey. An $f/2 \cdot 8$ Schmidt camera has recently arrived at Mount Stromlo Observatory and the higher dispersion available (approximately 50 Å/mm) should increase the accuracy and the resolution of the radial velocity measurements. During the next Magellanic Cloud season, we plan to use both the $f/1 \cdot 2$ and the $f/2 \cdot 8$ cameras on the four nebulosity complexes of greatest interest, viz., N 12A and 12B and N 9; N 63 and 64A; N 66; N 71 and 78. It will be of special interest to obtain radial velocities from the spectra of supergiant stars embedded in these nebulae and to study the velocities from the interstellar lines observed in some of these stars. The new material should also permit us to undertake limited studies of relative abundances of the lighter elements.

Results

Table 1 gives the radial velocities obtained at Mount Stromlo Observatory by Bok, Gollnow, and Mowat. The smoothed H I profiles obtained by Hindman are shown in Figure 2, which also shows the optical velocities with their associated probable errors. For N 9 the radial velocity found by Feast is also indicated. The radio profile represents the distribution of velocities of all the gas in the line of sight and this may extend over a distance of several kiloparsecs; on the other hand, the optical velocities refer to a limited region usually less than 50 pc in diameter. It is to be expected that the optical mean velocity will fall within the radio profile range but a detailed comparison is not possible until the dispersion of velocities in the emission regions is known.

Conclusions

The present results show the expected general agreement between optical and radio velocities and with further study it should be possible to associate the various emission regions with particular concentrations of H I, as represented by the various velocity peaks in the neutral gas profile.

Acknowledgment

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RADIAL VELOCITIES OF EMISSION NEBULAE

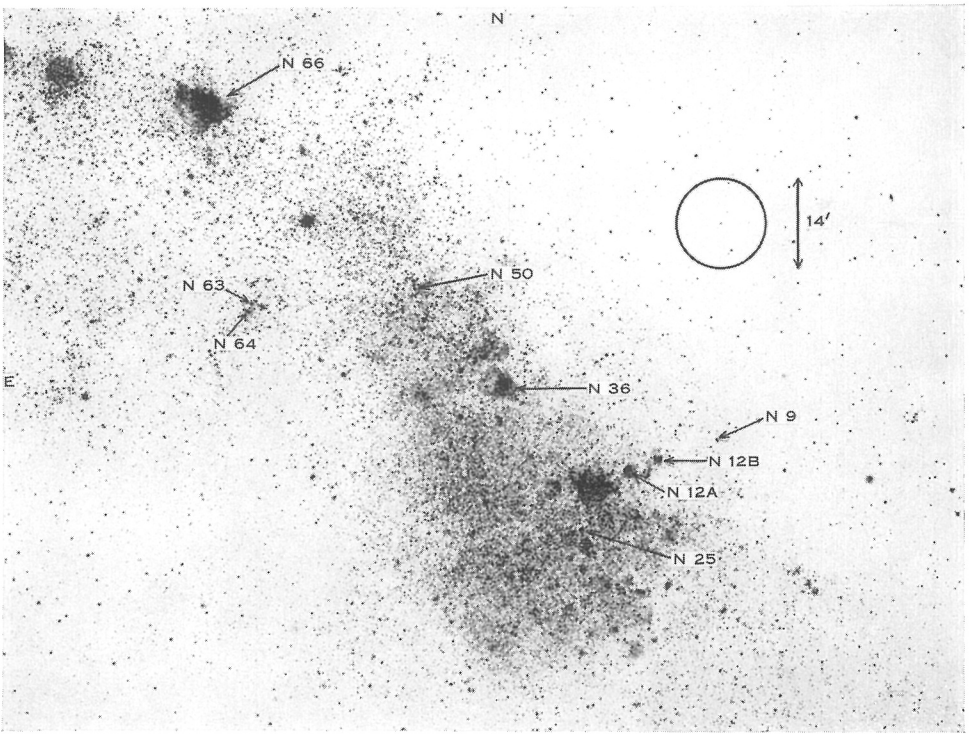

Chart of the Small Magellanic Cloud showing the nebulae for which spectra have been obtained at Mount Stromlo Observatory. Coordinates of the centre, $00^{h}\ 49^{m}.9$; $-73°05'$ (1963). Size of the radio beam, 14′ is indicated on the figure. Photograph taken by B. E. Westerlund with the Uppsala Schmidt telescope, Mount Stromlo.