III. THE MAGELLANIC CLOUDS

(A) INTRODUCTION

The Magellanic Clouds offer a unique opportunity to study fully resolved stellar systems at optical and radio wave-lengths. Optically, with the largest southern telescopes available it is possible to reach absolute magnitudes $+1$ to $+2$ by direct photography and absolute magnitudes -6 to -4 spectroscopically. The greatest value of the Clouds to galactic research is the opportunity to calibrate the absolute magnitudes of luminous objects within the Galaxy. Uncertainty regarding location in depth within the Clouds adds a random error of about $\pm 0{\cdot}13$ m, i.e. considerably less than the uncertainty of the distance modulus of the Clouds themselves.

In addition, study of the brightest stars may be useful both for calibrating the extra-galactic distance scale, and for picking out, far more easily than in the Galaxy, 'super-super-giants' with absolute magnitudes brighter than -7.

In radio work the chief interest is in the Clouds as galaxies. Data on large-scale properties such as size, luminosity, mass and mass-distribution are required.

An admirable survey of work on the Clouds with bibliography up to about 1954 is contained in the compilation of Buscombe, Gascoigne and de Vaucouleurs [1].

(B) OPTICAL PROGRAMMES

(1) *Photo-electric photometry*

Work on the establishment of sequences in the U-B-V system and on magnitudes of classical Cepheids is being continued at Canberra. The presence of very blue and very red stars in the Clouds indicates the desirability for a wide range of colours in the standard stars chosen for sequences. New sequences, down to magnitudes 18 and 19, in the Small Cloud will become available from the work of H. C. Arp at the Cape and Radcliffe Observatories. Studies of population characteristics, particularly in the Small Cloud, are also under way (H. C. Arp and Mt Stromlo). Three-colour photometry of stars in the general field and in associations is being carried out at the Radcliffe Observatory. NGC 330 is being observed at Mt Stromlo, NGC 2004 and the neighbourhood of S Dor at the Radcliffe Observatory.

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(2) *Spectroscopy*

Emission objects discovered on objective prism surveys have been listed by Henize [2] and by Lindsay [3].

Spectra with dispersions of 86 and 49 Å/mm of the brightest stars in both Clouds are being obtained in considerable numbers at the Radcliffe Observatory. Radial velocities of these stars discussed by Feast, Thackeray and Wesselink [4] have confirmed the rotation of the Large Cloud indicated by the radio work and also indicate a moderately large velocity dispersion of the order of 20 km/sec. According to Feast [5] and Feast and Thackeray [6] there are several bright Cepheids and a few red super-super-giants which have been shown to be among the brightest members of the Large Cloud. The H-R diagram of the brightest stars slopes upwards to the right among the B to A types in a manner similar to the apparent evolution tracks of young massive stars in galactic clusters.

Low dispersion, 100–400 Å/mm, spectroscopy has also begun at Mt Stromlo. In particular, emission objects are being studied by G. de Vaucouleurs.

The presence of planetary nebulae in the Small Cloud, with considerable spread in absolute magnitude, has been demonstrated by the spectroscopic work of Lindsay [3] and by photography in selected wave-lengths by Koelbloed [7].

(c) FUTURE NEEDS

Programmes on which further efforts are especially desirable are listed below, in which the first four items refer to the largest telescopes available, while the others would be suitable to smaller telescopes:

(*a*) Accurate photometry of classical Cepheids and RR Lyrae variables;

(*b*) Spectral classification and radial velocities of the brightest stars;

(*c*) Colour-magnitude arrays of associations and globular clusters (including radial velocities where possible);

(*d*) Searches for long-period, RV Tau and RR Lyrae variables in the general field;

(*e*) Objective prism surveys for classification and radial velocities, especially in the Small Cloud;

(*f*) Searches for bright variables (brighter than 13th magnitude);

(*g*) Identification charts.

It may be added that any optical researches designed to improve the value of the inclination of the main mass of both Clouds to the line of sight would be of special value in the rotational analyses.

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The photometry of Cepheid variables in both Clouds is of such fundamental importance that it will probably be undertaken at the Radcliffe Observatory and at the Leiden Southern Station (with the new 36-inch light-collector) in addition to Mt Stromlo. Co-ordination of efforts to avoid an undesirable degree of overlap is necessary.

Many more radial velocities of individual stars are required for a satisfactory comparison of the rotation of the Large Cloud with the radio results on the neutral hydrogen gas.

For a complete census of the brightest stars in both Clouds an objective-prism survey enabling members to be picked out by radial velocities is most urgent. In the discussion, the possibility of Dr Fehrenbach bringing his 40-cm objective prism to the southern hemisphere for this purpose was raised. In the Large Cloud the census of bright *blue* stars is reasonably complete because practically all stars classified in the Henry Draper Extension as O, B or Con are members. The census of bright members of type later than A is probably very incomplete.

The fact that the Henry Draper Extension does not include the Small Cloud means that here our census of bright members is at present restricted to eleven stars in the H.D. Catalogue and to the emission objects listed by Henize [2] and Lindsay [3]. Spectral classification from objective prism spectra extending to a fainter limit than the H.D. Extension is a most urgent problem in the Small Cloud and could also be profitably carried out in the Large Cloud.

The few known red 'super-super-giants' apparently show a tendency to variation in light, probably irregular in cycles lasting months or years. More might be discovered, with quite small telescopes, with exposures suited to the magnitude range 10–13.

Studies of colour-magnitude arrays of associations and globular clusters in the Clouds are of paramount importance to current ideas of stellar evolution. The wealth of such objects—and their bewildering variety may not have been fully appreciated—implies that it should be easy for those engaged in such work to co-ordinate their programmes without overlap. Radial velocities of the globular clusters are also urgently required.

All workers on the Clouds with large telescopes are familiar with the difficulty of identifying individual stars in rich fields, more especially when only X, Y co-ordinates are available, as with the Harvard Cepheid variables. Through the co-operation of Professor Malmquist and the Canberra workers a number of charts of both Clouds, marked with X, Y co-ordinates, obtained with the Uppsala Schmidt at Canberra are likely to become available. Such identification charts will be of immense aid to

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many workers. It may be mentioned that the extensions to the Clouds shown by the radio work will probably imply an eventual extension of the Harvard *X, Y* system including negative values.

(D) RADIO WORK

The work of the Sydney radio astronomers is yielding results of the greatest importance to our understanding of the two Magellanic Clouds. So far, surveys of the Clouds have been done for the 21-cm line by Kerr, Hindman and Robinson [8] and by Kerr and de Vaucouleurs [9, 10]; at 3·5 m in the continuum by Mills [11], and one has been done at 15 m by Shain [12]. It is planned to repeat the 21-cm survey with increased resolution in the near future.

The 21-cm observations have shown that there is a large envelope of neutral hydrogen around each Cloud; the rotation of each system has been demonstrated, confirming the view that the Clouds are flattened and tilted systems; but as previously mentioned improved values of the tilt are required. Further, from the 21-cm observations the masses and mass distribution have been estimated from the rotational characteristics and the gas is found to be probably the least flattened component of each system; the rotational velocity appears to vary with distance from the equatorial plane according to both optical and 21-cm observations.

The main 21-cm problems for the future are as follows:

(*a*) Study of the inner parts with higher angular resolution, to trace structural details;

(*b*) Study of the outer parts with higher sensitivity, including a search for a possible link between the Clouds and between the Clouds and the Galaxy;

(*c*) More detailed comparison of radio and optical velocities;

(*d*) Study of the variation of velocity dispersion across each system, where it may be simpler to separate such variation from other effects than it is in the Galaxy;

(*e*) Extension of the theory for the case of a system where the energy is fairly equally split between random and rotational motion.

In continuum observations, one difficulty is in the separation of the Clouds from the galactic foreground. In this case, observations of the Clouds may help to solve the problem of the origin of the radio continuum in the Galaxy, through comparing the distribution of the radiation over the Clouds with the distributions of various known classes of objects.

According to Mills [11] at 3·5 m, there is little or no sign of a corona

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round the Clouds, and the systems are underluminous in a radio sense, by comparison with galaxies of other types. The ratio of radio to optical luminosity is about the same for the two Clouds.

De Vaucouleurs [13] has made a comparison between various distributions. He finds that the distribution of the 3·5-m radiation resembles those of the interstellar gas and the number of bright stars rather than that of the luminosity; according to Mills [14] it thus appears to be related to population I.

A portion of the LMC has so far been studied at 15 m. by Shain [12]. The most striking feature is the absorption dip in the vicinity of 30 Doradus.

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