Cloud—at least in the region investigated—the most frequent period is $3^{d}.6$, and no variables appear with periods less than 1^{d}. The only one which was found is clearly a galactic object.

This result is confirmed by comparing Figures 4 and 5. In Figure 4, concerning the Small Cloud, the first vertical line of each group represents the observed number of variables from pairs with intervals between 80^{m} and 7^{h}; the second line represents stars observed in pairs with intervals between 1^{d} and 2^{d} and not observed in preceding pairs; the third line corresponds to stars observed only in pairs with intervals of 20 or more days. Figure 5 is similar except that it refers to stars of the Large Magellanic Cloud. The first group of lines contains only variables found at Córdoba, the second group variables found at Córdoba and at the Harvard Observatory, the third Harvard variables with known periods, and the fourth Harvard and Córdoba variables with known periods.

One sees that the new variables have altered considerably the distribution of periods for the Small Cloud, but not for the Large. In Figure 5 the fifth group of lines illustrates the colours of Córdoba and the sixth those of the Harvard variables. The proportion of white variables is 65%, of the yellow ones 16%, and of the red ones 19%. Apparently the region is somewhat obscured, but only partially, and it does not seem to us that this can have an influence upon the distribution of the periods.

References

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Discussion

Heard: Can the speaker comment on the apparent scarcity of eclipsing variables which he has noted in the Large Cloud?

Landi Dessy: In the SMC we found a number of eclipsing variables around 17th magnitude. Here in the LMC we have found none.

77. REVIEW OF MAGELLANIC CLOUD PROBLEMS

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It must be obvious to all of us that no such Symposium on the Magellanic Clouds as we have been holding over the past few days would have been possible 10 years ago. At that time, radio work on the Clouds had scarcely begun. de Vaucouleurs, Buscombe, and Gascoigne were preparing their summary on Cloud problems as a preliminary to work with the Canberra 74-inch reflector, while the first results of work with the Radcliffe reflector were slowly beginning to emerge. Even five years ago, such a Symposium could scarcely have been fruitful, but the interest of many northern astronomers in the Clouds had certainly been excited. Now there are far more instruments and astronomers concentrated on Magellanic Cloud problems than ever before and the string of papers presented to this Symposium with lively discussions gives striking evidence of their activity.

https://doi.org/10.1017/S007418090005289X Published online by Cambridge University Press

On the optical side, the successful application of the Fehrenbach technique of objective prism radial velocities and of the Walravens' technique of multi-colour photometry commands special admiration.

In this review of Magellanic Cloud problems I shall attempt to strike a compromise between summarizing salient points of the papers that have been presented at this Symposium and reviewing some of the known facts, while trying to emphasize the gaps in our knowledge of the Clouds. We certainly need to digest the new material for some time in order to see clearly the most fruitful programs that can be planned for the future.

I intend to divide the topics up into four main groups:

(1) The Clouds as galaxies;

(2) the gaseous substratum;

(3) the larger subunits, associations, and clusters;

(4) the general field of stars.

I. The Clouds as Galaxies

One of the most striking discoveries concerning the Clouds with radio telescopes has been the bridge connecting the two Clouds. The bridge is quite clear on the recent isophotic maps of the 21-cm line presented here, despite the appearance of many discrete sources with the 210-foot Parkes telescope. The steep precipices of the contours on the preceding side of the SMC and the following side of the LMC strengthen the idea that we are dealing with a double system isolated from the Galaxy. However, the possible existence of a weak bridge connecting the Galaxy and the LMC still requires further investigation; the answer to this problem seems more likely to be provided by the radio than the optical astronomers.

The chief characteristic of both Clouds is their irregularity. Each contains a main bar (visible to the naked eye) with no pronounced nucleus. They are the standard irregular galaxies, and it was interesting to me to hear that Arp groups as many as 66% of external galaxies as similar irregulars although they only provide 0·3% by mass. There have been some specific suggestions for the actual location of the nucleus in each Cloud and it is certainly rather surprising that in the LMC the centre of radio and optical rotation, as well as the centroid of HI emission, seem to be displaced a full degree from the centroid of light within the main bar (cf. NGC 55 rotation by Robinson and de Vaucouleurs). However, is there really any reason to suppose that either Cloud must have a specific nucleus? To an external observer, they must appear as small satellites in a system whose nucleus is at the centre of the Galaxy! So far as we can tell, the gravitational force due to the Galaxy at the distance of the Clouds is closely comparable with the force due to either Cloud.

One simplifying idea has become increasingly acceptable in recent years and particularly at this Symposium. This is de Vaucouleurs' inclined plane system, especially with regard to the LMC. de Vaucouleurs suggested this model as a result of his faint-star counts; the direction of his major axis has been confirmed, at least roughly, for the LMC by the rotational velocity-gradient from both radio and optical observations. The velocity dispersion of the gas (measured by Feast, and by the Parkes observers with improved resolution) as well as for the stars (measured by Radcliffe observers), is considerably less than the velocity of rotation, thus implying a flattened system. Finally, de Vaucouleurs' classification of a flattened galaxy like NGC 55 as an irregular magellanic system seen edge-on has received support from Mathewson's measures of the ratio of radio to optical emission in normal galaxies and magellanic-type galaxies.

However, accepting the LMC as an inclined plane system, the value of the inclination remains extremely uncertain. de Vaucouleurs has given values ranging from 15 to 27° and Westerlund mentioned a value as large as 45° in his outer survey of LMC clusters. The value of the mass of the LMC is proportional to $\mathrm{cosec}^2\, i$. We are thus left with a corresponding uncertainty in mass of 7 to 1 due to uncertainty in i alone. The mass is also uncertain by a factor equal to the uncertainty in the distance. A still smaller uncertainty arises from lack of knowledge of the effect of translation in the plane of the sky upon the rotation curve. A concerted attack on the problem of accurate measurement of i for both Clouds would seem to be just as important as continued efforts to improve the accuracy of our knowledge of their distances.

The motion of the Clouds in relation to one another and the Galaxy cannot be studied with profit unless one knows the Sun's circular motion in the Galaxy far more accurately than at present.

Finally, while dealing with the Clouds as galaxies, we must consider the all-important problem of distance so that it is necessary to digress temporarily into the domain of individual stars. We have had so much faith in the period–luminosity law of cepheids that it was a shock when the Herstmonceux group reported a considerable difference in the relationship observed in the two Clouds. Dr. Gascoigne's paper has perhaps restored some confidence that the difference may not be as large as feared. The difference as reported referred to the relatively few bright cepheids and it ought to be easy to check that by observing as many of the bright cepheids as possible. At the faint end photometry is difficult, as Gascoigne rightly emphasized, and we also need independent observations of many cepheids, preferably of both Clouds by the same observer. Accurate photometry of cepheids in various parts of both Clouds clearly remains a top priority program for optical astronomers.

The RR Lyrae variables are still uncomfortably faint objects for all existing telescopes, and there are still residual doubts as to their true absolute magnitudes and to their constancy in $\overline{M}$ from cluster to cluster. The brighter group of Dessy-Wesselink variables remains a mysterious phenomenon about which we need to know much more.

The Walravens' photometry in five colours offers very great possibilities for determining luminosities of Cloud stars — if the technique can be pushed to 15th or 16th magnitude we enter the region in which we have comparable galactic stars whose luminosities are relatively well known. It seems possible too that the equivalent widths of Balmer lines in A0 stars at 15th magnitude should also be measurable in the near future.

Novae at maximum have been used as a distance indicator, and a regular search at more than one observatory needs to be organized. No nova has been discovered in the Clouds for 11 years but it is quite possible that they are occurring at the rate of about one per annum in the Magellanic Cloud system.

Fitting of colour-magnitude arrays in clusters, such as those reported by Dr. Gascoigne, is a currently popular technique, but as with the cepheids involves difficulties of faint photometry in crowded fields.

All the above distance indicators involve some allowance for absorption. Fortunately this correction is small for the Clouds, but if we want a distance modulus correct to $0 \cdot 1$ *m* we must make some allowance for absorption both within the Clouds and within the galactic foreground. The purely geometrical method of measuring angular diameters of HII rings is an attractive one, especially if it can be supplemented by measures of electron densities. However, the general irregularities of HII regions in both Clouds perhaps renders this too blunt a tool, like the diameters of clusters and brightest stars in clusters.

II. The Gaseous Substratum

The high resolving power of the Parkes telescope has revealed a bewildering mass of new material on the detailed distribution of neutral hydrogen. The correlation of optical and radio observations ought to be much more easily within our grasp compared with the corresponding identifications within the Galaxy. In the Galaxy optical astronomers are in general confined to the solar neighbourhood by heavy absorption, even though Courtès' combination of narrow Hα band-pass and small focal ratio has achieved remarkable success in apparently penetrating close to the galactic nucleus. In both Clouds the absorption problem is very small, and in the Large Cloud, apparently seen as an open system with little extension in depth, we can identify many isolated HI regions in McGee's survey with optical HII regions. Despite this general correlation, it seems likely that we shall be faced for some time with many problems of detail. For instance, some of the 21-cm radiation may come from galactic hydrogen at high latitude. This is perhaps a greater danger in the SMC than in the LMC. Furthermore, in the optical picture Aller has presented some exceedingly complex contours of the HII regions. Direct photographs show only too clearly the wide range of patterns of spherical masses, irregular wisps, and small, almost pinpoint, Henize nebulae. Many of the gaseous clouds certainly appear to be gigantic on the galactic scale, with 30 Doradus vying with all as a superassociation.

Unfortunately, the 21-cm picture of the SMC is extraordinarily confused. This is in strange contrast to the much more uniform optical picture of the Small Cloud than the Large. Hindman has suggested the presence of some five or six discrete gaseous bodies with two of them being responsible for the double peaks in the 21-cm profile, separated by some 40 km/sec. McGee reported a similar double peak covering a wide area of intense emission in the region east and south of 30 Doradus in the Large Cloud. Now it may seem reasonable to suppose that neutral hydrogen is moving outwards from 30 Doradus by $+20$ and -20 km/sec on the periphery of a central region of ionized hydrogen. But the velocity dispersion in the central region found by Feast and Courtès is remarkably small for such a model. In the Small Cloud we have no phenomenon comparable with 30 Doradus; it seems rather unlikely that we have such vast expanding masses around relatively insignificant optical objects, and we may have to look for some other origin for the double peaks. Arp's plea for observations of eddy sizes and energy in eddy spectra also calls for concerted efforts by optical and radio astronomers. Comparison of radio and optical velocities in nebulous regions should certainly be prosecuted.

Mathewson's discrete sources at 1410 and 408 Mc/s also show some correlation with observed HII regions, particularly at 30 Doradus. Here it appeared in the discussion that care will have to be taken to distinguish between true Cloud sources and background radio sources. Clearly both Clouds provide a foreground very rich in peculiar optical objects and some chance coincidences are bound to occur. The closest cooperation between radio and optical astronomers will be needed, but nevertheless the field is a rich one for gaining a better insight into the nature of various types of radio sources, and the origin of thermal and nonthermal components.

Mathewson also reported some polarization at 408 Mc/s, possibly connected with the bar of the LMC, but pointed out that this might well arise in the galactic foreground, like the polarization at high galactic latitude reported earlier in this Symposium.

Arp's emphasis on the need for more observations of polarization of the Clouds is fully justified, but perhaps there is a better chance of detecting it at optical than radio wavelengths. It is gratifying to know that such a program is in progress at Mount Stromlo.

The absence of radio coronae around the Clouds is noteworthy, although the relationship of this feature to general galactic forms seems to be somewhat obscure at present.

The gaseous component of the Clouds has been compared by Aller and Faulkner with that of the Galaxy. Here at last there seems to be some quantitative evidence for a small difference between the Clouds and the Galaxy in the sense that helium, oxygen, and neon are some 20 to 25% deficient relative to hydrogen in the Clouds. In the discussion it appeared that an incorrect allowance for reddening was unlikely to account for the difference.

III. Associations and Clusters

We have been presented with a number of new colour-magnitude arrays by Bok, Woolley, and Westerlund. The picture is one of clusters of varying ages but with the emphasis on youth. The brightest and largest clusters easily claim attention and these always show a vertical blue branch with sometimes a sprinkling of red supergiants. Bok gave us a vivid picture of the enormous potential for star building that exists in the region of his clusters. A satisfactory simplification in our thinking has appeared at this Symposium in that the stars of intermediate colour ($B-V \sim +0{\cdot}5$ to $+1{\cdot}0$) often found in clusters can now be almost entirely eliminated as foreground stars, while Feast has indicated from spectra that a few cases in NGC 330 are very probably to be regarded as unresolved composite objects.

It is gratifying to note that some less conspicuous clusters have been observed, like that described by Sir Richard Woolley with the top of the main sequence as faint as 16·5 and those in the wing of the SMC by Westerlund. The variety of clusters on direct photographs of the Clouds is a very striking feature and I think that more attention ought to be paid to more of the numerous smaller and poorer clusters despite the associated difficulties of close images. It must be remembered that at the distance of the Clouds the Pleiades would appear only about 20 sec of arc across.

Turning to the globular clusters, we have had some impressive colour-magnitude arrays presented by Gascoigne of six clusters and of NGC 121 by Tifft. We now have colour-magnitude arrays for 10 Cloud globulars. The general conclusion seems to be that we see globular clusters in the Clouds at all stages of development. It is striking that the three clusters in which RR Lyrae variables have been detected seem to be the oldest (10^{10} years) and to resemble halo clusters closely.

The fact that NGC 1866, the classical blue globular, contains a number of 3-day–period cepheids emphasizes the importance of comparing its colour-magnitude array with those of the red globulars containing RR Lyrae variables. Hodge has found a few more cepheids with other periods in other blue globulars. If the statistics of such variables can be increased, comparison of the colour-magnitude arrays and periods in each cluster might throw new light on the period–luminosity law.

Radial velocities of globular clusters are urgently required to compare the velocity dispersion as a function of integrated colour.

IV. General Stellar Field

In the general stellar field, Westerlund reported results of surveys of peculiar objects that could be picked out from his objective prism spectra. These included Wolf-Rayet, carbon, M and S stars, and planetaries. The distribution of these throughout the Clouds should give us a pointer in problems of stellar evolution; such a detailed overall picture of a stellar system can of course be gleaned only in the Magellanic Clouds. Further, we have at present in the Clouds the best means of calibrating the luminosities of all objects down to say $M_V=0$. Early M stars are found associated with OB stars.

The carbon stars (avoiding regions of OB stars) seemed to be the objects with the strongest tendency towards localization. This appears to me to be a highly significant observation, since all young stars in the Clouds must be seen close to their birth-place unless they are runaway stars. A velocity of 10 km/sec in the plane of the sky will shift a star in the Clouds by only about 37 sec of arc in 10^6 years.

The Wolf-Rayet stars appear to have a range of at least 5 absolute magnitudes, and are more numerous in the Large Cloud. Planetaries have been found in both Clouds with some difficulty and appear to be fainter than -3 in M_{pg}. Dessy's search for long-period variables in the LMC has been rewarded. Detection of periods for these stars is a time-consuming task but is urgently needed. The ordinary Mira-type variables probably lie at a still fainter magnitude level, and the need for their detection has been stressed before.

With the non-variable M stars we run into stars that must be common in the galactic foreground. This brings us to the vexed question of optical distinction of true Cloud members from the foreground.

In the general field of the Clouds, freed from clustered areas one has less than a 50% chance of picking out a Cloud member until one goes fainter than $m_{pg}=14\cdot0$, and perhaps not more than 80% chance at about $m_{pg}=17$. In this field we have had two striking contributions to the Symposium. Fehrenbach's objective prism technique is now providing us with a powerful and rapid tool for detecting Cloud members through the large radial velocity shift. It is relatively easy to pick out the B type members of the Clouds because there are hardly any in the galactic foreground. But among the A–M stars one is constantly running into foreground stars. Fehrenbach's criterion of high velocity weeds out the great majority of these stars in the Galaxy. As mentioned in the discussion, there remain a few high velocity Population II stars for which one needs a luminosity classification as well. Nevertheless, it should soon be possible to draw up a fairly complete census of the brightest Cloud members, down to say $m = 11\cdot5$.

Secondly, Sir Richard Woolley discovered a gold mine in measuring a 50-year-old Cape astrographic plate and showing that proper motions could be used to eliminate stars of intermediate colour as foreground stars. It is to be hoped that modern astrophysicists will bear in mind the importance of bequeathing such legacies to posterity.

The Walravens have also had striking success in picking out Cloud members for the earlier types in their very accurate photometry.

Tifft has shown how the population types of the general field seem to vary in different parts of the SMC and this is in line with the findings for clusters and associations.

In conclusion, I would like to say that to me personally, and I am sure to all of us, the happiest feature of this Symposium has been the opportunity for radio and optical astronomers to get together and discuss in such detail the problems of the Magellanic Clouds which have suddenly become so interesting to astronomers all over the world. Such stimulating and fruitful discussions on the Magellanic Clouds have never occurred at a General Assembly of the IAU, where there are so many other problems in our minds. The discussions here in Sydney seem to have suddenly become much more lively. If there is any conclusion to be drawn from this, I would suggest that it is because we know far less about the Magellanic Clouds than about the Galaxy. The tools to remedy that situation now exist and have been conceived. Let us hope that this Symposium will inspire us, and of course especially young astronomers, to make good use of them.