APPENDIX 2. REPORT OF THE COMMITTEE ON THE MAGELLANIC CLOUDS

(prepared by S. C. B. Gascoigne, Chairman of the Committee)

The major instrumental advance in the current period has been the completion of the 210-foot telescope at Parkes, New South Wales. This has already been the source of a most impressive stream of results. New 40-inch reflectors are to go into operation early in 1964 at both the Cape and Mount Stromlo Observatories. Considerable progress has been made by the ESO organization, and a 40-cm objective prism telescope, with smaller instruments, has been set up at Zeekougat, Cape Province. Major developments are planned for a site in Chile, especially by ESO and the Kitt Peak National Observatory.

A Symposium on the Magellanic Clouds was held at Sydney in March, 1963, as part of URSI/IAU Symposium no. 20, and was attended by about 50 participants, some 30 of whom came from outside Australia. The many new results presented there are referred to freely throughout this report. Brief summaries of the proceedings have been published by Faulkner (**17**) and Robinson (**67**).

Hogg has produced an Atlas of the central part of the SMC. This consists of 15 charts, each covering one degree square, and based on plates taken with the 74-inch reflector at Mt. Stromlo. Copies are available from the Mt. Stromlo Observatory.

Thackeray (**80**) has written a very good review of work in the Clouds, to appear in Vol. 2 of *Advances in Astronomy and Astrophysics*.

Large-Scale Structure

Striking advances have been made from the Radiophysics Laboratory in Sydney. For work on the 21 cm line McGee and Murray have built a 48-channel receiver with a frequency resolution of 7 km sec^{-1}. Using this instrument at an angular resolution of 2·2°, Hindman *et al.* (**36, 37, 38**) were able to show that the Clouds are enclosed in a common hydrogen envelope, with steep leading and trailing edges, and that over much of the SMC the velocity profile has two peaks separated by about 40 km sec^{-1}, with a strong suggestion that these peaks originate in separate masses of gas. At this frequency the 210-foot dish has an angular resolution of 14·5′ (about 250 pc). With it and the multichannel receiver, McGee and Milton (**63**) have shown that the neutral hydrogen in the LMC breaks up into a number of separate cloud complexes, the positions of which correspond closely with those of optical emission regions or of young stellar associations. There is dominant feature about 2° long, running north and (mostly) south of 30 Doradus. Others have diameters of up to a kiloparsec, and masses of 10^7 Suns. In the SMC on the other hand, Hindman (**35**) finds, apart from a few sharp-profile features, a smooth distribution of gas over the body of the Cloud. The velocity bifurcation remains, and there may be as many as six separate bodies of hydrogen. Only in the 30 Doradus region is this bifurcation found in the LMC.

Mathewson and Healey (**60, 61**) report continuum observations made at the four frequencies 136, 408, 1410 and 2650 MHz. The LMC radiation is mostly nonthermal (spectral index −0·6), with numerous sources superimposed. Most of these can be identified with optical H II regions, and are therefore thermal in origin, but at least one appears to be a super-nova remnant (**62**). 30 Doradus has a strong thermal core, of diameter 4′, surrounded by nonthermal source of 24′ diameter, which is in turn enclosed by an extended H II region. This structure is very similar to that of the galactic nucleus, which 30 Doradus seems to resemble closely. Much of the nonthermal component comes from the direction of the bar, where the existence of a strong magnetic field is implied, and the remainder from an extended region more or less included within the optical boundaries of the LMC. The emission from the SMC consists of a similar, much weaker nonthermal component, roughly coinciding in position with the optical

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Cloud, together with a number of superimposed discrete sources, many of which appear to be identical with SMC emission objects.

Westerlund (**97**) has studied the surface distribution in the LMC of clusters and peculiar objects recognizable as such from objective prism spectra. The outer clusters (**59**) form an obviously elliptical system with axial ratio close to $1/\sqrt{2}$, suggesting a tilt of 45°, in contrast to de Vaucouleurs' estimate of 15°–27°. Corresponding to this uncertainty in the tilt there is a seven-fold uncertainty in the mass. The centroid of the planetaries is near the optical centroid but differs from that of the clusters and from all other centroids so far defined. The carbon stars avoid the central and OB regions, and like galactic carbon stars, exhibit a tendency to cluster.

There have been several studies (**6, 71, 83, 85, 86**) of the relation between the morphological character of the Clouds and of other galaxies. The Clouds appear typical of a class of irregular galaxies related to barred spirals, and in particular de Vaucouleurs' suggestion that NGC55 may be a Magellanic type galaxy seen end-on has received support from the radio astronomers (**68**).

Wesselink (**90**) finds a marked deficiency in the number of galaxies counted on 74-inch plates taken within the SMC compared with the number in external fields, and interprets this as implying a normal dust content for the SMC. In a second paper (**91**) he suggests that such a dust content is not incompatible with the small absorptions found for SMC member stars. Just how small these absorptions are is still a matter for debate (cf **89**). Walker (**88**) has indications from eight stars in the SMC that the interstellar feature there at λ4430 appears to depend on colour excess in the same way as in the galaxy.

Wolstencroft (**106**) has reported polarisations of up to thirty per cent in the integrated light of the Clouds. These high values are not substantiated by Visvanathan (**87**), whose careful work shows very small polarisations for five SMC stars.

Bardalyan (**8**) and Ishida (**49, 50**) have studied the correlations between the surface distribution of interstellar gas and dust, OB stars and cepheids. Some of their conclusions may be modified by the incorporation of more recent data than they could have had available.

In a major paper, Feast, Thackeray and Wesselink (**24, 74**) have analysed the Radcliffe velocities of 61 stars and the Lick velocities of 17 nebulae, all in the LMC, to find a well-determined velocity gradient which agrees closely with that defined by the 21 cm observations. Feast (**21, 23**) has since obtained radial velocities of 42 LMC nebulae, at 15·6Å/mm, and with this additional material finds that there is now good optical evidence for differential rotation in the LMC. The mass probably lies in the range $0{\cdot}5 - 1 \times 10^{10}$ solar masses. The velocity dispersion is small, indicating concentration to a plane. 10 per cent of the super-giants studied in both Clouds have large velocity residuals. These stars are believed to be the counterpart in the Clouds of the high velocity OB stars in the galaxy.

The position in the SMC is much less clear. Here the stellar velocity gradient, derived from 40 stars, is only a third of the 21 cm gradient, but as will be clear from (**35**) there are complications in the radio picture. Bok and others are observing velocities for SMC emission nebulae.

Spectroscopy and Bright Member Stars

Fehrenbach and Duflot (**25, 26, 27**) have applied their technique of objective prism radial velocity measurement to the detection of Cloud members, the criterion of high radial velocity excluding most of the galactic foreground stars (though the proportion of galactic high velocity stars which remains is surprisingly large (**79**)). In four regions, 2° × 2°, they have discovered 113 Cloud members, only 16 of which were known previously. The Walravens (**89**) have measured some 600 stars with their five-colour technique. Colour-colour relations enable

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about half of these to be recognized as Cloud members, with colours identical with those of corresponding galactic super-giants. Similar conclusions have been reached by Wesselink (**92**), from *UBV* photometry of known members, and by Buscombe and Kennedy (**13**), from spectra of eight SMC super-giants. Combined spectral and photometric measurements have enabled Westerlund, Danziger and Graham (**102**) to detect eight member stars of early type in the wing of the SMC.

Thackeray (**75**) has obtained coudé spectra, at 15·6 Å/mm, of three Cloud super-giants. He is obtaining spectra of the Fehrenbach stars, and, with Hutchings, of new members of the SMC, partly with a view to strengthening radial velocity data in the SMC for comparison with radio results. Hutchings has measured equivalent widths from Radcliffe spectra (mainly at 49 Å/mm) of 39 LMC and 11 SMC members. Feast has obtained spectra of individual stars in NGC330 (**22**), and of 21 stars in the vicinity of 30 Dor (**19**). Nine of the latter are WN stars. Westerlund and Lindsey Smith (**105**) have obtained photometric data for 53 LMC Wolf-Rayet stars. They find that WC stars have consistently smaller colour indices than WN stars, and that the luminosities of the latter depend on location, the most luminous, in 30 Dor, being about two magnitudes brighter than field Wolf-Rayets. With Henize (**34**) and Lindsey Smith (**104**), Westerlund has also studied planetary and small diffuse nebulae in the Clouds. The upper limit of the luminosities of SMC planetaries is about $M_{pg} = -3$, as in the galaxy. Mass for mass, and relative to the galaxy, the LMC is poor in planetaries but rich in Wolf-Rayets; the SMC is about normal.

Lindsay (**55**) has listed 593 stellar-like emission objects in the SMC, and, with Mullan (**55a, 57**), a total of 467 similar objects in the LMC. A number of the latter are identical with Henize emission-line stars, and at least 30 of the SMC objects are believed to be planetaries

Feast (**19**) has made an extensive spectroscopic study of 30 Doradus, to find electron densities ranging from 200 to 2000 per cc, and a normal H/He ratio. The velocity dispersion is 11·3 km sec^{-1}, small enough so that a stable system of large mass may eventually be formed. This low value has been confirmed by Courtès (**14**) with his elegant Fabry-Pérot technique. Feast is measuring electron densities in other LMC nebulae. Aller and Faulkner (**1, 2, 15**) have made spectral scans of 10 SMC and 33 LMC emission nebulosities, and from these derive absolute surface brightnesses in Hβ together with the relative intensities of the principal nebular lines. Special attention was paid to 30 Doradus (**18**) and to NGC346 in the SMC. They find that the excitation patterns and chemical compositions appear similar to those of galactic nebulae, though Faulkner thinks He and perhaps O may be somewhat under-abundant in 30 Doradus. Westerlund and Henize (**103**) have described a curious emission object in the wing of the SMC.

Clusters

Two extensive catalogues of LMC clusters have been published. That of Shapley and Lindsay (**72**) is based on blue plates taken with the ADH Schmidt, covers all the Cloud and contains 898 entries; that of Lyngå and Westerlund (**59**) is based on blue and red Uppsala Schmidt plates, and lists 480 clusters, all further than 3° from the Cloud centre. The authors think that most of the latter are fairly old open (or 'galactic') clusters.

The young associations in the LMC have been studied extensively. Westerlund (**94**) has published colour-magnitude diagrams for 1450 stars in 26 clusters and fields, with diameters ranging from 20 to 300 parsecs. All have strong vertical branches of very blue stars; red stars, when present, have colours greater than $B-V = 1·0$, and all Wolf-Rayets in the field occur at the tops of their respective giant branches. Good agreement is obtained between the observed distribution and the Sandage-Salpeter luminosity function, corrected for evolutionary effects. Similar results have been obtained by the Boks (**10**), who find also for 14 associations a mean integrated absolute magnitude of $M_v = -10·5$, and suggest the use of these objects as extra-

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galactic distance indicators (**11**). Combining optical and radio measurements, Bok (**12**) estimates for NGC1929–1937 a total mass of stars, 2×10^4 Suns; of ionized hydrogen, 2×10^4 Suns; of neutral hydrogen, 5×10^6 Suns. In the SMC Feast (**22**) finds that Arp's colours for four yellow super-giants in NGC330 are not confirmed by spectra, and that the cluster is similar in stellar composition to young clusters in our own Galaxy. Westerlund (**99**) has obtained colour-magnitude diagrams for six clusters in the wing of the SMC; two are like NGC330, three like NGC458, and one globular, like NGC121. Hodge (**41**) has listed 23 'young populous' or 'blue globular' clusters in the LMC, and has measured a colour-magnitude diagram for one of them, NGC1831 (**46**), and for an open cluster, NGC1844 (**42**). Woolley (**110**) has described an LMC cluster, which, with an age of 10^8 years, is older than any other discussed in this paragraph.

Tifft (**81**) has made a careful study of NGC121 in the SMC, finding for it a colour-magnitude diagram similar to that of a normal globular cluster, with a giant branch terminating at $V = 16{\cdot}7$, and cluster variables at mean $V = 19{\cdot}6$. The surrounding field for the SMC halo is similar, and the modulus derived for both cluster and halo is $m - M = 19{\cdot}1$. Gascoigne (**32**) has observed Kron 3 and NGC339, also in the SMC. The giant branches for these terminate at $V = 16{\cdot}0$, as in NGC361 and 419, and he suggests (**30**) that Kron 3, and with it possibly NGC339, 361 and 419, belong to the group of intermediate-age clusters, with age about 10^9 years, discussed by Arp. On the other hand Westerlund (**99**) finds that L113 resembles NGC121, and is hence more like a halo cluster.

In the LMC NGC1783 has been studied by Sandage and Eggen (**70**) and by Gascoigne (**29**). Gascoigne also has colour-magnitude diagrams for NGC1466 and 2257, both of which contain short-period variables, and for NGC2231. The giant branches in the two former terminate at $V = 16{\cdot}2$, with the variables at about $V = 19{\cdot}3$, suggesting a modulus of $m - M = 18{\cdot}6$, for the LMC. Except for two very red stars, the brightest giants in NGC2231 are at $V = 17$. In this they resemble NGC2209, briefly discussed by Hodge (**40**). Measurements of the integrated light of some clusters have been made by Kron (**52**), who reports an anomalous spectral distribution, as revealed by six-colour photometry, in NGC419 and 1846, and by Aller and Faulkner (**3**), who describe observations made with a spectral scanner. Kron and Mayall (**53**) have discussed the relation between the globular clusters in the Clouds and those in other galaxies, including our own.

Variables

Woolley *et al.* (**112**) have published two-colour photographic light-curves for 41 cepheids in a region of the SMC. They find for the mean period-colour relation

$$\langle B \rangle = 17{\cdot}83 - 2{\cdot}85 \log P$$

the slope of which differs appreciably from that of 2·23 found by Arp for the SMC. Similar reductions are in progress at Herstmonceux for 15 cepheids in a second LMC field, and Hodge has material for a third, also in the LMC. Gascoigne (**32**) has presented the results of photoelectric photometry of 14 SMC and 13 LMC cepheids. Except for three in the SMC all these stars have periods greater than ten days. His SMC period-luminosity relation has a slope of 2·61, and he finds the cepheids of longer period to average 0·4 magnitudes brighter in the LMC than in the SMC. For neither cloud has the period-luminosity relation yet been established beyond doubt.

Arp and Kraft (**7**) have discussed the relation between galactic cepheids and those observed by Arp in the SMC. A re-examination of Harvard plates of the SMC (**65**) has shown that the majority of the known variables are cepheids, and it is expected that this survey will double the number of known cepheids in the SMC.

Tifft (**81**) and Gascoigne (**31**) have determined magnitudes for the variables in the globular clusters NGC121, 1466 and 2257. Tifft has extended Thackeray's work on some variables near NGC121 which are almost certainly members of the SMC. One in particular appears to be a true population II cepheid, with a period of 1·43 days. Wesselink (**93**) has discovered five variables with periods less than a day in the central part of the SMC, all considerably brighter than the variables in NGC121. He has periods for 46 variables in his SMC field. Hodge (**44**) has described a new type of variable he has found in the LMC, and with Wright (**47**) has found about ten cepheids near globular clusters in the LMC. These are more than a magnitude brighter than would be expected for population II variables. Dessy (**54**) has discovered 277 variables in an LMC field south of 30 Doradus, at the western end of the bar. None has a period less than a day.

The General Field

Much of the colour-magnitude work on clusters has been accompanied by corresponding work on adjacent field stars (or vice versa). Generally, the colour-magnitude diagram of a field is a superposition of those of the clusters it contains, and similar problems of interpretation arise with both. A major advance in the period under review has been the application of three quite different methods for distinguishing between member and foreground galactic stars—the objective prism technique of Fehrenbach, the multi-colour photometry of the Walravens, and the Herstmonceux measurements of proper motion. In particular, it now seems clear that the apparently yellow super-giants in the Hertzsprung gap are in fact almost all foreground stars. This has been a welcome simplification.

In the field around NGC121, the SMC halo, Tifft (**82**) finds a spread in the luminosities of the red giants which he interprets as a spread in age; he considers the older stellar components of the SMC to be significantly younger, on the average, than the old stellar component of the galaxy, though NGC121 itself must be comparable in age with the halo clusters in the galaxy. Westerlund (**95, 99, 100**) considers that the wing, on the other side of the SMC, consists predominantly of blue stars, with a common age of $\sim 10^7$ years, together with an appreciable mass of low-density hydrogen, a considerable fraction of which may be ionized. But the globular cluster L113, well in this field, seems as old as NGC121. Hodge (**43**) has published a colour-magnitude diagram to $V = 18{\cdot}0$ for 1057 stars in an LMC field. This is characterized by the usual blue vertical main sequence, a red giant branch, and yellow super-giants, which, as remarked above, now appear most probably to be foreground stars. Some of the strongest evidence for this has been provided by Woolley *et al.* (**108**), who derived a colour-magnitude diagram to $V = 14{\cdot}5$ for some 700 stars in a nearby LMC field. The foreground stars have been eliminated by proper motions determined from a pair of plates taken with the Cape astrograph, the earlier in 1912. What remains is the vertical main sequence, (most probably) red super-giants with colours in excess of $B-V = 1{\cdot}5$, but no stars in the Hertzsprung gap. This results appears to hold at least to $V = 16{\cdot}5$. A photometric survey to $V = 14{\cdot}5$ has been carried out for some 1300 stars in a second LMC field.

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Note: The IAU/URSI Symposium no. 20 has now been published as *The Galaxy and the Magellanic Cloud.* Ed. F. J. Kerr and A. W. Rodgers, Published by the Australian Academy of Science, 1964.

APPENDICE 3. RADIOSOURCES EXTRAGALACTIQUES ET GALAXIES

(préparé par J.-F. Denisse)

Depuis la dernière Assemblée Générale de l'Union Astronomique Internationale, les progrès accomplis dans le domaine de la Radioastronomie extragalactique ont été considérables, surtout ceux qui résultent de l'observation dans le continuum radio-électrique.

Les catalogues de radiosources existants ont été améliorés ou étendus (**1, 2**) et l'origine du désaccord entre le catalogue 3C et le catalogue de Mills est maintenant bien comprise. Des catalogues nouveaux ont été établis ou sont en voie de parution notamment à Cambridge (**3, 4, 5**) et à Parkes; certains, qui concernent une centaine de sources, donnent des positions particulièrement précises (10″ à 60″) qui ont permis de nouvelles identifications (**6, 7, 8**); enfin la position de quelques radiosources est maintenant connue avec une précision de 1″, par occultation (**9, 10, 10 bis**).

La structure d'un grand nombre de radiosources a été déterminée grâce aux observations interférométriques effectuées à Jodrell Bank (**11, 12**), au California Institute of Technology (**13**), à Nançay (**14**), en Australie (**15**) et à Great Malvern en Angleterre (**16**). D'autre part certaines structures sont accessibles à des instruments à lobe unique (**17**) et des occultations ont fourni quelques mesures à très haut pouvoir de résolution (**9, 10, 10 bis**). Toutes les observations s'accordent pour confirmer que plus de 50% et peut-être 75% des sources extragalactiques ont une structure double, voire plus complexe (M87, NGC5128); d'autres sont constituées d'un noyau et d'un halo (Hyd. A); plusieurs radiosources intenses ont un diamètre apparent inférieur à 1″ (3C48). Il n'est pas rare d'observer dans les cas les mieux connus des variations de structure avec la fréquence (**14, 10**).

La connaissance du spectre radioélectrique des radiosources a également fait d'énormes progrès, grâce aux nouveaux catalogues et aux mesures de flux effectuées spécialement dans divers laboratoires. Après une compilation préliminaire de Kuzmin (**18**), Conway, Kellerman et Long (**19**) ont déterminé le spectra de 160 sources et le groupe de Parkes celui d'un très grand nombre de sources, avec une précision moindre. Des mesures à très haute fréquence sont en cours à l'Observatoire du Michigan. Si la densité de flux S de nombreuses sources varie comme une puissance $-\alpha$ de la fréquence $\nu(S \sim \nu^{-\alpha})$, l'indice spectral α étant alors souvent compris entre 0·6 et 0·8, le spectre de plus de la moitié d'entre elles présente une courbure dans le domaine de fréquences observable, l'indice α croissant toujours avec la fréquence.

Enfin la polarisation linéaire du rayonnement, prévisible s'il est du au mécanisme synchrotron, a été découverte d'abord dans Cyg A et NGC5128 (**20, 21**), puis dans de très nombreuses radiosources (**22, 23, 24, 25**). Des programmes importants d'observation sont en cours notamment au Naval Research Laboratory au California Institute of Technology, à Green

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