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28*a*. SOUS-COMMISSION DES NUAGES DE MAGELLAN

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MEMBRES: Arp, Dessy, Kerr, Lindsay, Oosterhoff, Thackeray.

INTRODUCTION

This report brings up to date a review of the Magellanic Clouds published at the end of 1954 by Buscombe, Gascoigne and de Vaucouleurs (*Australian Journal of Science* (**17**), no. 3, 1954).

Major instruments which have come into use in the southern hemisphere since then include the 74-inch reflector at Mount Stromlo, the 20-inch Schmidt at the Uppsala Southern Station, Mount Stromlo, and the 36-inch photo-electric reflector at the Leiden Southern Station in the Transvaal.

A new system of rectangular co-ordinates, defined primarily by CPD stars, has been proposed

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by Wesselink (**95**). This would replace the Harvard X, Y system. Co-ordinates of the HV stars in both Clouds, of CPD stars in the SMC, and of HDE stars have been computed in the new system; a limited number of copies are available for distribution on application to the Radcliffe Observatory.

A set of charts covering the Clouds is being prepared at Mount Stromlo in a joint project with the Uppsala Observatory. These charts are enlargements, to a scale of 3 inches per degree, of yellow-sensitive plates taken with Uppsala Schmidt (clear aperture 20 inches, focal length 67 inches, plate size $4° \times 4°$). Nine of these charts cover an area of $10° \times 10°$ centred on the LMC, and four an area of $7° \times 7°$ centred on the SMC. The charts reach a limit of about 18th magnitude. Sets should be available early in 1961 from Mount Stromlo.

INTEGRATED PROPERTIES

In recent years four determinations have been made of the integrated magnitudes of the Clouds, (**19, 28, 31, 32, 48**), and in spite of the difficulties of this work the agreement is surprisingly good. The results have been collected by de Vaucouleurs (**26**) who finds for the LMC a 'total' B magnitude of 0·6, and a mean $(B-V)$ colour of 0·55. For the SMC the corresponding figures are 2·8 and 0·50, and, assuming a modulus of 19·0, the absolute B magnitudes are $-18{\cdot}4$ and $-16{\cdot}2$. There is an appreciable variation of colour over the SMC, the denser central part being appreciably bluer.

Radio-frequency radiation from the Clouds has been measured at 21 cm (**53**), 50 cm (**74**), 3 m (**69**), 3·5 m (**70**) and 15 m (**79**). There is a good discussion of this work by Mills (**72**). Like other galaxies of their general character the Clouds are relatively weak radio emitters. They have continuum spectra similar to those of the galactic disk and M 31, consistent with a synchrotron-type process of origin. 30 Doradus is, however, a thermal source, optically thick at 15 m, and Shain has pointed out how this property may be used to make the important distinction between radiation originating on the far side of the LMC and that originating between the near side and ourselves, i.e. in the galactic corona. In the LMC the angular extent of the radio and optical emissions are not dissimilar, with little suggestion of an extensive corona of the type observed around M 31. The SMC situation is confused.

The 21-cm observations have given information on the distribution, mass and radial velocities of neutral H in the Clouds. They provided confirmation of de Vaucouleurs' suggestion that the Clouds are flattened rotating systems, and from the resulting rotation curve allowed the first mass estimates to be made (**54, 55**). In the SMC especially these indicated a very high proportion of H($\sim$ 50%).

More recently discrepancies have appeared between the rotational velocities derived from 21-cm observations and those from stellar and nebular radial velocities. The latter are higher, and suggest an upward revision of the masses, which in the case of the LMC de Vaucouleurs (**25**) thinks should be from 4·5 to 25×10^9 Suns. This higher figure implies that the proportion of neutral H is down to about 5%, and also that the Clouds probably form a closed rotating system (*cf* Idlis (**48a**)). The question is still open.

Meanwhile Kerr and his associates have made a new series of observations, with similar angular resolution ($\sim 1°{\cdot}5$) but a very sensitive 50-channel receiver. The original masses of neutral H are confirmed to within a factor of 2. The Clouds are found to be enclosed in a common envelope of neutral H, which terminates very sharply on the western side of the SMC and eastern side of the LMC.

De Vaucouleurs (**15, 16**) has made extensive star counts in each Cloud, to magnitude limits of 14·3 and 16·0, and has been led by these to picture them as flattened rotating systems of considerable extent, which because of their tilts appear elliptical in outline, and which exhibit a degree of spiral structure. In the LMC the spiral arms are characterized by very long, tenuous extensions; Johnson (**50, 26a**), however has suggested that these may be filaments of Hα nebulosity, possibly outlying fragments of the Vela-Puppis emission nebula. Since then a number of authors (**20, 49, 52, 61, 65, 75**) have used the distribution of clusters, stars, H II regions, optical and radio-frequency emissions as a basis for discussing the structure and classification of the Clouds, without reaching any sort of agreement.

Using Arp's sequences, Elsasser (**32**) has made star counts to 19 B in 13 regions of the SMC. He finds a luminosity function there similar to that in the region of the Sun, with 60% of the light coming from stars brighter than $M = +1$. In another paper (**33**) he presents evidence, from extensive photo-electric measurements of sky brightness, of the long suspected bridge between the galaxy and the LMC. Star counts have also been discussed by de Vaucouleurs (**18**), Schilt (**77**) and Epstein (**34**).

CLUSTERS AND PHOTOMETRY

The magnitude sequences on which much of the work summarized in this section depends have been measured by Arp (**2**), Bok and Bok (**8**), and Eggen and Sandage (**29**). There is also a great deal of unpublished work on this subject; the agreement is generally good.

Kron (**59**) and Lindsay (**65**) have published lists of clusters in the SMC, found in each case from inspection of ADH plates. De Vaucouleurs (**24**) has rough magnitudes for these, measured on small scale plates (1 mm = 19″·3) where the cluster images are quasi-stellar. Hodge (**45**), also working from ADH plates, has published a list of 35 red globular clusters in the LMC, together with uncalibrated colour-magnitude diagrams, and has in press a similar catalogue of populous young clusters. Gascoigne has UBV measures of various Cloud clusters; on this basis the SMC globular clusters resemble each other and NGC 362 (a galactic globular cluster) but differ markedly from 47 Tucanae.

So much colour-magnitude work has been and is being done in the Clouds that for brevity it is presented in semi-tabular form. The remainder of this section refers to colour-magnitude arrays of clusters and surrounding fields.

Arp (**3, 4, 5, 6**). Four SMC clusters and surrounding fields, three to $V = 19+$. The globular clusters NGC 419 and 361 appear not unlike galactic globulars, but the blue globular clusters NGC 458 and 330 differ appreciably from their nearest galactic counterparts (h and χ Persei) with wide gaps near tops of their vertical main sequence, and much narrower Hertzsprung gaps. Arp deduces (**1**) the SMC is composed of young stars and old stars, those of intermediate age being undetectable or absent; the region of recent star formation appears displaced from that of old star formation (**2**) the difference between the young SMC and galactic clusters implies that the young SMC stars are poorer in metals than young galactic stars.

Tifft. The SMC globular cluster NGC 121, to $V = 20+$; an SMC field near the cluster Kron 21; an LMC field at the west end of the bar (including NGC 1850 and 1856) to $V = 18+$; other LMC fields, especially NGC 1978 and one round NGC 2173. Tifft's NGC 121 diagram differs significantly from Arp's for NGC 419 and 361, in the sense that it more closely resembles that for a galactic globular cluster. Its upper end terminates at $V \sim 16{\cdot}7$, $B-V \sim 1{\cdot}6$.

Westerlund (**98**): Multi-colour (B,V,R,IR) work on five LMC regions, near 30 Doradus and Constellation III, to $V{\sim}16$. Diagrams for 26 associations, clusters and fields. The clusters are all younger than 10^7 years, and closely resemble galactic clusters in this age-group, with similar vertical main sequences and similar initial luminosity functions. The identified WR stars are all at the upper ends of the main sequences.

Hodge: Diagrams for three LMC globular clusters (NGC 1846, NGC 1978, anon 4), all like Arp's SMC globulars (**45a**); for the younger clusters NGC 1831 and 1844; for about 1000 field stars in northern part of LMC, to $V \sim 18$; for five associations in north of the LMC; and for various small fields. His younger clusters appear not unlike the open clusters in the galaxy but differ in their much larger number of stars, and in the unexpected location of giants in their colour-magnitude diagrams (**47**).

The *Herstmonceux* group (Eggen, Sandage, Woolley, *et al*) are working in two fields on the north-west and northern parts of the LMC (**29**). Woolley (**100**) has diagrams for these fields and for three young clusters, to $V \sim 16$, and Sandage and Eggen a diagram for the globular cluster NGC 1783 to $V \sim 17$.

Gascoigne: Diagram of NGC 1783 to $V \sim 19$; it is similar to Arp's SMC clusters. *C–m* arrays for field stars and clusters are being determined by Westerlund, Nitisastro and Gascoigne in the region south of Herstmonceux field I. Bok is working in Harvard Constellation III, Hogg in the region of NGC 330 in the SMC.

SPECTRA

Several surveys have been made for emission objects, using objective prism plates. Henize (**44**) has found in the two Clouds 236 emission-line stars and 532 emission nebulae. Doherty, Henize and Aller (**27**) have made photometric measurements of those in the LMC. Lindsay (**62, 64**) has compiled similar lists for the SMC, and in his latest (**66, 68**) reports 600 emission objects in the SMC, including 53 planetaries, and 1000 in the LMC with 120 planetaries. Koelbloed (**57**) had previously found 16 faint planetaries in the SMC. In a search of 100 square degrees of the LMC Westerlund and Rodgers (**96**) found 50 W stars, 14 of which were new, and 34 planetaries.

Westerlund (**98**) has made a survey of the LMC on infra-red objective prism plates for M stars. He gives a catalogue of 303, the grouping of which 'appears sufficiently obvious to serve as a criterion for membership'. Sharpless (**84**) has a note on the M stars near 30 Doradus.

Feast, Thackeray and Wesselink have in press a connected account of their spectroscopic observations of 50 SMC and 108 LMC stars (**40**), based on some 300 spectra taken in over 800 hours of observing time. The brightest stars ($M_{\rm bol} \sim -11$) all tend to show P Cygni characteristics, and are probably near the limit of stability for massive stars (this point has also been discussed by Code and Houck (**12**)). As a group, the Cloud stars do not show any *general* spectral peculiarities which cannot be attributed to high luminosity; in particular, there is no evidence for metal poorness, nor for differences between Cloud and galactic Cepheids, or Cloud and galactic interstellar matter. The match between the spectra of the gaseous nebulae IC 1644 (SMC) and 30 Doradus (LMC) is good and suggests no significant abundance differences. Together with *UBV* photometry, the spectral types suggest an average reddening of 0·10 magnitude, arising partly in the galaxy and partly in the Clouds. A previous discussion (**37**) of the kinematic aspects of 26 LMC radial velocities had confirmed the radio picture of the LMC as a rotating body, but pointed out that both stars and nebulae suggested an appreciably higher velocity-gradient across the Cloud, and hence a higher mass. This result is supported by de Vaucouleurs' (**25**) radial velocities for seven outlying LMC emission objects.

Code and Houck (**11**) have data on 25 early-type Cloud stars, from which they confirm the essential similarity between these and high-luminosity galactic OB stars, but find that the spectral types inferred for the SMC stars from the photometric data do not agree well with those obtained directly. They suggest this may be due to a different law of interstellar reddening in the SMC (but Arp would attribute it instead to metal deficiency). H. J. Smith (**85**) has studied 11 LMC P Cygni stars, and Buscombe has spectra of 10 SMC B stars. The de Vaucouleurs (**23**) have a spectrum of the bar of the LMC, notable for strong He absorption lines. Following Morgan they infer an excess of OB stars and K-M giants, and a deficiency of A, F and G stars, as compared with the solar neighbourhood.

From spectrophotometry of three plates of 30 Doradus Johnson (**51**) finds for this great complex $T_e = 14{,}000°$, a helium-hydrogen ratio $N(\mathrm{He})/N(\mathrm{H})$ of 0·13 (agreeing with that found by Mathis for the Orion nebula) and a gaseous mass of $5 \times 10^6\ M_\odot$. This makes 30 Doradus easily the largest known H II region. Feast has also studied 30 Doradus, and has in press an extensive investigation of its electron temperatures and pressures and radial velocity variations. Kolmogoroff's law of turbulence does not apply in the range 9-60 pc. Aller and Faulkner have obtained spectral scans of 10 SMC and 33 LMC emission nebulosities. They have paid special attention to 30 Doradus and to NGC 346 in the SMC, and find that although the He I 4471 Å to Hδ 4340 Å intensity ratio may be slightly smaller in NGC 346, the He/H ratios in the two Clouds are probably comparable.

Walraven has applied his photo-electric method of two-dimensional classification (*B.A.N.* **14** no. 496, 1960), to about 60 B stars in the SMC and 40 in the LMC. Some of these stars are as faint as 15th magnitude.

VARIABLE STARS

A large part of the Joint Discussion on the 'Luminosity of Cepheids' (**43**) held at Moscow in 1958 was concerned with data and problems relating to Cloud Cepheids. Arp (**7**) has published two-colour photographic light-curves for 69 SMC Cepheids, periods 1 to 50 days. He finds a linear P–L relation (mean $B = 17{\cdot}45 - 2{\cdot}25 \log P$) about which individual variables scatter with an s. d. of ± 0·24 magnitude. There is a considerable scatter in the individual colours of his Cepheids. The Herstmonceux group, Hodge and Tifft are all working in the LMC on projects similar to Arp's in the SMC, and Oosterhoff is measuring Cepheids on the Leiden Franklin-Adams plates.

Many new variables are reported, especially from Herstmonceux. In the northern part of the LMC, Hodge has found 'numerous faint variables ($V = 16{\cdot}5$ to 18) . . . with highly irregular light-curve and colour variations, which cannot be easily accounted for by the normal processes of pulsation, flares, eclipses, etc.' Dessy (**13**) has continued his previous work on faint variables in the SMC.

Thackeray (**90, 92**) has described the deviation of periods and light-curves for five variables in NGC 121-three cluster type, two long-period. Alexander has discovered 28 short-period variables in NGC 2257. Periods for six, ranging from 0·51 to 0·69 days, have been found (**1a**).

Novae in the Clouds have been discussed by Buscombe and de Vaucouleurs (**10**) and by Schmidt (**78**), to check McLaughlin's relation between maximum luminosity and rate of decline, and to derive a modulus.

H. N. Russell (**76**) has studied the Harvard data on four eclipsing binaries in the Clouds, mainly systems of the β Lyrae type, and apparently similar in every way to galactic eclipsing systems.

EVOLUTIONARY PROBLEMS

Many estimates have been made for the distances of Clouds, based on the apparent magnitudes of various types of variables, colour-magnitude arrays and so on. It does not seem possible at present to give a much better estimate for the modulus than 19·0 ± 0·5 magnitude. The large uncertainty in this figure is to some extent a reflection of our lack of knowledge of the chemical composition and evolutionary history of the Clouds. Arguing in part from the apparently very low dust/gas ratio in the SMC, the Burbidges (**9**) suggested that this Cloud was metal-poor, an idea which has received support from Arp and Hodge (**47**). The Pretoria astronomers do not believe it necessary to invoke composition differences (**40, 41**); further, Wesselink (**89**) finds no single case of an extra-galactic nebula in the centre of the SMC, and says 'the normal ratio of gas to dust is not excluded by this observation.' Finally, attention

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should be drawn to a useful discussion of Cloud problems, held as part of the Stockholm conference in 1957 (**91**).

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President of the Sub-Commission

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