Radcliffe reflector at Pretoria. About 30 systems not fainter than about magnitude 13 have been investigated.

E. Vandekerkhove (**2**) has examined the gradient at 5000Å in a few galaxies in relation to the radial velocities.

E. Holmberg (**3**) has continued his elaborate investigations of possible systematic errors in measured redshifts. An effect possibly connected with a parameter correlated with apparent magnitude is now examined. G. and A. de Vaucouleurs (**4**) and J. Neyman and E. L. Scott (**41**) find no appreciable bias in the redshift data of bright galaxies.

M. Schmidt has described the Mount Wilson programme in which optical spectra have been obtained for 30 of the 50 galaxies identified with radio sources (*Notes on Discussions of Galaxies*, Berkeley, August 1963, by Thornton Page). The redshifts indicate absolute magnitudes of -20 ± 1 (using $H = 100$ km sec^{-1} Mpc^{-1}). Three are as faint as -18 and NGC6166 is -22. The five extraordinary ones with large redshifts may have absolute magnitude -25. They range from 3C48, $16^{m}\cdot2$ redshift 0·368, to 3C273, $12^{m}\cdot7$ (variable) redshift 0·158, with an optical 'tail' 20″ away; and all are radio sources of small diameter (a few seconds of arc). The others are 3C147, 3C196 and 3C286, all very small and very luminous.

Redshifts of 92 galaxies have been determined by N. U. Mayall and A. de Vaucouleurs (**5**).

G. and A. de Vaucouleurs (**6**) have given classification and radial velocities for bright Southern galaxies previously observed at Mt Stromlo. A new radial velocity survey was started in 1960 at McDonald Observatory; about 120 galaxies have been observed so far.

General and multicolour photometry.

G. and A. de Vaucouleurs have given much work to all kinds of photometric research on galaxies. Concerning photographic surface photometry the detailed work on bright Southern galaxies has been continued with improved isophotometers (**6**). Data for about 70 galaxies are reduced. A new digital method developed by W. Jones and R. M. Gallet, at the National Bureau of Standards, Boulder, Colorado, has been modified for the purpose.

Photo-electric *UBV* scans of NGC55, 300, 4487 (M87) and of the Sculptor, Fornax and Draco systems have been reduced. As a rule the $r^{1/4}$ law of luminosity distribution holds for giant ellipticals but not for dwarfs (**7**).

Integrated magnitudes and colours in the *UBV* system for some 550 galaxies north of $-40°$ have been measured with the 36-inch reflectors of McDonald and Kitt Peak observatories. Earlier observations at Flagstaff comprising 148 galaxies were published (**10, 11**).

The *Reference Catalogue of Bright Galaxies* giving data on types, diameters, ellipticities, colours, surface luminosities, velocities, and bibliography for 2600 galaxies was completed; it will be published by the University of Texas Press in October 1964 (**8**).

G. de Vaucouleurs, as Chairman of the Group on Galaxy Photometry, has made the following summary of work reported to him up to 10 October 1963.

REPORT OF THE WORKING GROUP ON GALAXY PHOTOMETRY
(prepared by G. de Vaucouleurs)

A most gratifying increase of interest and activity in the field of galaxy photometry has taken place in the two years since the formation of the Group on Galaxy Photometry at the Berkeley meeting in 1961. From answers to Circular no. 2 received to date the following summary was prepared:

1. *Photographic photometry* (*out of focus or Schraffier-k.*):

F. Zwicky and E. R. Herzog (Pasadena) have completed work on 89 Palomar 48-inch fields

in zones $+18°$, $+24°$, $+30°$, ($b > 0°$) to $m(\text{pg}) = 15{\cdot}7$; published in vol. 2 of *Catalogue of Galaxies and Clusters of Galaxies* (1963). Work is in progress in zones $+36°$ to $+54°$ ($b > 0°$), and $0°$ to $+18°$ ($b < 0°$).

2. *Photo-electric magnitudes and colors (integrated)*:

J. Bigay (Haute-Provence Obs.) has measured in the *UBV* system about 100 bright northern galaxies, including many in the Virgo cluster; about 50 to be published soon. Observations of 55 objects in the Coma cluster to $m = 16{\cdot}3$ with the 193-cm reflector are in progress. Data for 25 objects in cluster 11082,+2857 to $m = 17{\cdot}1$, and 9 objects in cl. 11138,+2932 to $m = 16{\cdot}7$ are ready for publication.

P. W. Hodge (Berkeley) has published and discussed *UBV* data for 60 early-type galaxies observed with the 60- and 100-inch telescopes at Mt. Wilson (**9**). The results are in general agreement with de Vaucouleurs's exploratory surveys (**10, 11**) except that near $B-V = +1{\cdot}0$ E-So types are up to about $0{\cdot}1$ mag. bluer in $U-B$ than indicated by the meagre sample in the Flagstaff data (This is confirmed by the much larger sample in the unpublished Mt. Stromlo and McDonald data).

R. Shobbrook (Mt. Stromlo Obs.) has observed in the *UBV* system 53 bright southern galaxies with the 26-inch (Mt. Bingar station) and 50-inch reflectors; to be published in his thesis. This is the first photo-electric program in high southern declinations. The results confirm Hodge's data for E-SO types.

W. G. Tifft (Lowell Obs.) has published and discussed his Mt. Wilson multicolor data on 47 bright northern galaxies (**12**) with additional observations for 12 objects (**13**). A new program of multicolor photometry has been initiated at Flagstaff.

G. de Vaucouleurs, F. Lopez, S. N. Svolopoulos and collaborators (McDonald Obs.) have observed about 550 bright galaxies north of decl. $-40°$ in the *UBV* system with the 36-inch reflectors at McDonald and Kitt Peak. A new wide field photometer designed by H. L. Johnson has been built for this continuing program which will eventually include about 1000 bright galaxies. Until the final catalogue is published, the *UBV* output data for individual objects (recorded on punch cards) will be made available on request.

3. *Photo-electric scans*

R. H. Miller and K. H. Prendergast (Yerkes and McDonald Obs.) have published a detailed, precision photometry of NGC3379 (**14**); observations of a few other objects (NGC720, 3115) are in progress. Miller has discussed the intrinsic limitations due to fluctuations in the number of field stars below the detection threshold (**15**).

G. O. Abell (Los Angeles), has reduced scans along at least one axis of eight bright ellipticals (NGC205, 404, 584, 720, 819, 3315, 7619, 7626) serving as checks of an interpolation formula used in the reduction of photographic data (sect. 4).

G. de Vaucouleurs and collaborators (McDonald Obs.) have reduced multiple *UBV* scans taken at Flagstaff, Kitt Peak and McDonald of one or more axes of NGC55, 300, 4486, and IC342 and of the Sculptor, Fornax and Draco dwarf ellipticals extending to faint limits. The data are used in part for calibration of the Mt. Stromlo photographic photometry (sect. 4), in part for luminosity distribution studies in giant and dwarf ellipticals.

4. *Photographic isophotes or luminosity profiles*

G. O. Abell (Univ. of Calif., Los Angeles) has observed the ellipticals NGC4374, 4406, 4459, 4473, 4486, 5813, 5982, 6340 in connection with his program on the luminosity function in clusters (reduction is in progress).

A. R. Fish (Univ. of Calif., Berkeley) has a paper in press (**16**) discussing masses of elliptical galaxies which includes new photometric data from Lick 120-inch photographs on NGC741, 750, 751, 1395, 1889, 2300, 3158, 3193, 3348, 3605, 3608, 4472, 4473, 4486, 4649, 4889, and 5557.

I. King (Univ. of California) has observed a selection of ellipticals with the 48-inch Schmidt at Palomar and the 60-inch cassegrain at Mt. Wilson in connection with theoretical studies of the structure of stellar systems.

Mrs M. H. Liller (Harvard Obs.) has completed a study (to be published soon) of 31 E and SO galaxies brighter than $m = 14{\cdot}0$ in the Virgo Cluster on 48-inch Palomar Schmidt plates.

J. L. Sersic (Cordoba Obs.) is preparing a *Photometric Atlas of Southern Galaxies* from 60-inch reflector plates, including NGC55, 253, 1097, 1291, 1316–17, 1365, 1536, 1549, 1553, 2997, 4594, 5128, 5236, 5253, 6438, 6769–70–71, 7793, and object Mac-Leish (no recent information has been received, but some initial results have been published in *Zeitschrift für Astrophysik* and *Revista Astronomica* since 1958 and a preliminary version of the Atlas was circulated at the Berkeley meeting).

F. Bertola at Asiago Observatory (Italy) has in progress a photographic isophotometry of NGC 1068, 3115, 3432, 4258, 4490, 4605, 4618, 4625, 5005 and 6503. In addition the rotation of NGC 925, 1068, 3310, 3432, 4490 and 4605 has been studied by means of the long slit technique.

Mrs V. C. Rubin and H. Willauer (Georgetown University) have measured luminosity profiles of southern E and SO galaxies on Mt Stromlo plates supplied by de Vaucouleurs.

G. de Vaucouleurs and collaborators (Univ. of Texas) have continued the reduction of Mt. Stromlo 30-inch and 74-inch photographs of bright galaxies south of $-35°$ (supplemented by some Cordoba 60-inch plates kindly supplied by Dr J. L. Sersic). Isophotes and photometric parameters (as defined in *IAU Symposium* no. 15) have been published or are in press for NGC55, 300, 1313, 1316–17, 4945, 6744 (**17**).

Reduction is complete for NGC1291, 1365, 1433, 1487, 1510–12, 1566, 1672, 1947, 5643, 6300, 6743, 7059, 7064, 7070, 7135, 7144, 7232A, 7424, 7582, 7689, 7702, and IC5201. Reduction is in progress for NGC1326, 1515, 1448, 2434, 6890, 7124, 7125, 7125A, 7126, 7145, 7162, 7162A, 7166, and I5181. Measurements are in progress for another series of 20–30 objects. This material will be prepared for publication in a photometric atlas of southern galaxies.

A computer program for an application to galaxy isophotometry of techniques of numerical mapping in two-coordinates initially developed by R. M. Gallet and W. Jones at the U.S. National Bureau of Standards has been adapted and tested by J. Vallee at the University of Texas, and D. Obitts at the Bureau of Standards.

DIGITIZED MICRODENSITOMETER

A two-coordinate digitized microdensitometer is in construction to provide input data for this program which will greatly increase the speed and accuracy of surface photometry of extended objects.

OTHER PHOTOMETRIC STUDIES

Kron and Shane, using the 120-inch telescope of the Lick Observatory, are working on a programme of photo-electric calibration of the limiting magnitude of the galaxy counts made by Shane and Wirtanen on 20-inch plates. Magnitude calibration for 15th-magnitude galaxies in Zwicky's catalogue is also a part of the programme.

C. J. Van Houten (**18**) has given the results of a surface photometry of 20 extra-galactic nebulae,

mostly ellipticals, SO nebulae and early spirals. The investigation was based on photographic as well as photo-electric observations by Van Houten, Hiltner, Oort and Oosterhoff. The analysis was made on the basis of a two-component model: the bulge system, which is morphologically similar to an elliptical nebula, and the disk system, which is strongly flattened. In practically all cases it was assumed that the isophotes of the bulge system had constant axial ratios. In order to correct for absorption caused by dust particles in the galaxies themselves an investigation was made about the scattering properties of interstellar dust, however, without conclusive results. An extensive analysis was made of NGC4594 in which the relative distribution of bulge, stellar disk and dust component were derived. It appeared that in the disk the distribution of stars and dust was very dissimilar, the former having a maximum density at 3 kpc from the centre, while hardly any dust was found within 8 kpc from the centre. Various results were derived for the other nebulae, in particular concerning the brightness distribution and the dust layers. It was found that the formulae for light-distribution in elliptical nebulae derived by Hubble and by de Vaucouleurs gave an equally good fit for most of the nebulae investigated. A large colour difference was found along the *minor* axes of some mixed systems (i.e. having bulge and disk) in the sense that the nucleus was redder.

Baum (**1**) mentions the necessity of knowing something about the stellar contents of galaxies of the kind used for multicolour redshift work. On the basis of observations on the 8-colour system he has tried to compute population models for elliptical galaxies. At 4830Å the model could be described as 25% population II plus 75% old population I. In the spiral galaxy M74 the disk population underlying the inner spiral arms has a spectral energy-distribution roughly similar to that of an elliptical galaxy. The spiral arms, though photographically impressive, contribute comparatively little to the total light of M74, in the photovisual region perhaps 10%. The width of an individual arm increases systematically with the wave-length, the infrared width being about 1·5 times the ultra-violet width. The colour distribution across the arm is also asymmetric, which has been confirmed for M101. Baum has also investigated the nearby dwarf galaxies. All evidence indicated that they are truly population II.

Optical polarisation

Aina Elvius and John S. Hall have made photo-electric measurements of polarisation with the 69-inch Perkins telescope near Flagstaff, Arizona, in the irregular galaxy M82, the peculiar galaxy NGC5128, and 14 other extra-galactic objects, NGC185, 205, 221, 224, 253, 891, 2841, 3031, 3077, 4258, 4565, 4631, 5195, 7331.

A. Elvius (**19**) found unusually strong polarization, up to 15 per cent, in M82. This object was therefore studied in more detail than any other object in the survey. In the case of NGC5128 polarization of 5 per cent has been found in some regions in the dark lane, where Sérsic has observed strong absorption and reddening of light. The electric vector is approximately parallel to the dark band. Comparison has been made with observations of polarization in radio wave-lengths.

Internal motions, spectra and composition

E. M. and G. R. Burbidge (**20**) have continued their determination of rotation curves, mass distributions, masses and mass-to-light ratios. Following the results incorporated in the report in *Trans. IAU*, **11A** 1961, the following galaxies have been studied, partly in collaboration with K. H. Prendergast, NGC2903, 3623, 3646, 157, 4736, 5248, 253, 1084, 7469, 4258, VV254, NGC6503, 3521. NGC7469 is a Seyfert galaxy and again, as in NGC1068, it appears that the gas in the nucleus is moving at speeds greater than the escape velocity.

Following work done earlier (**21**) on objects in Vorontsov-Velyaminov's *Atlas of Interacting Galaxies* they have continued to get spectra of these objects to determine their redshifts and rotation, when present (**22**). It is concluded that these objects are most likely of fairly recent origin.

The same authors have surveyed the amount of excitation of interstellar gas in spiral and irregular galaxies (**23**). A remarkable reversal of the normal intensity ratio of the emission lines of Hα and [N II] as seen in spiral arm regions is found in the nucleus of many galaxies where the light is coming mainly from K giants. A more detailed theoretical study has been made by G. R. Burbidge, R. J. Gould and S. R. Pottasch (**24**). Prediction of far infra-red line emissions has been made by R. Gould (**25**).

A redetermination of the mass of M32 from the velocity dispersion of the stars in the nucleus by G. R. Burbidge, E. M. Burbidge, and R. A. Fish (**26**) led to a value in good agreement with that obtained by A. Poveda (**25a**) on the basis of the velocity dispersion determined by Minkowski. The mass and mass-to-light ratio of NGC3379 were obtained in the same way (**27**). Determinations for a number of objects have been given by A. Poveda (**27a**).

In a study of members of the Hercules cluster E. M. and G. R. Burbidge draw the conclusion by the virial theorem that the cluster is either dispersing or must contain much mass not in the form of visible galaxies. A study of the group centred on NGC383, from radial velocities published by Humason, Mayall and Sandage, led to the same result (**28**), whereas in the quintet VV116 the virial theorem is satisfied for reasonable values of the masses (**29**). In Stephan's Quintet the fifth member appears to be a foreground object.

G. R. Burbidge and K. H. Prendergast (**30**) discussed the permanence of spiral arms in the presence of differential rotations from observations in NGC5055.

At the Mount Wilson and Palomar Observatories (**31**), work done by Baade on the precise position of all emission nebulae in M31 is being prepared for publication by Arp. An effort will be made to give illustrative data on the connection between these emission nebulae and the spiral structure in M31. Schmidt attempts to determine the helium abundance of the interstellar gas in H II regions at various positions in M31. G. Münch has continued observation of the emission lines of [O II] in the nuclear regions of M31.

M. F. Walker (**32**) found that the nucleus of M32 is in rapid rotation. The radial velocity increases linearly to 65 km sec^{-1} (relative to the centre) at a radius of 2″5; it then decreases to zero at 9″ from the centre. Walker has accumulated spectra of the nuclear region of 17 galaxies at the 120-inch Lick telescope. Both the prime focus spectrograph and the coudé spectrograph were used, the latter with the Lallemand image tube. The results substantiate the view, first put forward by R. Minkowski in 1960, that rapid rotation at the centre is a general feature of galaxies. The nucleus of NGC1068, a Seyfert emission galaxy and a radio source, shows four discrete gas clouds within 3″5 of the centre being ejected with differing velocities, ranging up to 800 km sec^{-1} relative to the velocity of the nucleus. Infall cannot be ruled out, since the spacial orientation is not known. If it is ejection, the cause may have been a violent event in the nucleus, such as the Burbidge 'chain-reaction' of super-novae explosions. The 4227Å line of (Fe V) was detected for the first time in the nucleus of a galaxy. A sharp component of the emission lines can be followed well out into the spiral. The gas is apparently not moving in the same way as the stars, and is certainly not following a circular orbit.

C. R. Lynds of the Kitt Peak National Observatory has obtained a series of spectrograms of the filamentary halo of M82 with the prime-focus spectrograph of the Lick 120-inch telescope (**33**). The emission line character of the spectra proved the gaseous nature of the filaments. The radial velocities can be interpreted as indicating expansion away from the centre of M82. The parallels with the Crab nebula suggest that the filaments have a bearing on the radio-frequency emission of M82.

E. M. and G. R. Burbidge, K. H. Prendergast and V. Rubin have studied galaxies where non-circular motions are suspected (e.g. NGC253). The velocity field of the centre of M51 clearly indicates motions which are in addition to the rotational velocities.

The physics of the barred spirals has received considerable attention in recent years. E. M.

and G. R. Burbidge and K. H. Prendergast (**34**), examining the velocity distribution in NGC7479, showed that the bar is rotating as a solid body, but the falling off in velocity outside the bar is faster than the Keplerian curve, and indicates streaming motions in the outer arms. Various results were also obtained for NGC3504, NGC1365, NGC5383, often indicating non-circular velocities.

G. and A. de Vaucouleurs (**35**) with a prime-focus spectrograph on the 82-inch reflector of McDonald Observatory have made detailed observations of the late-type barred spirals NGC4631, 4027, and 7741 which indicate the presence of large-scale streaming motions of the interstellar gas away from the nucleus and along the bars; the streaming velocities are of the order of 50 to 100 km sec^{-1} (see IAU Symp. no. 20, p. 269).

A. E. Whitford (**31**) has obtained infra-red spectra of the nuclear regions of bright galaxies with a view to using the Sharpless stellar luminosity criteria in the region 7600–8800 Å as an indicator of the proportion of giant and dwarf contributions to the total light. On spectrograms at 200 Å/mm taken with the prime focus spectrograph of the 120-inch telescope of the Lick Observatory no certain trace of the Na I doublet at 8183–8195 Å could be seen for the galaxies M31, 32, 81, NGC2681, 3115, 4406. If contributions of dwarfs to the total light in the infra-red come from types earlier than M0 the lines would be weak and the observations put a limit on the amount of late-dwarf enrichment to account for a mass-luminosity ratio of 15 or more.

D. B. Wood of the Berkeley Astronomy Department measured 22 galaxies through 12 narrowband filters. The Mgb triplet was found to be a sensitive feature. Synthesis of stellar population to match the photometric data showed that dwarf K stars are important contributors to the total visual light, expecially in massive systems.

From photo-electric spectrophotometry of the nucleus of M31 with the 74-inch telescope of the David Dunlap Observatory, S. van den Bergh and R. C. Henry (**36**) confirm Morgan's conclusion that metal-rich cyanogen giants yield a substantial contribution to the total luminosity of the nucleus in blue light.

Van den Bergh has used the 52-inch Schmidt of the Karl-Schwarzschild Observatory to obtain plates in five colours of the galaxies M31 and M33, in order to study the distribution of bright young stars and their relation to the spiral structure. The limiting magnitude of the blue plates is 21·7. Descriptions and finding charts for 188 OB associations in M31 are being prepared.

V. C. Reddish (**38**) has investigated the distribution of bright stars in M31 in relation to the phenomena of obscuration in the system.

In this connection special attention should be drawn to the importance of following up recent enlargements and modifications of Hubble's system of classification, though this system in its classical form remains of paramount importance as basis for investigations on galaxies. A modification introduced by Morgan (**39**) is based on the spectroscopic work on composite spectra of galaxies by Morgan and Mayall, and is intended to be indicative of the general kind of stellar population encountered in the majority of galaxies classified. G. de Vaucouleurs (**40**) has introduced a modified system in which an important point is that in the types discrimination is made between 'ring types' and 'spiral types'. Revised types in this system have been published for 1500 bright galaxies (**50**).

REPORT ON THE ACTIVITIES SINCE AUGUST 1961 OF THE COMMITTEE FOR RESEARCH ON SUPER-NOVAE

(prepared by F. Zwicky, Chairman)

At the Assembly of the IAU in Berkeley in August 1961 a Committee for Research on Super-novae was established within Commission 28. The original members of the Committee were as follows.