28. GALAXIES

As with the 1970 report, it has not been possible to write an all-inclusive account listing everything published by the great number of astronomers in this field (which greatly exceeds the commission membership). The subject headings below are not intended as completely separate divisions, but rather as guides to the contents. Where possible, references are given by the numbers in *Astronomy and Astrophysics Abstracts*; elsewhere, commonly-used abbreviations for journals are used and volume numbers alone without years.

Among the colloquia and symposia on extragalactic astronomy whose proceedings have been published in the last three years are the following. IAU Symposium No. 38, on 'The Spiral Structure of Our Galaxy' (03.012.013), contained a few papers concerned with external galaxies, as did IAU Symposium No. 37, on 'Non-Solar X- and Gamma-Ray Astronomy' (04.012.002). 'Quasars and High-Energy Astronomy' (04.012.005) contained several papers on galaxies and QSOs. Some theoretical work relevant to external galaxies was contained in 'Structure and Evolution of the Galaxy' (Athens; NATO Summer Study; 05.012.006).

A 'Study Week' on 'Nuclei of Galaxies', held at the Vatican in April 1970 (06.012.002), was entirely devoted to the nuclei of galaxies, QSOs, and related theoretical work, and the proceedings are a most valuable reference work. A conference on 'The Magellanic Clouds' (06.012.010) was held at the ESO dedication in Santiago, in 1969.

IAU Symposium No. 44, on 'External Galaxies and Quasi-Stellar Objects' (Uppsala, August, 1970, published 1972) contains a great variety of papers on all topics relevant to Commission 28; most are not included in this report but occasional items are referenced as '*IAU* **44**'.

A large part of the First European Astronomical Meeting, held under the auspices of the IAU in Athens, September 1972, was devoted to problems connected with galaxies. Among the Invited Lectures there were: J. H. Oort, 'Recent Radio Work in Nearby Galaxies'; G. Monnet, 'Recent Optical Work in Nearby Galaxies'; G. Burbidge, 'Galactic Nuclei (including our own Galaxy)'; A. Unsöld, 'Chemical Evolution of Galaxies'; B. Strömgren, 'Chemical Evolution of Galaxies'; G. Contopoulos, 'Theory of Spiral Structure'; D. Lynden-Bell, 'Theory of Spiral Structure'; B. E. Westerlund, 'Magellanic Clouds'; J. Einasto, 'Galactic Models and Orbits'. Lynden-Bell gave a summary of the Invited Lecture of V. Ozernoy on Galactic Nuclei.

Several contributed papers also dealt with the above subjects. Among them were 'Neutral Hydrogen Studies of Nearby Galaxies' by R. D. Davies and R. J. Stephenson; 'The H I Distribution in Nearby Galaxies' by D. T. Emerson; 'Gas Motions in the Nuclei of Seyfert Galaxies from H I Observations' by P. J. Warner; 'Structural Changes in Galaxies Due to Collisions' by S. M. Alladin; 'On Galaxy Parameters as Derived from Primeval Turbulence' by N. Dallaporta and F. Lucchin.

I. GALAXIES IN GENERAL

Morphology; catalogues; statistical studies

A revision of the 'Reference Catalogue of Bright Galaxies' (BGC), by G. and A. de Vaucouleurs, is in progress; photographic diameters from the BGC and from Vorontsov-Velyaminov's MCG were

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statistically reduced to a system of isophotal diameters and axis ratios at $\mu_B = 25{\cdot}0$ mag sec^{-2} by comparison with about 70 galaxies for which detailed surface photographic photometry is available with photoelectric calibration in the *B* system. Precisely defined *total V* magnitudes, color indices and average *B* surface brightness $B'(0)$ within the isophotal face-on diameter $D(0)$ were derived for more than 1200 galaxies for which *UBV* data are available. Compilation and reduction to uniform systems of all existing radial velocities, 21 cm fluxes and radio continuum emission data for bright galaxies is in progress. Two lists of errata to the BGC were published (*Pub. Astron. Soc. Pacific*, **84**, 461, 462, 1972).

G. N. Sastry and H. J. Rood (06.160.014) derived rectangular coordinates of the 2712 clusters of galaxies listed in Abell's *Catalogue* that allow quick identifications to be made on the charts of the *National Geographic-Palomar Observatory Sky Survey*. Right ascensions and declinations for epoch 1950 were also calculated. They also devised a classification scheme of rich clusters based on the distribution of the ten brightest galaxies (05.160.011).

K. Rudnicki and colleagues in Cracow completed a catalogue of 15650 galaxies in a $6° \times 6°$ field centered on R.A. 11^h19^m, dec. $+35°53'$, observed in blue, yellow, and red with the Palomar 48-inch Schmidt. Limiting magnitudes are 19 in all three colours.

A review article by G. de Vaucouleurs (05.158.072) discusses 'The large scale distribution of galaxies and clusters of galaxies'. F. Zwicky reported on preliminary results obtained with an objective transmission grating on the 40-cm Schmidt telescope at Zimmerwald; such gratings can probably be made as large as 1 m square (02.034.026) and on large Schmidt telescopes should be very valuable in extragalactic survey work.

S. van den Bergh (05.160.002) considered from a discussion of the space density of nearby bright spirals that the Local Group is most probably a real group and not a chance association.

F. Zwicky is checking the 48-inch Schmidt Palomar Sky Survey plates (1950–1956) for supernovae by blinking them against older 'Reject' plates or against more recent plates taken of the same fields. Of the predicted 200 (±) supernovae brighter than $m_{ph} = 18{\cdot}0$, he has so far located about 40, in close agreement with the predicted number to be found on the plates surveyed. Completion of this project will be of considerable value for the determination of the frequency of occurrence of supernovae, as well as for the so-called $V \times \Delta$ statistics (V = symbolic velocity of recession, Δ = distance of the supernova in radians from the nucleus of the parent galaxy).

3484 galaxies were searched for supernovae on overlapping portions of the Palomar Sky Survey, by C. S. Chai and S. van den Bergh (04.125.005). The present data indicate that an 'average' galaxy produces between 4 and 10 supernovae per 1000 years.

Recession velocities; absolute energy distribution

J. B. Oke has been using the multichannel spectrometer to obtain spectral energy distributions and redshifts of galaxies in very distant clusters. The technique is an extension of one used by Baum in 1962 and is described in detail along with some results by Oke (06.160.012). Two galaxies in the cluster (0024 + 1654) first worked on by Humason and Sandage, give $z = 0{\cdot}38$ and 0·41, respectively. The apparent visual magnitudes are 19·9 and 20·2. Two galaxies in the cluster (1447 + 2617), also first worked on by Humason and Sandage, have redshifts of 0·365 and 0·373 and visual magnitudes respectively at 20·5 and 20·3. The brightest galaxy in a cluster (1021 + 0427) discovered by Zwicky has been observed. It has strong emission lines, an apparent visual magnitude of 18·6, and a redshift of 0·28. The continuum may be partly non-thermal. The absorption lines in 3C 295 give $z = 0{\cdot}46$ in agreement with the redshift found by Minkowski many years ago.

The brightest galaxies in two clusters discovered by Gunn in a 16^h field have been studied. One of these, in cluster 23, gives $z = 0{\cdot}27$ and $V = 19{\cdot}6$. The other, in cluster 34, has $z = 0{\cdot}29$ and $V = 19{\cdot}7$; λ 3727 of [O II] is strong in this object.

E. C. Kintner (05.158.096) derived 79 radial velocities (69 new) from spectrograms obtained with the Carnegie image-tube Cassegrain spectrograph attached to the Kitt Peak National Observatory 84-inch telescope. G. Chincarini and H. J. Rood (*Astron. J.*, **77**, 4) derived radial velocities for 144 galaxies.

Optical radial velocities were obtained by W. K. Ford, V. Rubin, and M. Roberts (05.158.024) for about 20 galaxies for which 21-cm velocities differed significantly from published optical velocities. The average difference, optical velocity minus 21-cm velocity has been decreased from 115 km s^{-1} (old optical values) to 33 km s^{-1} (new values). It seems clear that errors in previously published values have been underestimated. Moreover, there is no evidence for a difference between optical and 21-cm velocities out to a redshift of 4000 km s^{-1}.

The automated, computer-controlled spectrophotometer at the Cassegrain focus of the McDonald 205-cm Struve reflector was placed in regular operation in 1971 and used for studies of velocity dispersion and energy distribution in galaxies. D. Wells (thesis) derived the integrated energy distribution in the spectra of a dozen galaxies of various morphological types (E to Im) to calibrate 10-color photometry of 55 galaxies of all types observed by G. and A. de Vaucouleurs and J. E. Solheim, which will be used for calculation of K-corrections. The velocity dispersion in the nuclei of M 31, M 32, NGC 3115, 3379, 4111, 4486, 4486B were measured from high-resolution scans with the same instrument.

Photometry; far UV flux; polarimetry

The results of an 8-year (1960–68) program of *UBV* photometry by G. and A. de Vaucouleurs were sent to press (*Mem. R.A.S.*). Evidence for intergalactic extinction in the Local Supercluster was obtained from an analysis with H. Corwin of $B-V$ color excesses of galaxies observed in this survey (*Astron. J.*, **77**, 285).

With G. R. Carruthers, T. Page planned the Far-UV Camera/Spectrograph Experiment S201 on the NASA Apollo-16 Mission. Galaxies in the ten regions of the sky observed, each region of about 315 square degrees, include the Large Magellanic Cloud, 160 galaxies in 13 groups, 95 in two clusters, and 69 field galaxies. Other objects which may reveal $\lambda\lambda$ 550–1600 Å emission, include 14 X-ray sources, 8 radio sources, and 8 QSOs. Preliminary results (*Science*, **177**, 213; Chap. 13 in 'Apollo-16 Preliminary Science Report', NASA, 1972) show a strange difference between the far-UV flux and distribution of very hot stars in LMC and the Hα emission regions measured earlier by K. G. Henize. The north-eastern region of LMC is relatively very much brighter in $\lambda\lambda$ 1250–1600 Å flux than in Hα, possibly indicating a lack of interstellar hydrogen there. Quantitative results must await computer analysis of microdensitometer readings (1024 $\times$ 1024 on each of 160 photos and spectra). One of the experiment's goals was to record redshifted Lyman-alpha emission from intergalactic hydrogen in clusters of galaxies. If it exists on the photos (from which local Ly-α was filtered out by CaF_2), such emission is very faint.

A. Elvius made polarization observations at Lowell Observatory on galaxies with dust clouds or dust lanes (NGC 3067, 3718, 4216, 4438, 4565, 4826, 5883, 5907). She used the dual-beam photoelectric scanning polarimeter constructed by J. S. Hall. A short report on some of the galaxies with dust lanes was given at the IAU Symposium No. 52. The most interesting result was obtained for NGC 3718 where the 'dust bar' was found to show polarization with the electric vector along the absorption lane, thus indicating that a large-scale magnetic field runs parallel to this peculiar bar structure.

A. Elvius (*Astron. Ap.*, **19**, 193) pointed out that the assumption of scattering of Hα (as suggested by A. Sandage and N. Visvanathan, *Ap. J.*, **176**, 57) rather than recombination in the filaments implies a new interpretation of the observed radial velocities in M 82. It was suggested that the model of M 82 may be entirely different from models previously adopted, if no other explanation is found for the high degree of polarization of Hα observed by Sandage and Visvanathan.

Content of galaxies; spectrophotometric studies of individual galaxies

An extensive review of the nuclei of galaxies was given by G. Burbidge (04.158.045). A full bibliography was given, and nuclei ranging from those of normal galaxies to those in which explosive events have occurred were discussed.

H. Spinrad and B. Taylor, with J. E. Gunn, R. D. McClure, and J. W. Young, concluded work on the stellar content of the nuclei of nearby spiral and elliptical galaxies. Stellar synthesis models for M 31, M 32, NGC 4594, and NGC 3379 and other nearby galaxies were published (04.158.028; 05.158.041, 054). It was concluded that all luminous galaxies have supermetal-rich cores. An evolutionary model of the disk population of M 31 was synthesized by B. Tinsley and H. Spinrad (06.158.008).

In comparing U- and B-plates of the Tautenburg 52-inch Schmidt telescope 7 scattered groupings of blue objects have been discovered in the outer regions of M 31. With distances from the center of the Andromeda nebula between $R = 22{\cdot}8$ kpc and $R = 27{\cdot}9$ kpc the objects still surpass the most distant association OB 188 of van den Bergh ($R = 25{\cdot}0$ kpc). The new objects fit a spiral structure (G. A. Richter, 06.158.007). In another discussion the existence of more distant spiral arms in M 31 was suggested (F. Börngen, *Astron. Nachr.*). L. Richter and N. Richter (*Astron. Nachr.*, **292**, 133) found 13 single OB-stars on the southern borders of M 31. Some of them are more than 30 kpc, in one case 57 kpc, distant from the center of the galaxy. According to their brightness and position in the two-color diagram they definitely belong to the galaxy. H. Arp and F. Bertola (05.158.004) obtained photographs to faint limiting magnitudes for the giant ellipticals NGC 383, NGC 541, NGC 1275, NGC 4261, and NGC 4486 and found the galaxies extend to diameters of several tenths of a parsec. Smaller ellipticals in groups about these giants have similar gradients, but spirals are sharply bounded. The faint outer luminosity is probably due to dwarf stars originating in the central regions. Total masses and mass-to-light ratios will be larger. In many clusters the outer regions of galaxies adjoin.

G. Chincarini *et al.* (06.158.005) presented spectrographic and photometric data for the giant double galaxy in the cluster Abell 1775. They derived a lower mass limit of $2 \times 10^{13}\ M_{\odot}$.

P. W. Hodge studied the structure and the content of NGC 205 photoelectrically and photographically. Isophotometry (*UBV*) provided information on the detailed shape of NGC 205. The isophotes are elliptical in the center and intermediate regions, but show distortion in the outer regions, probably due to tidal interaction with M 31. An anomalous color distribution for an elliptical galaxy was found, the center being decidedly bluer than the outer regions. This is interpreted as being due to the presence in the central area of a number of bright O and B type stars, as first detected photographically by Baade.

The number and distribution of the resolved O and B type stars in the central area of NGC 205 were determined. They lie in an elliptical area nearly centered on the center of NGC 205 and having a mean dimension of approximately 340 parsecs; the centroid is approximately 45 parsecs from the nucleus of the system. The stars measured range from $M_V = -5{\cdot}3$ and $-3{\cdot}7$, respectively. The age of the complex was estimated to be $\sim 5 \times 10^6$ years. The luminosity function suggests that the total mass of Population I stars involved is between 2×10^6 and 2×10^5 solar masses.

Twelve dark nebulae are identified; their distribution is similar to the distribution of OB stars. The ratio of general to selective absorption in one of the dust clouds is found to be approximately $\Delta V/\Delta(B-V) = 3{\cdot}4 \pm 0{\cdot}6$, in good agreement with the solar neighborhood value. Masses estimated for the dust regions range from 10 to 460 solar masses.

Brightness and colors of all of the eight globular star clusters known for this system give a luminosity function that lies approximately 2 magnitudes fainter than that for the clusters of M 31. The colors are normal. A new evaluation of the distance of the local-group galaxy IC 1613, $(m-M)_0 = 24{\cdot}43$, was obtained from Baade's work on its stellar content by A. Sandage (05.158.071).

The nature and origin of the low surface brightness companions to our Galaxy, such as the Sculptor, Fornax and Draco systems, are very interesting cosmogonically. Now three faint objects that are probably Sculptor-like dwarf galaxies have been found by van den Bergh near M 31 (*Ap. J. Lett.*, **171**, L31).

Two infrared objects nearby in the equatorial plane of our Galaxy, discovered in 1968 by P. Maffei, were studied by a group of astronomers from Leuschner, Lick, and Hale Observatories (05.158.006). It was concluded that these objects are galaxies which are very highly reddened by extinction in our Galaxy, and it was suggested that they are members of the Local Group. Maffei 1 appears to be an

elliptical and Maffei 2 a spiral; the rotational velocity of Maffei 2 was determined by L. Bottinelli and colleagues (05.158.055) from 21-cm observations to be 200 km s^{-1}, and they thought it was probably more distant than the Local Group. Using a correlation which he derived from data on late-type galaxies between intrinsic color index and maximum rotational velocity, S. van den Bergh (06.158.102) suggested a value $(B-V)_0 = 0{\cdot}60$ for Maffei 2. He suggested (05.158.067) that Maffei nos. 1 and 2 are associated with IC 342 and that all three are about 2 Mpc distant and thus outside the Local Group.

The chemical composition of different galaxies was discussed by G. and M. Burbidge (03.065.080). Evidence was collected for abundance differences, and the relation of these to nucleosynthesis on the galactic scale was discussed.

L. Searle (06.158.029) found that the N/O abundance ratio, and probably also the ratios O/H and N/H, decrease from the inner to the outer areas, from study of spectra of H II regions in Sc galaxies.

G. Welch and Forrester (*Astron. J.*, in press) conducted a spectro-photometric study based on image-tube spectrograms of selected absorption features in the galaxies NGC 3115 (E7/SO) and NGC 4472 (E2). They found significant radial variation – in the sense of decreasing strength with distance – in the violet cyanogen bands at λ 3883, the G-band the MgI + MgH blend at λ 5175 and the 'D' line of neutral sodium at λ 5892.

Physical conditions in the nucleus of M 82 were determined by M. Peimbert and H. Spinrad, from narrow-band photoelectric photometry (03.158.064). A helium/hydrogen abundance ratio of 0·13 was found.

Several people have studied NGC 5253, a galaxy in an interesting stage of evolution. G. A. Welch (04.158.047) showed that, while the central region contains much ionized gas, the underlying distribution of stellar surface brightness resembles that of an E galaxy. L. Bottinelli *et al.* (*Astron. Ap.*, **17**, 445) found its H I gas content was that of a lenticular early-type galaxy. T. Bohuski *et al.* (*Ap. J.*, **175**, 329) measured emission line profiles in the center of NGC 5253 and NGC 5408 (Irr), with the pressure-scanned Fabry-Perot interferometer on the 36-inch at Cerro Tololo, and found that the velocity dispersions in the giant H II regions making up the nuclei of these two galaxies are quite small, only 30 km s^{-1} for NGC 5253. The nitrogen abundance is probably lower in the irregular NGC 5408 than in the peculiar elliptical NGC 5253. J. L. Sersic *et al.* (in press) studied the morphology and spectrum of NGC 5253 and suggested that it may have suffered a violent event of moderate intensity; the presence of a long jet supported this interpretation.

Radioastronomical studies; H I *content and continuum*

Surveys of M 31 and M 33 in 21-cm radiation by R. D. Davies, S. T. Gottesman, and G. de Jager at Jodrell Bank (03.158.098, 099; 04.158.085; 06.158.001) showed the existence of detectable neutral hydrogen out to the edge of the optical object. Velocity distributions were derived for these galaxies which enabled rotation curves to be extended further from the center than is possible with the available optical data. The mass distributions derived from the rotation curves imply that substantial amounts of matter exist in these outer regions. One possible explanation of this material with a low mass-to-light ratio has been made in terms of cool neutral hydrogen, by B. M. Lewis (*Astron. Ap.*, **16**, 165).

Observations were also made by Davies of the irregular galaxies (Type I), NGC 6822, IC 10 and IC 1613. Their neutral emission covers a larger area than the optical counterpart. All these objects show significant rotation. The smaller optical size of the irregular galaxies is interpreted as the consequence of the low neutral hydrogen densities in their outer regions; a similar low rate of star formation is found in the regions of low gas density in M 31 and M 33.

A study was made of the neutral hydrogen content of more distant galaxies, by McCutcheon and Davies 1970 (04.158.035). Sb and Sc galaxies with the greatest absolute optical luminosity appear to have the largest neutral hydrogen content on average. Optical and 21-cm velocity measurements of external galaxies are now available for a total velocity range of 2967 km/sec and indicate that the radio and optical redshift is the same to within 1%.

The systems M 81/M 82/NGC 3077 and NGC 5194/5195 were studied at Jodrell Bank. These surveys are to be used in collaboration with the Leiden and Groningen groups who are taking observations with the Westerbork synthesis telescope to obtain high angular resolution. The Jodrell observations show extended neutral hydrogen throughout the M 81/M 82/NGC 3077 system. Such widespread intergalactic neutral hydrogen within a cluster is unique.

The same receiver system has been used to study the dwarf companions of M 101 and M 31. Neutral hydrogen was detected in 3 companions of M 101; their luminosities and neutral hydrogen contents are similar to those of the Magellanic clouds.

L. Bottinelli (05.158.003) obtained the H I large scale distribution for 35 galaxies, leading to a relation between the H I diameter, the photometric diameter and the morphological type. The true mean H I projected surface density is surprisingly independent of type and the H I distribution is frequently asymmetrical. The study of the integral properties of galaxies was extended down to type Sab by L. Bottinelli *et al.* (03.158.088). 21-cm line investigations by C. Balkowski *et al.* (*Astron. Ap.*, **21**, 303) were extended to galaxies of type SO. The relative amount of H I is not, for early-type galaxies, as low as would have been expected from an extrapolation of values for later types. SO's appear to have an H I component comparable to that for Sa's but, as they have no spiral arms, this raises an important issue for the origin of spiral structure. A 21-cm study of the heavily obscured galaxy IC 10 was made by L. Bottinelli *et al.* (*Astron. Ap.*, **18**, 121).

Extragalactic continuum work at Groningen is pursued using the Westerbork synthesis array, the main areas of research being the study of the detailed radio properties of relatively nearby galaxies of all types.

R. J. Allen and E. Raimond (*Astron. Ap.*, **19**, 317) made a radio map of the spiral galaxy Maffei 2 at 1415 MHz. R. J. Allen, J. E. Baldwin, and R. Sancisi have completed aperture-synthesis observations of neutral H and radio continuum in the edge-on spiral galaxy NGC 891. R. J. Allen and A. H. Rots are studying 21-cm continuum emission from the spiral galaxies M 101 and NGC 6946, while R. D. Ekers and colleagues are making a 21-cm continuum survey of E and SO galaxies. Further extensive programs still in progress are a study of 21-cm continuum emission from Virgo Cluster galaxies, and a study of the radio properties of galaxies with radio luminosity intermediate between 'normal' and 'radio' galaxies. Aperture-synthesis studies of neutral H in galaxies have been completed by D. H. Rogstad and G. S. Shostak for M 101 (05.158.086, 087), and by Rogstad, Shostak, and Rots for NGC 6946 and IC 342 (in press). The question whether NGC 7320 is a member of Stephan's Quintet or a foreground galaxy was examined by R. J. Allen (04.158.009), who concluded that it was probably a foreground object. This was also G. Tammann's conclusion (04.158.071). Radio continuum measures at 21-cm wavelength in the region of Stephan's Quintet, however, show very interesting structure (Allen and J. W. Hartsuiker). Radio continuum emission was observed at this wavelength from the NGC 383 chain of galaxies, but none was detected from the chains VV 150 and VV 172 (R. D. Ekers). Allen and W. T. Sullivan observed 21-cm continuum emission from the interacting galaxies NGC 2798-9. Radio observations of neutral H in four Seyfert galaxies were made by Allen and colleagues (05.158.001).

Heeschen (03.158.095, 096) investigated some radio properties of nearby giant E and SO galaxies. About one-half of the galaxies studied have active radio nuclei, similar to those of variable QSO's and radio galaxies. These objects all have complex radio spectra, while those of larger radio size have simple power-law spectra. He also finds a correlation between degree of sphericity of the galaxies and radio emission in the sense that spherical systems are more likely to be radio sources than are flattened systems.

Rotations; masses; and mass-to-light ratios; mass discrepancy

T. Page continued work on about 100 spectra of southern galaxies obtained with an image-tube spectrograph at the Newtonian focus of the Cordoba 60-inch telescope in Argentina. These calibrated spectra have yielded velocities and energy distributions from 3500 to 6800 Å, including emission-line intensities. Results are being used to determine stellar and gas content. He is also working with

A. D. Code, G. A. Welch and others on OAO-2 ultraviolet photometer and spectrophotometer data on about 20 bright galaxies, and with H. J. Rood and G. Chincarini on image-tube spectra obtained at Kitt Peak. With Rood, Kintner, and I. A. King, he published a detailed study of the Coma Cluster of galaxies (*Ap. J.*, **175**, 627), using accurate radial velocities and magnitudes which show dynamical differences between the central core and outer regions, and $M/hL = 330$.

A proper listing of the 88 individual radial velocities of galaxies used by Page in 1961 to determine average masses and mass/luminosity ratios of galaxies in pairs was published (03.158.032), and a summary of known binary galaxy characteristics is in press in *Galaxies and the Universe*. The latter, delayed several years in publication, records new statistical data on the types, sizes, masses, and orientations of galaxies in pairs. These show that, by type, size and mass, galaxies in pairs and small groups do not differ significantly from those in the field. Page's study of angular momenta in pairs (based on orientations) is not yet complete because of serious selection effects in all available lists and catalogues of binary galaxies.

Rotational velocities in M 31 were determined by V. Rubin and W. K. Ford (03.158.026) from observations of H II regions, 3 kpc $< R <$ 24 kpc from the excited gas in the nuclear disk, $R <$ 2 kpc (Rubin and Ford (06.158.100), and for stars, $R <$ 2 kpc (Rubin, Ford and Kumar, in preparation). There is a flat ($z \sim 25$ pc) rotating gas disk within 400 pc of the nucleus; in some position angles there are superimposed expansion motions, and low lying clouds are falling to the plane. Beyond 400 pc, rotational velocities rise to over 200 km s^{-1}, and then fall to a minimum near $R = 1600$ pc. For $R >$ 3 kpc, velocities from the H II regions show a maximum $V = 250$ km s^{-1} near $R = 10$ kpc, and then are flat at 200 km/sec out to $R = 24$ kpc. Observations by M. Roberts at 21-cm indicate that the rotational velocity remains at $V = 200$ km s^{-1} out to 34 kpc.

Stellar velocities resemble the gas velocities, with a steep velocity gradient across the nucleus, and a minimum near $R = 1600$ pc, thus confirming Babcock's 1939 observations.

Abundance studies across the galaxy (Rubin, Kumar, Ford, *Ap. J.*, **177**) indicate an overabundance of nitrogen, oxygen and sulphur (relative to hydrogen) in the nuclear gas, and in some innermost H II regions. Abundances of these elements systematically decrease across the disk to $R = 15$ kpc, beyond which there is no certain trend. The He I λ 5876 line is too weak to make any statement concerning an abundance variation in helium.

F. Bertola and M. Capaccioli (03.158.035 and later correction) computed the mass of M 87 by means of the virial theorem, using the luminosity profile given by de Vaucouleurs, and obtained a value $2{\cdot}7 \times 10^{13}\ M_{\odot}$. The mass-to-light ratio was 100. Bertola and S. d'Odorico (*Ap. J. Lett.*) derived rotations and masses of the double galaxy NGC 7752–53 and, from the large velocity difference between them, concluded that the system is not bound. Bertola (*Mem. S. A. Italia*) reviewed the difficulties of observing absorption-line rotation curves for galaxies with little or no ionized gas, and gave results for the E or SO galaxies NGC 4762, NGC 4697, NGC 128, and NGC 4125. Two Fabry-Perot interferometer systems were placed in operation at McDonald Observatory in 1971–72 for work on galaxies in conjunction with a red-sensitive Varo image converter, and a systematic survey was started to measure internal motions and rotation in galaxies smaller and/or fainter than those accessible to unaided photography.

W. C. Saslaw (03.158.062) found that the radii, R, and constant angular velocities, ω, of the central regions are correlated in Sb and Sc galaxies. These correlations may differ for the two classes of galaxies. In Sb galaxies, R and ω may also be correlated with the mass of the galaxy. He found little correlation between the position of a galaxy on the dynamical $R - \omega$ sequence and the stellar content of its central regions. This suggests that different amounts of evolution from similar initial conditions are insufficient to account for the variety of dynamical and stellar properties among Sb and Sc galaxies (05.151.002). Although protogalaxies may form with a variety of initial conditions, whose details may be dispelled early by dissipative processes, Saslaw (05.162.044) considered that rotation curves may provide clues to conditions during an early era of dissipation. He calculated quasi-stationary rotation curves for highly turbulent, gaseous, non-magnetic protogalaxies which are acted upon by external torques. The main observed properties of rotation curves for evolved Sb and Sc galaxies can be reproduced if the initial density and viscosity distributions are not strongly

centrally concentrated, if the central solid-body regions of protogalaxies do not contract substantially as they evolve with detailed angular momentum conservation, and if the outer regions evolve non-homologously.

S. J. Aarseth and W. C. Saslaw (*Ap. J.*, **172**, 17) examined the mass discrepancy in groups, firstly from the point of view of systematic errors in the determinations. The average net effect of these is to increase the discrepancy between virial and luminosity masses. On the hypothesis that the groups are unbound and expanding, models of initial instability were developed which can give rapid expansion, and models with significant mass loss can also reproduce the observed discrepancies. It should be possible to distinguish observationally between the hidden-mass and the expansion hypotheses.

A. M. Wolfe and G. Burbidge examined the possibility that the large mass-to-light ratios in elliptical galaxies could be produced by the existence of much hidden mass in the form of 'black holes'. Observational data were used to set limits on the amount of mass in such a form.

Non-circular motions

For about forty galaxies whose velocity fields indicate the non-circular motion, T. Kogure and N. Toya (04.158.021) compiled various observational data and made an attempt at preliminary classification according to the region where some non-circular motion appears. Statistical studies show that the radio luminosity and nuclear brightness of galaxies have positive correlations with occurrence of the non-circular motion, whereas no such correlation is found for the total mass and neutral hydrogen mass of galaxies.

Radial velocities of H II regions in M 33 and M 101 were measured with the McDonald interference filter scanner (G. and A. de Vaucouleurs, 05.158.050). An extensive observational and theoretical analysis of the structure and dynamics of barred spiral galaxies, in particular of the Magellanic type, was published by G. de Vaucouleurs and K. C. Freeman (*Vistas in Astronomy*, **14**, 163).

For each of the barred spiral galaxies NGC 1300, 3551, and 5383 spectra in numerous position angles in the nucleus, the bar, and the arms have been obtained by Rubin and Ford. Velocities of excited gas, and of the stars in the bar are presently being derived to study details of the velocity fields in barred galaxies. For NGC 1300 and 5383, observations at 21-cm are underway by the Dutch astronomers, using the Westerbork interferometer.

A study of non-circular motions in the nuclear region of the highly disturbed Sc radio galaxy NGC 253 was made by M.-H. Ulrich and M. Burbidge (03.158.033). Evidence for outflow of gas in a cone at a considerable angle to the axis of rotation was presented.

H. Arp and F. Bertola (04.158.002) measured the velocities of the compact components in the nucleus of NGC 1808 (Morgan's 'hot spots'). They concluded that the components are not in dynamical equilibrium and are probably moving outward from the nucleus.

D. W. Weedman (03.158.027) studied gas motions in the nuclei of some Markarian galaxies, some of Tifft's spirals with blue nuclei, and some bright spirals. An apparent difference of 1300 km s^{-1} between emission and absorption lines in NGC 4569 was found by A. W. Rodgers and K. C. Freeman (04.158.011) and by E. M. Burbidge and P. M. Hodge (05.158.069) to be due to an error in the Humason, Mayall, and Sandage catalogue; the latter authors measured the rotation curve of NGC 4569 and by comparison of the parameters with other well-studied rotation curves deduced that NGC 4569 is indeed at the distance of the Virgo cluster although it has a velocity of -370 km s^{-1}. Large velocity differences reported earlier in the peculiar southern galaxy NGC 6438 were not confirmed by observations made at Cerro Tololo (*Ap. J.*, **171**, 253).

Theoretical: structure and evolution

G. Contopoulos (05.151.001) studied the dynamics of galaxies near the inner Lindblad resonance and near the particle resonance. Near the inner Lindblad resonance the response of slightly growing

waves is trailing if the imposed field is either trailing or leading. Self-consistent models were also found by Contopoulos and E. Georgala (1st European IAU Meeting, 1972; *Ap. J.*, 1973, in press) which, in the limit of infinitesimal growth, tend to the model found by J. W. Mark (*Proc. Nat. Acad. Sci.*, **68**, 2095) in the trailing case, while they give infinite amplitude near resonance in the leading case. Thus a preference of trailing spiral waves is obvious.

Non-linear effects near the inner Lindblad resonance were studied by Contopoulos (03.151.029). Stellar orbits are trapped near two periodic orbits, similar to two perpendicular ellipses. Thus two elliptical rings are formed. The main ring is a continuation of the spiral arms. It seems probable that the gas moves along the main ring which appears like a bar. R. B. Tully (thesis, 1972) found that such a model explains the kinematics of the central region of M 51, while the expansion models seem inadequate. S. C. Simonson and G. L. Mader also found that such a model can explain most of the observed kinematic features near the center of our Galaxy.

It seems that bars are formed near the inner Lindblad resonance, both in the case of normal and barred spirals. A study of the dynamics of barred spirals has started by Contopoulos (Maryland lecture notes, 1972) and Mihalodimitrakis.

A study of the particle resonance in spiral galaxies was made by Contopoulos (*Ap. J.*, in press). At corotation distance there are four equilibrium points, two of them unstable (at the minima of potential) and two stable (L_4, L_5, at the maxima of potential). Orbits near L_4, L_5 librate around these two points. This phenomenon, found first by Barbanis (03.151.044) was explained theoretically. It was found that if the spiral force is 4% of the axisymmetric field, about 40% of the mass in a ring around the center, 2 kpc wide, is trapped near L_4 and L_5. Self consistent models were also considered.

A review of our present knowledge concerning the theory of spiral structure is contained in the Maryland Lecture Notes of Contopoulos.

In theoretical studies of the evolution of galaxies, W. C. Saslaw developed a method for deriving the statistical mechanics of violently relaxing systems directly from the 6-N dimensional Liouville theorem (04.151.020), and suggested a quantitative mathematical definition of violent relaxation. Saslaw and D. S. De Young (06.151.049) showed that under very general conditions self-gravitating systems with particles of different mass cannot be in equipartition. Thus the rate of evolution of dense stellar systems is usually faster, and the conditions for forming dense galactic nuclei are less restrictive than previously supposed.

A. and J. Toomre computed the forms that can be produced by close encounters between galaxies and applied the discussion to various galactic bridges and tails found between close pairs of galaxies. Further theoretical studies of structures lying out of the principal plane of the galaxy are being made by C. C. Lin and A. Toomre.

Clusters

W. W. Morgan and L. P. Bautz (04.160.015) developed a classification system for clusters of galaxies, based on the relative contrast of the brightest member galaxy. Clusters containing a supergiant D galaxy define Type I; at the other extreme (Type III) are clusters which contain no members significantly brighter than the general bright population. Type II clusters are those whose brightest galaxy, or galaxies, are intermediate in appearance between class cD and the Virgo-type giant ellipticals. A list of seventy-six clusters classified according to the present system was given.

Objective prism spectra for galaxies in the Coma and Virgo clusters were obtained by A. G. Davis Philip and N. Sanduleak (03.160.003), and composite color indices were obtained from which the bluest and reddest galaxies were picked out and color-magnitude diagrams for the clusters were drawn. The method was applied also to the Hercules cluster and Abell Nos. 2197 and 2199 (03.160.004), and with J. W. Sulentic, to Abell No. 194.

Turnrose and Rood (03.160.006) found that a model of the Coma cluster which consists mainly of ionized gas has serious physical restrictions. Hβ and X-ray data limit the temperature to the range 10^4–10^6K, substantial heating mechanisms are required to maintain that temperature over

the age of the cluster, and some way of preventing collapse of the gas is needed. Rood, Page, Kintner, and King (04.160.008; *Ap. J.*, 1972) analyzed radial velocities in the Coma cluster in conjunction with data on the density distribution. It was found that the cluster extends to more than 200′ in radius, with bright and faint galaxies distributed nearly the same. Some spirals are members. Several different determinations of M/L give values around 250 $M_\odot/L_\odot$.

Welch and Sastry (*Ap. J. Suppl.*, **169**, 3; *Ap. J.*, in press), by isodensitometry of deeply exposed plates of the Coma cluster, detected diffuse luminous material at the center of the cluster. They also compared the ability of thermal, synchrotron and inverse Compton mechanisms to match currently available observations of diffuse radiation in the central region of the Coma cluster. Brookes and Rood (05.158.059) found that plots of radius versus magnitude for elliptical and SO galaxies in the core of the Coma cluster show bright and faint sequences separated by a transition region.

Chincarini and Rood (06.160.002) studied the dynamics of the core of the Perseus cluster. The velocity dispersion, 1420 ± 140 km s^{-1}, is the largest of any cluster studied up to the present. To prevent the escape of the giant radio galaxy NGC 1265, and to stabilize the cluster, a mass on the order of $10^{15} M_\odot$ is required.

Rood, Rothman, and Turnrose (04.160.011) investigated the dynamical parameters of 50 nearby groups, derived primarily from basic data compiled by de Vaucouleurs. It was found that the mass ratio M_{VT}/M (ratio of virial-theorem mass to that derived by summing the masses of individual galaxies) is significantly correlated with both radius and velocity dispersion.

G. B. Field and W. C. Saslaw (06.160.013) found correlations in these data between the 'mass discrepancy' and the average morphological type of galaxies in the group, and the time for galaxies to cross the group. They discussed the correlations in terms of binding by large amounts of ionized gas and of gravitational mass loss or ejection of intergalactic gas.

Sastry (04.160.010), by studying Palomar Sky Survey print and plate reproductions, found a number of 'blue objects' in rich clusters. A preliminary survey suggests that there is a tendency for the blue objects to cluster around radio-cD galaxies.

Rood (*Ap. J.*, **171**, 1) showed that if a centrally concentrated cluster is expanding because a force has accelerated the galaxies outward, its velocity dispersion does not decrease from the cluster center to its borders, but first *increases* from the center to a 'turnover radius'.

II. COMPACT GALAXIES

Positions, estimated apparent photographic magnitudes, colors and structural characteristics of 4000 compact galaxies were published in a catalogue of Selected Compact Galaxies and Post-Eruptive Galaxies by F. Zwicky (Bern 1971) which can be purchased from the author. Variability characteristics, spectral features, symbolic velocities of recession, etc. of several hundred objects, as well as finding charts for some groups and clusters of compacts are also given. The search for outstanding compacts and post-eruptive galaxies has been continued. The new results will be published in an addition to the above catalogue. Coincidences with radio sources are being checked by several observers. Additional variable compact galaxies or compact galaxies with supernovae have also been found.

A spectroscopic survey of 141 compact and peculiar galaxies from Zwicky's lists was made by W. L. W. Sargent (03.158.063). The objects fall into several categories: Seyfert-like spectra, sharp emission lines as found in giant H II regions, galaxies with only absorption lines, and some with continuous spectra without visible lines. Resession velocities, apparent and absolute magnitudes, and spectral characteristics were tabulated. In one of these objects, NGC 1614 (II Zw 15), M.-H. D. Ulrich measured the rotation of the nuclear region and estimated its mass; she found Sargent's velocity to be in error, the correct value being 4654 km s^{-1}.

Among the interesting Zwicky compact galaxies, two studied by W. L. W. Sargent and L. Searle (04.158.093) have spectra like giant H II regions. Either they are young systems, or they have radically different stellar luminosity functions from that in our Galaxy. In a later study of these objects, Searle and Sargent (*Ap. J.*, **173**, 25) determined abundances of He, O, Ne in these objects.

Helium has a normal solar-neighbourhood abundance, but O and Ne are underabundant relative to hydrogen. It was suggested that star formation may occur in bursts in galaxies like these, the burst separated by long quiescent periods. Search for objects in the quiescent phase could check this hypothesis.

The search for spherical compact galaxies in a field of 35 square degrees round the globular cluster M 3 resulted in a catalogue of 745 objects down to 18·5 mag (L. Richter, N. Richter and H. Schneller, *IAU* **44**). The catalogue contains positions, *UBV* magnitudes, and concentration indices and will be completed by spectral classification by means of the new 135-cm objective prism on the Tautenburg Schmidt camera. The statistical results of the catalogue show that most of the compact galaxies are normal members of large clusters of galaxies. They include more than 30% of the whole cluster population. On Tautenburg plates about 20 objects per square degree can be selected down to 18·5 mag. In a newly started search for compact galaxies in a field of 10 square degrees round M 92 more than 210 new objects down to 18·5 mag were found by L. Richter and N. Richter (*Astron. Nach.*, **292**, 103). The light outburst of the compact galaxy R 1344·5+3010 was observed between 1966 and 1967 with an amplitude of one magnitude in *B* within a few weeks (L. Richter and N. Richter, 04.158.044).

J. L. Sersic has prepared a list of galaxies with peculiar nuclei, in continuation of earlier studies by Sersic and M. Pastoriza. F. Bertola and F. Lucchin (06. 158.130) studied morphological properties, colours, and magnitudes of the first 600 of the Zwicky compact galaxies. A high percentage of double and multiple galaxies was found.

P. Chamaraux *et al.* (04.158.020) observed five compact galaxies for neutral H, and for the first time a definite detection resulted in one (II Zw 40) and probably two others, with a low internal velocity.

III. RADIO GALAXIES; QSOS; SEYFERT, MARKARIAN, AND N-TYPE GALAXIES; REDSHIFTS

Identifications of sources, morphology, statistical studies

J. B. De Veny, W. H. Osborn, and K. Janes prepared a Catalogue of Quasars (06.141.199), with published optical data and a bibliography to June 1971.

Possible identifications in the 5C 4 radio sources in the field of the Coma Cluster of galaxies were listed by M. A. G. Willson (04.160.009) and a re-examination of the field was carried out by C. Barbieri and F. Bertola (*M.N.*, 166, 399) using deep III aJ 48-inch Palomar Schmidt plates. M. V. Penston (06.141.206) made a complete search for optical identification of the Ryle-Neville radio survey.

Smith and Spinrad began a program of radio source optical identification, using new deep red-region reflector photographs. Faint radio galaxies have been found at the positions of 3C 13, 16, 42, 44, 49, 55, 68.1, 208.1, 330, 434, 435, and 458.

From a complete photographic *UBV* photometry near M 3 by W. Bronkalla (06.113.013), in a field of 3·1 square degrees to the limiting magnitude $B=20^{m}0$, for the number N of blue objects (with $U-B=-0{\cdot}4$) per square degree brighter than magnitude B, the relation $\log N=(0{\cdot}66\pm0{\cdot}08)(B-18)-0{\cdot}04\pm0{\cdot}07$ was obtained. The percentage of the blue objects is 2% of the total number of stars brighter than $V=19^{m}5$. White dwarfs and QSOs are not distinguished.

On plates with the Tautenburg 52-inch Schmidt telescope optical objects down to $20^{m}5$ near the position of 5C2 radio sources were measured astrometrically. From a statistical investigation it follows that about 15% of all radio sources in the 5C 2 field are related to optical objects down to $20^{m}5$ (P. Notni *et al.*, *Astron. Nachr.*, **293**, 221). Similar investigations for the fields 5C 1, 5C 3 and 5C 4 are under way. In connection with the astrometric determination of positions of objects near 5C 2 radio sources it was suggested that some 5C 2 radio sources previously identified with normal spiral galaxies are associated with supernovae remnants in these galaxies (*IAU* **44**). Further it was supposed that two radio sources in Maffei 1 are also supernova remnants (*Phys. Sci.*, **231**, 1971).

An investigation into the real number of suspected QSOs in the Tautenburg catalogues of blue

objects was completed. From 353 blue objects of the catalogues 280 have $U-B \leqslant -0^{m}40$. 70% of these are on the right side of the blackbody line in the two-color diagram and therefore especially suspected to be QSOs. The other 30% are on the left side in the region of white dwarfs. But it was shown that these must also be suspected to be QSOs and not white dwarfs.

It was found that on Tautenburg plates about 50 blue objects per square degree, suspected to be QSOs, can be selected down to a B magnitude of 20·5 (N. Richter, *Ann. Univ. Obs. Wien*, **29**, No. 2). A special investigation by L. and N. Richter and W. Wenzel (06.113.044) into the variability of blue objects showed that variations of more than $0^{m}5$ seldom occur.

W. W. Morgan and his associates have been concerned with the morphology of Seyfert, N, and compact galaxies. The optical forms of five Seyfert galaxies (NGC 4051, 1068, 4151, 3516, and 1275) are related to the forms of a standard sequence of giant spirals and ellipticals [NGC 4303 (fS), 4501 (gS), 2841 (kS), and 4472 (E)] on the Yerkes form-classification system. The form-relationship is described in terms of an operator F, which, when acting on a normal spiral, produces a Seyfert galaxy. Successive applications of the operator F on gS and kS normal spirals generate a surface which can be used for an integrated classification of Seyfert galaxies, radio N-type galaxies, and some of the Markarian and Zwicky blue compact galaxies (Vatican Conference).

Some methods currently in use for the classification of the optical forms of the 'compact' galaxies and quasi-stellar objects were reviewed by Morgan in *IAU* **44**. It was shown that the category 'Seyfert galaxy' is basically a spectroscopic (rather than a form) classification.

An optical form-classification was described which is, in principle, identical with published classification criteria for QSO, N-type, and compact objects. The general characteristics of the forms of the Zwicky, Markarian and Haro objects were compared. The importance of maintaining rigid form-standards was emphasized.

Morgan (06.158.114) described a general N-type classification for galaxies having unstable nuclei; it derives out of morphologies by L. M. Ozernoy, and by Morgan himself. The N characteristic is represented by three subgroups (N+, N, N−), which are situated between the normal spirals on one side, and the QSS on the other. This arrangement formalizes the conclusions of a number of investigators. The classification is applied to a group of direct photographs of Zwicky compact objects obtained by W. L. W. Sargent with the 200-inch Hale reflector.

Some objects labelled QSOs are actually compact galaxies with easily-visible extended diameters; B 264 and Ton 256 (Arp, 04.141.198) are examples.

R. C. Roeder has continued to examine the statistics of the distribution of redshifts of QSOs. With R. G. Lake (*J.R.A.S. Canada*, **66**, 111) he found effects with periods of 0·070 and possibly 0·026, whose physical significance is not clear. Bahcall and Peeble's statistical test for the origin of absorption lines in QSOs was extended using several model universes (*Ap. J.*, **171**, 451). The results are inconclusive and depend on the model. The probable effects of terrestrial atmosphere on measurement of redshifts in QSOs were considered, with C. C. Dyer (*Nature*, **235**, 3). Gross effects depend on the wavelength bands which are most accessible to observers.

Wills and Bolton (02.141.183) measured improved radio positions for 451 4C radio sources in the area $+04° < \delta < +20°$, $03^{h}30^{m} < \alpha < 23^{h}30^{m}$, using the Parkes radio telescope, and suggested optical identifications with 22 galaxies and 72 quasi-stellar objects. Lynds and Wills (*Ap. J.*, **172**, 531) made spectroscopic observations of a complete sample of these identifications at Kitt Peak, including the 18^{m} object 4C 05.34 which has a redshift of 2·877, the highest presently known (03.141.066). The observations were analyzed using Schmidt's 'V/V_{max}' technique and the two-dimensional (radio and optical) luminosity function was derived at a distance corresponding to $z=1$. The number density evolution of the QSOs could be well represented by a linear law in V (co-moving volume). The distribution of QSOs around the sky was examined by Wills (06.141.190) who concluded that early indications that QSOs with redshifts $z>1{\cdot}5$ are concentrated near the North Galactic Pole are not confirmed by larger complete QSO samples. There is, however, a suggestion of a NGH/SGH asymmetry in the distribution of QSOs with $z>1{\cdot}5$ (and, especially $2 \lesssim z \lesssim 2{\cdot}5$), when a larger incomplete sample is analyzed. The redshift distribution among 208 radio-detected QSOs was also given. Wills (*Nature*, **238**, 70) suggested that the observational selection

effects on the z-distribution, pointed out by Roeder and by Roeder and Dyer, were somewhat overestimated in importance by these authors. Accurate radio and optical positions for the source 3C 220.2 agreed so well that Wills and Lynds (*Astrophys. Lett.* **11**, 1972) obtained a spectrogram of the object previously thought to be a galactic star, and found it to be a QSO with $z=1{\cdot}157$. Precise optical and radio positions for 41 radio sources were measured by J. Kristian, A. Sandage and C. Wade (04.141.180, 181).

BL Lac objects

The BL Lac objects, which are almost certainly extragalactic in nature although as yet no lines have been detected in their spectra so that no redshifts have been measured, have been the subject of radio, infrared, and optical observations. J. M. MacLeod (06.141.115) reviewed work and data and gave the results of new observations. P. A. Strittmatter *et al.* (*Ap. J. Lett.*, **175**, L7) gave the results of photometery, polarimetry, spectroscopy, and direct photography of four additional objects of the BL Lac class, together with infrared observations of one of them (OJ 287). An object that may be of this kind has been detected optically; it lies near the peculiar double galaxy NGC 2992-3 (D. Weedman, 06.113.020; P. Strittmatter *et al.*, *Ap. J. Lett.*, 1972).

Photometry, variability of QSOs and active nuclei, polarimetry

M. V. Penston and R. D. Cannon (05.141.046) presented observations looking for variability in 24 QSOs brighter than 17 mag. They concluded that probably all QSOs are variable. With R. A. Brett (05.141.079) they extended their optical monitoring program to include 19 N-type and Seyfert galaxies. Patterns of variability are similar to those found in QSOs. Cannon *et al.* (04.158.178) showed that no positional changes of the center of light of the N-galaxies 3C 371 and 3C 390.3 larger than 400 pc were seen on their plate material. M. V. Penston *et al.* (06.158.002) found variations in NGC 4151 at seven wavelengths between 0·3 and 3·4 μ. The optical and infrared light curves are different. M. V. and M. J. Penston and A. Sandage (06.113.064) gave *UBV* photometry for 113 stars near 18 QSOs, 2 unidentified radio sources, 10 Seyfert and 4 N-type galaxies. Epstein *et al.* (*Ap. Lett.*, in press) performed coordinated optical, infrared, and radio observations to search for variations of 3C 120, BL Lac, and OJ 287 with a time scale less than 24 hours.

The infrared radiation in Seyfert nuclei and QSOs, and possible models for its production, were discussed by G. Burbidge and W. A. Stein (03.114.074).

Optical monitoring of QSOs was continued at Herstmonceux by K. P. Tritton and R. A. Selmes (06.141.049). New variables are 3C 175 and 3C 232; variations were confirmed in 3C 249.1, 3C 263, and 3C 380. A new major outburst was recorded for 3C 454.3. No periodic variations were found.

Twelve QSOs and seven Markarian galaxies were investigated for variability on plates taken with the Sonneberg astrographs. Besides 3C 273, Ton 616, and Markarian 1, no variability exceeding the mean error was found. Ton 616 shows variability of 0·4 mag on time scales from hours to one year. The observed long-time-scale optical variations of QSOs and Seyfert galaxies are interpreted by extinction variations of grains in intervening clouds in the quasar envelopes moving against the central cores of the quasars. Small dust particles will be destroyed by thermal evaporation, whereas larger grains will evaporate by impacts of atoms. Both processes yield light curves which are similar to those observed. On the basis of this model the masses of QSOs having absorption lines with redshifts larger than the redshifts of the corresponding emission lines are estimated (06.141.198).

The integrated magnitudes of all bright Seyfert galaxies measured through various apertures were analyzed by G. de Vaucouleurs, R. Mitchell and H. Corwin in terms of a 3-component photometric model, including a nuclear point source, and the true nuclear magnitudes derived. Variations were detected in the nuclei of NGC 1566, 3516 and 5548.

Polarimetric observations were made by A. Elvius; preliminary results are as follows: 3C 345, a

QSO, has variable polarization, around 5%. I Zw 187, compact galaxy, probably an Ohio radio source (identified by J. Warner), has polarization around 2%, $\theta \sim 95°$. The Seyfert galaxies NGC 3227, 3516, 4254, 5548, all have polarization around 1–2%. NGC 4151 is unpolarized (<0·5%).

Spectrophotometry, studies of individual objects

Photoelectric spectrophotometry of emission lines, in particular [S II], in the nuclei of the Seyfert galaxies NGC 1068 and NGC 1275 by E. J. Wampler (05.158.040) gave evidence for strong reddening which was confined to the semi-stellar nuclei of these galaxies. Measurements were also made in NGC 7469, but the infrared [S II] was not detected in it. Gas motions in the nucleus of NGC 7469 were studied by M.-H. D. Ulrich (*Ap. J. Lett.*, **171**, L37). K. S. Anderson (06.158.095) studied the Hα profile in the Seyfert galaxy NGC 5548 and concluded that electron scattering is not the dominant factor in producing the extensive emission wings. The profile shows indications of discrete cloud structures. A similar conclusion was reached by M.-H. D. Ulrich from her spectrophotometry of NGC 3516 and NGC 5548 (*Ap. J.* **174**, in press) which suggested the presence of either disordered mass motions or coherent outflow of gas rather than electron scattering. The broad hydrogen wings could arise in a component of relatively high density and low mass, in which variations could take place in a time scale of a few years.

The absorption components at three discrete redshifts, seen in 1969 in NGC 4151, were found by R. Cromwell and R. Weymann (03.158.043) to be variable on a time scale less than a year. They were not visible at all on spectra by M.-H. D. Ulrich, who, however, detected two additional discrete emission clouds in the nucleus, as well as the two originally detected by M. F. Walker.

Y. Andrillat and S. Souffrin extended their spectrophotometric studies of Seyfert nuclei to the nuclei of galaxies with small-diameter radio sources, NGC 1052, NGC 3031, and NGC 2655 (05.158.021). They determined abundances of O, Ne, and N and physical conditions in the emitting gas in Seyfert nuclei, also the reddening (05.158.014). With D. Alloin they studied equivalent widths of absorption lines in the nuclei of galaxies to determine the stellar population (05.158.002). Y. Andrillat (05.158.082) found a new variation in the spectrum of the Seyfert galaxy NGC 3516; the relative intensities of lines of H and [O III] varied in an interval of $3\frac{1}{2}$ years.

N. Kaneko (*P.A.S. Japan*, **24**, 143) showed that the non-stellar continuum spectrum of the nucleus of the Seyfert galaxy NGC 1068 agrees with the energy distribution of a hot black body with the temperature of 2×10^5K.

K. Sakka, S. Oka and K. Wakamatsu (in press) found NGC 2782 to be a hot-spot nucleus galaxy. Its spectral features differ from, but its activity well competes with, those of Seyfert galaxies.

Spectra of seven compact galaxies were analyzed by K. Kodaira (06.158.074). Two of these show sharp emission lines superposed on F-type spectra, one shows a featureless continuum, and one has an A-type spectrum without emission lines, while the other three show G-type spectra.

Characteristics of extremely compact galaxies CGCG 1622+4112 and 1439+5344 were investigated by H. Karoji and K. Kodaira (*P.A.S. Japan*, **24**, 239) and M. Takada and K. Kodaira (in press), respectively, from analyses of their image-intensifier spectrograms.

From the spectrophotometric measurements of QSOs by Oke *et al.* (04.141.016) the ratio of the number of Hα photons N(Hα) to the number of photons shortward of 912ÅN_L has been estimated by C. K. Kumar. From the fact that only a few ($\approx$5 out of 70) low $z(\leqslant 1)$ objects are seen to have absorption lines in their spectra, they infer that the line emitting nebula on the average intercepts only 0·1 of the radiation of the central source ($\varepsilon \leqslant 0{\cdot}1$). Hence the increase of $N(\mathrm{H}\alpha)/N_L$ with α is interpreted to indicate that the high α objects have larger amplitudes of variation than low α objects.

Spectra of Cyg A obtained by R. Minkowski and M. Schmidt were analyzed spectrophotometrically by S. and J. Mitton (*M.N.*, **158**, 245) and it was found that a reasonable model could be constructed in which condensations at $T = 10^4$K are embedded in a tenuous plasma at $T_e = 10^6$K. Similar models have been suggested earlier for both QSOs and Seyfert nuclei. The excitation is probably produced by a continuing energy source, possibly X-ray emission from hot plasma in shocked filaments. A detailed theoretical study of the production of emission spectra in QSOs,

Seyfert and other explosive galaxies by such high-energy radiation or by energetic particles was given by J. Bergeron and S. Souffrin (06.158.009).

Among systems being studied spectroscopically by M. Feast at Radcliffe Observatory are the peculiar galaxies NGC 3256, 1487 and Anon $1^h18-41°$. Spectra have also been obtained of objects in the triple systems NGC 6770, etc., NGC 434, etc., and of the QSO PKS 2204-54. Direct photographs (U) of some suspected QSOs have been obtained (W. L. Martin and K. Tritton). Such work has benefited from a collaborative link with G. D. Nicholson (Telecommunications Research of C.S.I.R., Pretoria) at the Hartebeesthoek Station.

Direct photographs (B) have been taken in a survey of southern galaxies whose fragmentary published information suggested strongly concentrated nuclei. Calibrated spectra at 155Å mm^{-1} have been obtained of 74 such galaxies and of these 16 show emission lines of [O III], H, [N II], [Ne III] and [S II]. Three galaxies (NGC 3783, 4507, 5844) also show [Ne V], [Fe VII]?, He I, He II and [O I]. The widths of the Balmer lines are approximately 60, 30 and 10 Å, respectively, for these three. NGC 3783 has a very stellar nucleus and shows some infrared excess (in *J*, *H*, *K*, *L*). It would appear to be a Seyfert galaxy. In a continuation of the program photometry (*U*, *B*, *V*, infrared) is planned for the more interesting objects (W. L. Martin).

The central region of M 82, known in the near infrared to contain a number of bright knots, was studied photometrically and spectroscopically by S. van den Bergh (05.158.078). He found that the knots were probably star clusters some 100 times brighter than the most luminous in our Galaxy. He suggested their formation was triggered by the explosion that occurred in M 82 some 10^6 years ago. A combined optical and radio interferometric study of the nucleus was made by P. P. Kronberg, C. J. Pritchett, and S. van den Bergh (*Ap. J. Lett.*, **173**, L47). The nuclear structure is complex, with no detailed correspondence between the small radio components and optical hot spots or with the Kleinmann-Low 10 μ source.

NGC 6814, in Seyfert's list but lacking 'classical' Seyfert nuclear characteristics, was studied spectroscopically by M.-H. D. Ulrich (05.158.052) and photoelectrically by R. Kraft and collaborators (*P.A.S. Pacific*, June 1972). Although not of the characteristic high intensity, the nucleus shows the usual Seyfert-type emission lines and varies with small amplitude in the U band.

Hα interference-filter photographs of NGC 1275, with the filter tuned to the redshift of the main galaxy and to the gas with a relative velocity of $+3000$ km s^{-1}, demonstrate well the filamentary structure produced by the explosive event (R. Lynds, 03.158.044).

A large velocity difference was found by van den Bergh between the two components of the pair of galaxies associated with the radio source 4C 31.04 (04.058.102); if bound, the pair has a minimum mass of $6\times10^{12}M_\odot$.

Redshifts of QSOs and galaxies

Work on the measurement of redshifts in faint galaxies with the Lick image-dissector-scanner was begun by E. J. Wampler, L. Robinson, H. Spinrad and colleagues. Spinrad's preliminary values of z for some of his faint identifications for 3C sources are: 3C 299: $z=0{\cdot}367$; 3C 303: $z=0{\cdot}141$; 3C 318.1: $z=0{\cdot}045$. Tentative values of 0·75 and 0·76 are suggested for 3C 318 and 3C 434, respectively. M. Burbidge (03.141.125) presented further spectroscopic observations and redshift measurements for 19 QSOs and 5 radio galaxies.

Redshifts were measured at Cerro Tololo for 10 radio galaxies (M. and G. Burbidge, *Ap. J.*, **172**, 37), and their spectroscopic features were described. Spectroscopic observations and redshifts of 20 radio galaxies including 10 3CR sources, were published by M. Burbidge and P. Strittmatter (*Ap. J. Lett.*, **172**, L37), who also published similar observations for 22 QSOs (*Ap. J. Lett.*, **174**, L57); in the latter the variability of the large-redshift 5C 2.56 was discussed.

K. P. Tritton (06.141.141) studied objects suggested as QSO identifications in the Southern Hemisphere and listed the results of two-color (U, B) photography. Redshifts were given for 4 objects. An object with UV excess was suggested as the correct identification for the variable radio source PKS 2204-54 (*Ap. Lett.*, **11**, 187), which had previously been identified with a 17 mag SO

galaxy; the stellar object appears to lie in a cluster of galaxies. K. P. Tritton also measured redshifts for 20 southern radio galaxies (*M.N.*, **158**, 277).

The redshifts of the two components of the hydrogen lines in the N-galaxy 3C 390.3 were measured by M. and G. Burbidge (05.158.005). The difference between the redshifts corresponds to a velocity difference of 400 km s^{-1}.

M.-H. Demoulin Ulrich measured the redshifts and described the spectra of 6 radio galaxies (03.141.128). A mass within the innermost 1 kpc radius of NGC 3998 was determined, and estimates of the central density and mass-to-light ratio were discussed.

The spectrum and redshift of the optically variable compact galaxy identified with the radio source 3C 371 were studied by H. Arp and N. Visvanathan (03.158.002). Arp (03.158.003) found luminous corrections between the main galaxy and companion galaxies which form a loose chain; the redshift between the only companion which had detectable lines in its spectrum agreed with that of the main galaxy. However, Arp has found a small average difference between the redshifts of companions of a number of nearby large galaxies, in the sense that the companions have slightly larger values. Two small galaxies near NGC 772 had redshifts of about 20000 km s^{-1} while NGC 772 and one small galaxy nearby have about 2400 km s^{-1}. NGC 7603 is particularly interesting; Arp (05.158.134) found that it has a redshift of 8800 km s^{-1} and a companion galaxy apparently connected to it by one strong and one fainter spiral arm with a redshift of 16900 km s^{-1}.

A comparison of the spatial distribution of the 3C QSOs with small-redshift bright galaxies in the Reference Catalogue of the de Vaucouleurs showed that 4 QSOs with redshifts 0·5–1·4 are much closer to bright galaxies than would be expected if they were distributed randomly (M. and G. Burbidge, P. Solomon, and P. Strittmatter, 06.158.105). If the QSOs are actually associated with the galaxies, their redshifts cannot be cosmological. An additional case was found by H. Arp, M. Burbidge, and C. Mackay (*Ap. J. Lett.*, **171**, L41): 3C 455 is a QSO with $z=0{\cdot}543$ lying only 23″ from NGC 7413, $z=0{\cdot}033$, with which it was formerly identified.

D. W. Weedman (04.158.012) discovered that Markarian 205 lies within the spiral arms of a relatively nearby galaxy NGC 4319, and has a redshift some 10 times greater. Arp (06.158.068) found a luminous connection or bridge between the nucleus of NGC 4319 and Markarian 205, indicating their physical connection; the latter would then have a considerable non-cosmological redshift. The bridge in Hα light at the redshift of NGC 4319 has not been confirmed, but some luminosity in continuum light has been found between the two by R. Lynds and A. Millikan (*Ap. J. Lett.*, **176**, L5), although the latter authors believe this to be a separate background galaxy.

W. G. Tifft has worked on 'redshift magnitude band phenomena', i.e. a general correlation which appears to exist between redshift and galaxy magnitude with a related dependence on morphology (angular momentum) of galaxies (*Ap. J.*, **175**, 613; *Ap. J.*, in press). A third paper extends the redshift band concept beyond the confines of individual clusters. Investigations are underway in several additional galaxy clusters. Preliminary results in A 2199 show that a band phenomenon is present. Other clusters under study are Perseus, A 1367, and outer portions of the Coma cluster.

Absorption line spectra of QSOs

M. Burbidge and R. Lynds (04.141.192) discussed the absorption lines in QSOs, which are so strange in that they are generally sharp but can appear in one QSO at many different redshifts, some very different from that given by the emission lines.

The absorption-line spectrum ($z=0{\cdot}613$) of the QSO PHL 938 ($z=1{\cdot}955$) was studied by M.-H. Demoulin and N. Doras (03.141.116) and by Y. W. T. Chan and M. Burbidge (06.141.020). The absorbing gas has a small velocity dispersion, small number of atoms in the line of sight, and an abundance ratio Fe/Mg slightly higher than the current solar value. Chan and M. Burbidge also analyzed the properties of gas producing the multiple-redshift absorption lines in PHL 938, Ton 1530, and PKS 0237-23.

R. Lynds (05.141.064) analyzed the very rich absorption-line spectrum of the very large-redshift QSO 4C 05.34. Most of the sharp lines are probably Lα at a multiplicity of redshifts.

Groups of astronomers from Princeton and Hale Observatories studied the very interesting absorption-line spectrum of the radio-quiet QSO PHL 957 (*Ap. J.*, **171**, 233). The emission-line redshift is $z=2{\cdot}69$, and there are many absorption line systems ranging down to $z=2{\cdot}207$, or possibly as low as $z=1{\cdot}824$. The most prominent, at $z=2{\cdot}309$, has a very broad and deep Lα. The profile of this line was observed with a 'Digicon' digital image tube on the Lick 120-inch telescope, by E. Beaver and colleagues (*Ap. J.* 1972), and the line identifications were discussed in the light of the 'line-locking' hypothesis – that the absorption lines are produced in filaments of gas ejected and accelerated to ultra-high velocities by radiation pressure (R. Mushotzky *et al.*, *Ap. J.*, **174**, 7). The absorptions are probably produced near the energy source, because there is some evidence that excited fine-structure levels of the ground state are populated.

Markarian galaxies

The five lists of Markarian galaxies have proved an extremely fruitful field of study. Work on these by B. Markarian and colleagues and other workers in the U.S.S.R., is summarized in B. Vorontsov-Velyaminov's section of this report. W. L. W. Sargent (03.158.031) described spectra and gave redshifts for 30 objects, most of which have emission-line spectra, and of an additional 80 objects (*Ap. J.*, **173**, 7); he used these data to estimate the space density of Markarian galaxies and concluded that the brightest comprise 2·5% of all galaxies; the percentage rises to perhaps 10% for the faintest. The space density of very luminous Seyfert galaxies is about 3×10^{-6} Mpc^{-3} mag^{-1} at $M_p=-21$, or 0·5 to 1% of all galaxies at this absolute magnitude. D. W. Weedman (*Ap. J.*, **171**, 5) carried out calibrated spectrophotometry on 23 Markarian galaxies. With *UBV* measures, there is a clear separation in a two-color plot between those that are Seyfert galaxies and those that have narrow emission lines (Sargent estimated that the former comprise some 10% of all Markarian galaxies).

Neugebauer, Oke and Searle have completed a study of 18 Markarian galaxies. Observations include slit spectra, photoelectric scans, and infrared measures at 1·6 and 2·2 microns. These galaxies can be divided into two groups, Seyfert-like objects and objects which appear to be giant H II regions. The Seyfert objects can further be divided into two groups based on:

(a) the shape of the continuum,
(b) the profiles of the permitted and forbidden lines, and
(c) ratio of intensities of permitted to forbidden lines.

Redshifts, absolute magnitudes, and linear dimensions of 28 Markarian galaxies were obtained by M.-H. Demoulin Ulrich (05.158.008). Absolute magnitudes ranged from −17 to −23; the brightest objects were of Seyfert type, and the faintest, without a strong central concentration of light, of Magellanic type. Markarian 6 (IC 450) is especially interesting in that hydrogen emission lines redshifted by 3000 km s^{-1} with respect to the main body were discovered by E. Ye. Khachikian and D. W. Weedman (05.158.043) to have appeared in a period less than a year; they were attributed to a high-density cloud of ionized gas which developed in the nucleus. M.-H. D. Ulrich (*Ap. J. Lett.*, **171**, L35) found that in 13 months this component had weakened and become undetectable; this was explained by the expansion and consequent decreasing density of the ejected cloud.

Non-thermal X-ray emission

The temperature, ionization, and X-ray emission of the jet in M 87 were studied by J. E. Felten, H. Arp, and R. Lynds (03.158.028), and new photographs of the small knots in the jet were used to examine a model in which electrons producing optical synchrotron radiation are continually regenerated by cosmic-ray protons confined in the optical knots. The knots, to contain such protons, must contain at least $3\times10^{7}M_{\odot}$ of gas.

G. Burbidge (03.158.006) showed that the compact non-thermal radio source in M 87 may give rise to a powerful X-ray source through the Compton effect. The small optical structures in the jet

and some of the X-ray flux may come from electrons and magnetic fields generated in small dense pulsar-like objects ejected from the nucleus.

Saslaw and de Young (*Ap. Lett.*, in press) discussed the general dynamics and the X-ray and optical radiation produced by a massive object moving supersonically through a galaxy. A black body or a spinar-type model for the object can produce a long luminous trail when the wake is heated by cosmic rays or the ionization front acts as a catalyst for star formation. The results were applied to Markarian 205 and suggested that it might be a supermassive star of $\sim 10^4$–$10^5 M_\odot$, radius $\sim 10^{14}$–10^{15} cm and effective surface temperature $\sim$20000 K, based on Arp's observations of NGC 4319 and the bridge to Markarian 205.

T. Kogure (06.141.124) applied a revised expanding-source model of van der Laan type to the radio outbursts which occurred in 3C 120, 3C 273, and 3C 279; he pointed out that the outbursts are generally not the remnant phenomena of some primeval explosion but are the phenomena of an explosion in which the energy supply is still continuing. An empirical relation between the observable properties, radio surface brightness and radio index on the one hand and the intrinsic properties linear diameter of the radio source, radio luminosity, and optical luminosity on the other hand, was found. The relation is strong enough to yield useful distance estimates. In this manner, distances of 8 quasars and 17 unidentified radio sources were obtained (G. M. Richter, *Astron. Nachr.*, **292**, 59). On the basis of the radio index-surface brightness diagram, the luminosity function and the luminosity diameter function were determined. The luminosity function differs considerably from a simple power law and supports the distinction into two populations. In the strong population an evolution effect is clearly present and is in a good agreement with the models obtained from the log N-log S counts. The optical luminosities of quasi-stellar radio source, radio-quiet quasi-stellar objects and Seyfert galaxies were compared. At high luminosities ($M < -23$) there is no difference in the form of the optical luminosity function for radio-quiet and radio-emitting objects, whereas at low luminosities this function grows steeply only for radio-quiet objects. This result may possibly be interpreted as indicating a division between the optically bright QSOs and the less luminous objects. The QSOs with the highest radio index show only a small scatter in optical luminosities and thus yield a well-defined Hubble relation (P. Notni, G. M. Richter). The apparent super light velocity observed in some quasi-stellar radio sources are explained by a ring-like flash of radiation (G. M. Richter). A. Elvius (together with H. Alfvén and others) continues the work on antimatter, quasi-stellar objects, and galaxy evolution (*IAU* **44**).

IV. INTERGALACTIC GAS, COSMIC RAYS

D. Sciama considered the possibility that galaxies accrete a substantial quantity of interstellar gas; R. Hunt treated the problem by fluid dynamical equations (06.161.001). Velocity and density contours were calculated. The intensities of X-ray coronas surrounding accreting galaxies such as M 31 and M 87 were calculated (*Nature*, **238**, 320).

K. Brecher and G. Burbidge (*Nature*, **237**, 440) suggested that X-ray emission from clusters of galaxies may arise from inverse Compton collisions of relativistic electrons from the active radio galaxies in the clusters with photons from the microwave background.

B. Takase (*P.A.S. Japan*, **24**, 295) found that the lower the supergalactic latitude of galaxies the redder their corrected color and interpreted this as suggesting the presence of intergalactic absorbing matter concentrated toward the supergalactic plane.

A discussion of intergalactic ionized hydrogen in groups of galaxies was undertaken by P. Chamaraux (*Ap. Space Sc.*, **12**, 58), also Chamaraux *et al.* (05.161.002). The dynamical stability of 33 groups of galaxies was investigated; all except three are unstable if there is no intergalactic matter; it did not appear this could be due to uncertainties in the data, which have been carefully reinvestigated. In view of the possible existence of ionized hydrogen in these groups which may stabilize them, attempts of detection of Hβ have been made, giving higher lower limits for the temperature of the gas than before.

K. Brecher and G. Burbidge (*Ap. J.*, **174**, 253) examined the questions: are there cosmic rays

outside galaxies? Do the cosmic rays detected locally originate outside our Galaxy? Possible sources of extragalactic cosmic rays, their propagation, and confinement were considered.

V. COSMOLOGY

Hubble relation; value of H_0, q_0, extragalactic distance scale

Estimates of the apparent angular diameters of first-ranked E galaxies in clusters were shown to be tightly correlated with redshift (A. Sandage, *Ap. J.*, **173**, 485). The aperture correction to magnitudes of galaxies was derived as a function of z and q_0. With G. Tammann and E. Hardy (*Ap. J.*, **172**, 253), Sandage set limits on the local deviation of the universe from a homogeneous model. A new derivation of the Hubble constant, $H = 55 \pm 7$ km s^{-1} Mpc^{-1}, was obtained by Sandage (*Q.J.R.A.S.*, **13**, 282) from a new calibration of the Hubble plot and by using Sc galaxies of van den Bergh luminosity class I, with $cz > 4000$ km s^{-1}, to avoid local anisotropy. A discussion of the scatter in the Hubble diagram for first-ranked cluster galaxies and a formal value for q_0 are given in *Ap. J.*, **178**, 1, while photometry and the Hubble diagram for radio sources and a discussion of the possible turn-on time for QSOs are presented in *Ap. J.*, **178**, 25.

In a discussion of the extragalactic distance scale, S. van den Bergh (03.162.001) derived the Hubble constant by nine different methods – diameters of H II regions, the luminosity classification of galaxies, the brightest globular clusters in galaxies, mass-to-light ratios of galaxies, comparison of the third brightest members of clusters, supernovae, the surface brightness and diameters of galaxies, and the brightest stars in galaxies. His mean value was $H = 91_{-15}{}^{+19}$ km s^{-1} Mpc^{-1}. No significant difference between H locally and beyond the Local Supercluster were found.

J. Heidmann (04.160.001) found that the luminosity-diameter relation gives a distance indicator which is competitive with other methods and has the advantage of reaching far out in space. When applied to the Virgo cluster, it leads to a distance modulus $30{\cdot}7 \pm 0{\cdot}4$ and to a local Hubble constant 73 ± 14 km s^{-1} Mpc^{-1}.

An empirical and theoretical analysis of 'Inclination and absorption effects on the apparent diameters, optical luminosities and neutral hydrogen radiation of galaxies' was made by J. and N. Heidmann and G. de Vaucouleurs (*Mem. R.A.S.*, **75**, 85). The face-on diameters proved to be excellent geometric distance indicators for groups; the distances of 77 groups derived by this method lead to an average Hubble constant of 100 km s^{-1}, neglecting anisotropy (*IAU* **44**).

To investigate the isotropy of the Hubble constant, V. Rubin and W. K. Ford are obtaining radial velocities of a sample of 200 Sc I galaxies, $14{\cdot}0 < m \leqslant 15{\cdot}0$, distributed all over the sky. For Northern galaxies, magnitudes are taken from the Zwicky catalogue; for Southern galaxies magnitudes are to be determined. We presently have measured velocities for more than 50 galaxies in the sample.

Luminosity-volume test, luminosity-distance relation for QSOs; log N–log S

M. Schmidt (04.141.178) used a sample of optically selected QSOs to derive the space distribution and luminosity function, taking the distances to be given by the redshifts and a Hubble constant $H = 100$ km s^{-1} Mpc^{-1} and $q_0 = 1$. The number per comoving volume element was found to vary as $(Hz)^6$, similar to the density law derived for 3CR QSOs. M. J. Rees and M. Schmidt (06.141.057) discussed the validity of the luminosity-volume (V/V_m) test as applied to QSOs, in reply to a criticism by M. Longair and P. Scheuer (04.141.153). Detailed discussion of these statistics were made with two alternative laws for density evolution, $\varrho = 10^{5\tau}$ and $\varrho = (1+z)^6$ (Schmidt, *Ap. J.*, **176**). Statistics of high-redshift QSOs suggest that the density cannot increase beyond $z = 2{\cdot}5$.

The redshift-magnitude relation for the optically most luminous QSOs was investigated by J. N. Bahcall and R. E. Hills (*Ap. J.*, 1973). They found that the slope of the magnitude-redshift relation for the brightest QSOs is consistent with the value of 5 expected from the expansion of the universe if luminosities are evaluated assuming QSOs are at the cosmological distances implied by their redshifts.

F. Hoyle and G. Burbidge (03.158.102) examined the log S–log z diagram for radio galaxies in its relation to cosmology. They found that, whereas log N–log S plots have always been interpreted as number-distance effects, the flux-redshift plot for 3C galaxies with measured redshifts does not give a Hubble relation but rather a scatter diagram. Thus the log N–log S plot for these galaxies appears to be dominated by the radio luminosity function.

K. Brecher *et al.* (06.141.053) examined the log N–log S curves, and summarized possible ways of interpreting the observations within the framework of different cosmological models.

Cosmogony; cosmological models

The change of the slope in the luminosity function of the members of the Coma cluster near $M = -21$ was interpreted as an evolutionary effect by K. H. Schmidt and H. Oleak (06.160.001). Originally there should have existed many luminous objects now being evolved to invisible masses. If the faint part of the luminosity function is extrapolated beyond $M = -21$, the observed discrepancy in the mass determined by the virial theorem and by summing up the individual masses of the galaxies vanishes. It is shown that the eigenbewegungen of the galaxies prevent the existence of a radiation universe in the past, if the present mean mass density is larger than the critical value 10^{-30} g/cm^3 (H. Oleak, H. J. Treder, *Astron. Nachr.*, in press). A solution of the field equations of Treder's gravitation theory is given for the case of a universe filled with incoherent matter ($p = 0$). The observable universe behaves kinematically in a good approximation like the Milne-model but with flat subspaces $t = \text{const}$ (H. Oleak, *Ann. d. Phys.*, in press).

Dynamical studies of magnetic fields in the Magellanic type barred galaxy were made by M. Fujimoto *et al.* (*Progr. Theor. Phys. Suppl.*, **49**, 181). Comparing with observations of magnetic fields in LMC, they concluded that gas is circulating in the bar and magnetic lines of force are predominantly parallel to the bar.

Non-linear motions of a rotating ellipsoid of viscous uniform gas were treated by Fujimoto (06.061.028). He showed that the large-amplitude oscillations after the first bounce amplify an initial small precession. Introducing a special formula for the viscosity to the Maclaurin and Riemann ellipsoids with large angular momentum, their gradual transformations to the Jacobi ellipsoid were followed numerically.

Finite amplitude and non-spherical pulsations of a uniform gas cloud in smooth gravitational contraction are computed by T. Mizuno and Fujimoto (04.065.157). For some cooling laws, gas clouds collapse in a growing pulsation. H. Nariai and Fujimoto (*Progr. Theor. Phys.*, **47**, 105) derived the dynamical equation for rotating gaseous ellipsoid with uniform density embedded in an expanding universe, in order to assess the importance of the coupling of vorticity with the cosmic expansion in the process of galaxy formation. It was numerically shown that the ellipsoid becomes free from the expansion effects and starts to collapse when the ratio of density of the ellipsoid to that of the background attains the values of 5·4 to 5·6, depending on the configuration of the ellipsoid.

T. Matsuda (03.162.050) carried out numerical computations on evolutionary changes of such physical quantities as luminosity, gaseous mass, temperature, chemical composition, energy densities of cosmic rays, magnetic fields, turbulence, radiation fields and thermal energy. Results showed that the time variation of these quantities are rather small because negative feedback operates. Model galaxies with various initial densities of gas were examined, and it was concluded that the Hubble types of galaxies are not an evolutionary sequence but the initial gas density determines the type of galaxy as was suggested by Holmberg.

Two papers by T. L. May and G. C. McVittie (03.162.035; 06.162.009) describe a general method of solving Einstein's equations for uniform models of the universe that contain both matter and blackbody radiation. The material content is a gaseous fluid whose pressure may, or may not, be zero; the radiation is also treated as a fluid whose pressure is proportional to one-third of its density. Exchanges of energy between the two fluids are allowed for. A number of models are worked out and the constants of a model are shown to be determinable from observation. The temperature of the blackbody radiation fluid does not always vary inversely as the scale-factor; more complicated

relationships are possible and depend on the law of energy-exchange between matter and radiation inherent in the definition of each model.

G. C. McVittie (*M. N.*, **155**, 425) reconstituted the apparent magnitudes (V_c) of the brightest members of 39 clusters of galaxies from Hubble diagrams, and other indirect sources of information, which were to be found in the literature published up to September 1971. A statistical analysis of these led to the empirical conclusion that $V_c - 5 \log z$, where z is the redshift of the cluster, is a constant for the 39 clusters, whose redshifts range from 0·0128 to 0·461. A theoretical method was developed for finding the parameters, q_0 and σ_0, of zero-pressure models of the universe when the empirical conclusion is accepted. Pairs of values of (q_0, σ_0) such as (0·72, 1·09), (1·28, 0·92), (1·34, 0·83) are consistent with the data. The data also determine a relation between the Hubble constant H and the (constant) absolute magnitude M_V of the brightest cluster members.

A. M. Wolfe and G. Burbidge (04.162.029) examined the smoothness of the isotropic X-ray background; if it were due to clusters or superclusters of galaxies, the fluctuations that would be present would exceed those observed. The background may arise from more numerous and smoothly distributed objects of lower luminosity. Hierarchical universes in which the distribution of X-ray sources follows the cosmological mass distribution are ruled out.

Starting from Liouville's theorem, W. C. Saslaw (*Ap. J.*) developed general expressions for the growth of correlations in isotropic systems of gravitating point particles, and applied these to investigate the early evolution of clusters and density fluctuations in an expanding universe. The time scale for the development of clustering can be considerably shorter than the time scale for the growth of linear hydrodynamic perturbations. Successive stages of clustering to form galaxies, clusters of galaxies, and superclusters, can occur in simple models of our universe. The results also suggest a simple explanation for the observed secondary maxima of the density distributions within clusters of galaxies.

E. M. BURBIDGE
President of the Commission

WORKING GROUP ON GALAXY PHOTOMETRY AND SPECTROPHOTOMETRY

(Compiled from Circular No. 10 and Supplement, by J. L. Sersic)

H. D. Ables completed an optical study of nearby galaxies (*Pub. U.S. Naval Obs.*, **20**, 1). G. E. Kron, H. D. Ables, and A. V. Hewitt (*P.A.S. Pacific*, **84**, 303) carried out electrographic *UBV* photometry of the jet in 3C 273. H. D. Ables and P. G. Ables have made a comparison of electrographic, photographic, and photoelectric photometry of NGC 4881 (in press), and H. D. Ables and G. E. Kron have carried out electrographic *UBV* photometry of the jet in M 87. A photometric study by H. D. Ables of the Magellanic irregular type galaxies in the Reference Catalogue of Bright Galaxies is in progress. Studies of NGC 1569, IC 1613, and a A 1009 have been completed and published. The *B* and *V* surface photometry of A 2359 has been completed and the study of A 0956 is in progress.

G. F. Benedict completed a thesis on "Two Color Photographic Superposition Photometry of Lenticular Galaxies in the Virgo Cluster." Luminosity and color index profiles and gradients, integrated magnitudes and colors, concentration indices, effective radii, colors, and surface magnitudes, ellipticity and inclination values and major axis position angles were obtained for NGC 4254, 4267, 4298, 4302, 4313, 4321, 4377, 4379, 4380, 4388, 4419, 4425, 4429, 4435, 4438, 4461, 4503, 4531, 4548, 4550, 4552, 4564, 4567, 4571, 4596, 4608, and 4621. The limiting magnitude reached for these galaxies was $B/(")^2 = 24{\cdot}00$. Significant differences in photometric parameters between Morgan D-type and normal elliptical and spiral galaxies were found, and surprising similarities between the local color-index variations in D-type and spiral galaxies.

At Cordoba a spectrophotometric study of the nucleus of NGC 613, 1672, 1808, 2997, 5236, and 7552 has been made by M. Pastoriza. She also gives the photographic magnitudes of these nuclei and separately their condensations. An extensive photometric and spectrophotometric study of NGC 5253 has been made by M. Pastoriza, G. Carranza and J. L. Sersic. E. Agüero and J. L. Sersic