28. COMMISSION DES GALAXIES

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INTRODUCTION

Important progress has been made in almost all parts of the large field covered by the Commission. The most spectacular and dramatic new chapter of extragalactic research has expanded rapidly. Nine quasi-stellar sources only were known at the time of the XIIth General Assembly. The number of known objects of this class now ranges in the hundreds, and the discovery of the related class of radio-quiet quasi-stellar objects has opened a large field for investigations. Detailed observations of the objects do not keep up with the rapid rate of new discoveries, mainly owing to the small number of suitable telescopes, particularly in the southern hemisphere, and the restricted amount of available observing time.

The present report is based mainly on communications from members of the Commission. With the growth of the Commission's domain it was found necessary to distribute the task of compiling the report. Separate reports are given by:

A. Sandage, on: Quasi-stellar Sources and Objects,
Mrs E. M. Burbidge, on: Spectra, Internal Motions and Masses of Galaxies,
the Chairman of the Working Group on Galaxy Photometry, G. de Vaucouleurs,
the Chairman of the Committee on Supernovae, F. Zwicky,
the Chairman of the Committee on the Magellanic Clouds, A. D. Thackeray.

A report on Researches on Galaxies in the U.S.S.R. again has been given by B. Vorontsov-Velyaminov whose continued cooperation deserves the thanks of the Commission.

The response of the members of the Commission to the President's request for contributions to this Report was in general poor and seems to indicate a lack of interest. In particular, almost no contributions were received from those members who worked on theoretical cosmology and relativistic astrophysics. Under these circumstances the President and the Vice-President of the Commission, G. C. McVittie, felt unable to assemble a separate section on these subjects. With regard to these subjects, the Report is incomplete and superficial. Radio observations of galaxies are in the Report of Commission 40 on Radioastronomy.

SYMPOSIA

The First Texas Symposium on Relativistic Astrophysics was held 16 to 18 December, 1963 (1). The contribution by J. A. Wheeler and his co-workers has been published separately

https://doi.org/10.1017/S0251107X00030571 Published online by Cambridge University Press

in expanded form (2). A report on the Second Texas Symposium on Relativistic Astrophysics was held 15 to 19 December, 1964. A brief report has been given by I. Robinson, A. Schild and E. L. Schücking (3). A summary report on the Miami Conference on Observational Aspects of Cosmology held 15 to 17 December, 1965 has been given by Th. Page (4).

A meeting on Cosmology was held 14 to 16 September, 1964 in Padua as part of the celebration of the 4th centenary of the birth of Galileo Galilei (5).

The 13th Solvay Conference in Physics on The Structure and Evolution of Galaxies (6) was held in Brussels 21 to 25 September, 1964.

IAU Symposium No. 29 on Instability Phenomena in Galaxies was held in Byurakan, 4 to 13 May, 1966.

CATALOGS

A long felt need has been satisfied by the publication of the Reference Catalog of Bright Galaxies by G. de Vaucouleurs and A. de Vaucouleurs (7). I. R. King and A. F. Setteducati (8) have computed millimeter coordinates on the Palomar Observatory National Geographic Society Sky Survey charts for the galaxies listed in the Reference Catalog.

Volume V of the Catalog of Galaxies and of Clusters of Galaxies by F. Zwicky and E. Herzog (9) has been published. Volume III is in press, and publication of the final Volumes IV and VI is expected in December 1967. C. D. Shane and G. E. Kron are engaged in a photoelectric calibration of Zwicky's photographic magnitudes.

Volume II of the Morphological Catalog of Galaxies by B. Vorontsov-Velyaminov (10) has been published. This catalog now covers the sky between the North Pole and declination − 9°.

A catalog containing luminosity classifications of all known dwarf galaxies with diameters larger than one minute of arc has been prepared by S. van den Bergh. Descriptions and finding charts for 188 OB associations in M31 found on plates taken with the 52-inch (132 cm) Schmidt at the Karl Schwarzschild Observatory have been given by van den Bergh (11).

An Atlas of Peculiar Galaxies, mostly from photographs with the 200-inch telescope (508 cm) has been compiled by H. Arp (12).

A catalog of 688 emission nebulae in M31 with precisely measured positions by W. Baade has been completed by H. Arp (13) who has based a discussion of the spiral structure in M31 on this catalog (14).

An Atlas and Catalog of H II regions in galaxies has been compiled by P. W. Hodge (15).

M. Pastoriza and J. L. Sérsic have published a list of galaxies with peculiar nuclei in the southern hemisphere (16). A catalog of 300 H II regions in NGC 300 has been assembled by J. L. Sĕrsic (17).

F. Zwicky has prepared four lists of compact and post-eruptive galaxies which contain 703 objects; these lists are available on request. Additional lists are in preparation.

SPECTROSCOPIC OBSERVATIONS

D. S. Evans and R. S. Malin have continued observations of radial velocities of southern galaxies. Nine galaxies have been observed (18) of which only one has a previous velocity. A velocity measure of the globular cluster NGC 6273 is included in the paper. The paper also includes a velocity measure of part of the gaseous ring of 400″ diameter at $5^h43^m.4$, $-67°53'$ in the Large Magellanic Cloud. Observed radial velocities of + 289 and + 263 km s^{-1} indicate that this is actually a Cloud structure with a diameter of about 100 pc.

G. Carranza has measured radial velocities of 21 southern galaxies with a spectrograph designed by T. L. Page and attached to the 60-inch (152 cm) reflector at Bosque Allegre (19).

The observations are being continued. Spectra of peculiar nuclei of galaxies are being observed by Mrs M. Pastoriza, and some peculiar galaxies are being studied by J. L. Sĕrsic who has completed a study of the interacting galaxy NGC 6438 (**20**).

I. R. King is observing elliptical galaxies for rotation. Some, as observed by R. Minkowski, have pronounced rotation (**21**), while in others no rotation is observable.

V. C. Rubin and W. K. Ford Jr. have obtained low dispersion spectra of faint radio-galaxies, quasi-stellar sources, faint blue objects, and galaxies with telescopes of moderate sizes (< 84 inches, or 213 cm) making use of an RCA cascaded image tube. The spectra extend out to about 8400 Å and hence are valuable for recording lines to the red of the normal photographic region (**22, 23, 24**).

G. and A. de Vaucouleurs have new redshifts for about 100 galaxies derived from about 200 spectrograms taken between 1960 and 1966 with the prime focus B spectrograph of the McDonald 82-inch (208 cm) reflector. The list is to be published in 1967. Redshifts have been measured for about 30 galaxies by narrow band (15–20 Å) photoelectric spectrophotometry with the medium dispersion scanner at the Cassegrain focus of the McDonald 82-inch (208 cm) reflector (**25, 26**), and for about 10 galaxies with an experimental double beam photoelectric photometer equipped with a tunable interference filter attached to the McDonald 36-inch (91 cm) reflector (**27**). Both systems offer significant gains in sensitivity and observing time compared to photographic methods.

F. Zwicky has observed spectra of some compact galaxies (**28, 29**). Previously reported results about the great variety of spectra of all types and color combinations exhibited by these objects are claimed to have been confirmed.

GENERAL PROPERTIES AND STRUCTURE

S. van den Bergh (**30**) has discussed the associations OB 184 and OB 185 in Baade's Variable Star Field IV in M31. The same field is rediscussed by R. Racine (**31**) using composite *U*, *B* and *V* plates prepared by combining 48-inch (122 cm) and 52-inch (132 cm) Schmidt plates. Racine finds significant variations of reddening throughout Field IV. The most frequent value of the reddening is found to be $E(B - V) = 0{\cdot}15$ with some values as large as $E(B - V) = 0{\cdot}50$ occuring. It is not known which fraction of this observed reddening is produced in the Galaxy. Photometry of a 17th magnitude RR Lyrae variable projected on M31, which has been found by A. F. J. Moffat, may help to answer this question. Van den Bergh (**32**) has given a color magnitude diagram of the association *OB 78*. Moffat (**33**) has also used 48-inch and 52-inch Schmidt plates and plates obtained with the Kitt Peak 84-inch (213 cm) to study the brightest variables in M31. Moffat's data indicate that the number of cepheids per unit mass with periods larger than 20 days is between one and two orders of magnitude lower in M31 than it is in the Galaxy. There is some indication that the most luminous cepheids occur in those associations which have the smallest diameters.

Aina Elvius and John S. Hall (**34**) have now published the results of photoelectric polarization measurements in integrated light of NGC 5128 and other extragalactic objects, mentioned in *Transactions IAU*, **12A**.

They have later (**35**) made three-color observations of polarization in the light from NGC 1068, 7814 and 3034 (M82). About 5% polarization in ultra-violet light and less at longer wavelengths was observed in the nuclear region of NGC 1068, where M. Walker had already reported strong UV polarization. This polarization is probably due to synchrotron radiation from the nucleus of this Seyfert galaxy. The observed polarization of about 4% in the center of NGC 7814 is probably due to absorption in the dark band of dust clouds hiding the nucleus of this galaxy.

https://doi.org/10.1017/S0251107X00030571 Published online by Cambridge University Press

Results of the above mentioned polarimetric investigation on M82 and color data obtained in the same observations were discussed by A. Elvius at the IAU Symposium 29 on Instability Phenomena in Galaxies in Byurakan. The color of the filamentary structures in M82 seems to show considerable ultra-violet excess compared to colors usually found in galaxies. The degree of polarization of light from the outer regions of M82 was observed to be mainly in the range 10 to 25% in the ultra-violet and slightly less at longer wavelengths.

T. Hatanaka, S. Hayakawa, K. Ishida and M. Taketani (**36**) give a general review of the evolution of galaxies. This article is part I containing a summary of observational information and a discussion of the evolution starting with a description of the dynamical behavior of a system of gas clouds. The evolution is followed from a primordial gas of high temperature to the formation of galaxies of various types. Morphological features of clusters of galaxies and of galaxies are shown to be characterized by two parameters, the random velocities of the clouds and the rotational velocity of a system of clouds. The following parts II to VII are reviewed. These are concerned with discussions of the properties of the galactic nucleus, of radio galaxies, and of the structure and evolution of spiral galaxies and the stability of spiral arms.

P. W. Hodge has determined in the Sculptor dwarf galaxy colors and magnitudes of 523 stars (**37**). The resulting color-magnitude diagram is very similar to that of galactic globular clusters. In the slope of the giant branch and in the main period of the RR Lyrae variables, it closely resembles the cluster M3. A distance of 88 kpc is derived.

The distributions of the stars in all six dwarf galaxies of the Local Group has been used by P. W. Hodge (**38**) to compare observed and predicted limiting radii. For the three nearest galaxies, the observed limits agree with those computed, but for the three more distant ones, the observed limits are too small. This was interpreted to be in agreement with the fact that relaxation times computed for these objects are extremely large, 10^{12} to 10^{15} years. The orbital parameters of the galaxies were estimated. For the Fornax galaxy the radial velocity of which is known, parameters for the orbit could be fairly completely determined.

A study of the distribution within galaxies of H II regions detected in an Hα survey of some 91 galaxies (**15**) has been completed by P. W. Hodge, and a discussion of the significance of this to the problem of the location of star formation in galaxies was published (**39**).

P. W. Hodge has examined the three-dimensional shape of irregular galaxies by measuring the axial ratios for 131 irregular galaxies, using the Palomar Sky Survey prints and Lick and Mt Wilson photographs (**40**). The resulting frequency-distribution indicated that most irregular galaxies are flat with true axial ratios in the range 0·2 to 0·4. Irregular galaxies are in this sense less flat than late-type spiral galaxies, according to the general consensus for the latter.

I. R. King has completed photographic photometry of NGC 2300, 4261, 4472, 4621 and 4697. (See report of working group on galaxy photometry.) The radial profiles fit Hubble's law well, except at the very centers. They fit de Vaucouleurs' law less well, and the central deviation is greater. The profiles agree fairly well with the relaxed theoretical models computed by R. W. Michie and P. H. Bodenheimer (**41**) and by I. R. King (**42**). Combination of the photometry with velocity dispersions by R. Minkowski (**43, 44**) gives an average photographic *M/L* of 50.

In a summary of mass determinations T. L. Page (**45**) shows the statistical agreement between masses of single galaxies and those in pairs. This summary also shows a trend in mass/luminosity ratio to very large values in clusters.

A discussion of the characteristics of elliptical galaxies and the explosive origin of galaxies has been carried out by J. L. Sérsic (**46**).

Extending Brandt's method of analyzing observational velocity curves, B. Takase (47) has calculated the mass M, the angular momentum Q and the rotational energy T for about 20 galaxies most of which are Sb and Sc. These values were derived by integrating to the limiting radii which had been homogeneously determined by E. Holmberg. In combination with the corresponding integrated luminosities, the mass to luminosity ratio has also been estimated. The relations such as $Q \propto M^{5/3}$ and $T \propto M^{5/3}$ seem to hold in general from statistics.

J. S. Mathis (115) measured helium content of the interstellar gas in two irregular galaxies, NGC 4214 and IC 1569, and also (116) in the 30 Dor nebula in the LMC, and found that in all these cases it is about the same as the helium content of the gas in our Galaxy.

RADIO GALAXIES

H. Arp (48) has investigated pairs of radio sources which are separated by from 2° to 6° on the sky. In a number of cases peculiar galaxies have been found approximately midway along a line joining the two radio sources. The central peculiar galaxies belong mainly to a certain class in the recently compiled *Atlas of Peculiar Galaxies* (12). Among the radio sources so far associated with the peculiar galaxies are at least five known quasars. These quasars are indicated to be not at cosmological distances (that is, redshifts not caused by expansion of the universe) because the central peculiar galaxies are only at distances of 10 to 100 megaparsecs. The absolute magnitudes of these quasars are indicated to be in the range of brightness of normal galaxies and downward. Some of the radio sources which have been found to be associated with peculiar galaxies are galaxies themselves. It is therefore implied that ejection of material took place within or near the parent peculiar galaxies with speeds between 10^2 and 10^4 kilometers per second. After traveling for times of the order of 10^7 to 10^9 years, the luminous matter (galaxies) and radio sources (plasma) have reached their observed separations from the central peculiar galaxy. The large redshifts measured for the quasars would seem to be either (*i*) gravitational, (*ii*) collapse velocities of clouds of material falling toward the center of these compact galaxies, or (*iii*) some as yet unknown cause.

D. S. Heeschen and C. M. Wade (49) made a radio survey of galaxies in the Shapley-Ames catalog, at frequencies of 750 and 1400 MHz. The observations are complete to photographic magnitude 11·2. M. L. De Jong (50, 51) measured the brightness distribution of a number of galaxies at a frequency of 1415 MHz. He found the radio diameters of the galaxies to range from much less than to about equal to the optical diameters. He also found a somewhat higher than average density of radio sources in the neighborhoods of the galaxies. All of the above observations were made with the NRAO 300-foot (91 m) telescope.

T. A. Matthews (52) has studied identified radio-galaxies on photographs with the 48-Schmidt (122 cm) telescope and the 100-inch (254 cm) telescope using fine grain plates. Of about 65 objects studied 10% show absorption features, 7% jets from the nuclear regions, 9% plumes outside the galaxy, 17% structure in the nuclear regions, 9% structure in the envelopes, 47% nonsymmetry in the surface brightness or in the extent of the envelope, and a few show other rarer peculiarities. Matthews suggests that the discussed features are probably caused by the violent explosion which produces the radio source, but no comparable study has been done yet on D galaxies that are not radio sources.

A. Sandage (53) has observed redshifts of nine radio galaxies and finds one of them (3C 305) to be a flattened, rotating galaxy with a faint, uniformly textured spiral arm. In this connection it should be emphasized that NGC 1275 was originally interpreted as a tightly wound spiral on the basis of 200-inch photographs (54). It has later been classified as ED2 from its appearance on a red 48-inch Schmidt plate (55). It is, however, clearly not a spheroidal nebula. The central region surrounding the Seyfert nucleus has a structure which actually is somewhat reminiscent of that found by Sandage in 3C 305, but more irregular, and a spectrum of type A (**56**). The examples of 3C 305 and NGC 1275 show that, as should be expected, the identifications of strong radio sources as spheroidal galaxies on the basis of their appearance on 48-inch Schmidt plates are not entirely reliable. Some galaxies of types E and D with peculiarities may turn out to be spirals or irregulars on more detailed observations.

F. Sato (**57**) has investigated the physical conditions of the radio galaxies NGC 1068, NGC 1275 and Cyg A in terms of the ionization mechanism of hydrogen atoms. Three possible mechanisms were examined, collisions of thermal electrons, thermal radiation from hot stars and ultra-violet synchrotron radiation. The conclusion is that every mechanism meets difficulties. If collisions of thermal electrons play a role in ionization of hydrogen atoms, the kinetic energy of electrons are not high enough to maintain the ionization for the life time of emission line phenomena.

It would seem reasonable to suppose that ultraviolet radiation from hot stars is responsible for the ionization, but this possibility is excluded because of absence of Bowen resonance-fluorescence lines of O III in the case of NGC 1068. If the ionization is produced by synchrotron radiation, relativistic electrons must be provided either by acceleration or by continuous production. Both the acceleration and the production of the relativistic electrons meet difficulties from a point of view of energy balances.

G. de Vaucouleurs has investigated peculiar galaxies showing signs of instability (**58**).

B. E. Westerlund and L. F. Smith (**59**) report identifications and investigations of southern radio sources. An investigation of the Parkes radio source 0521–36 by B. E. Westerlund and N. R. Stokes (**60**) shows that it is a compact (N) galaxy of high optical luminosity and strong radio emission.

D. E. Osterbrock and R. A. R. Parker (**117**) measured the intensities in the spectrum of the nucleus of the Seyfert galaxy NGC 1068, and showed that in the ionized gas $T > 8000°$ and that substantial amounts of neutral gas are mixed into the ionized regions. Frequent collisions between high-velocity clouds probably produce a large part of the observed ionization.

GALAXY COUNTS. CLUSTERS OF GALAXIES

An exhaustive search for dwarf galaxies in the Fornax cluster of galaxies was carried out by P. Hodge, M. Pyper and J. Webb (**61**). Fifty dwarf objects were chosen as probable members of the cluster, and photometry revealed that some are probably sculptor-type dwarfs and others are dwarf irregular galaxies. The spatial distributions of giant and of dwarf galaxies in the cluster are sufficiently different to suggest the presence of equipartition of galaxies of different masses.

The distributions of the stars in all six dwarf galaxies of the Local Group have been used to compare observed and predicted limiting radii (**62**). For the three nearest galaxies, the observed limits agree with those computed, but for the three more distant ones, the observed limits are too small. This was interpreted to be in agreement with the fact that relaxation times computed for these objects are extremely large, 10^{12} to 10^{15} years. The orbital parameters of the galaxies were estimated, and it was found that for the Fornax galaxy, the radial velocity of which is known, parameters for the orbit could be fairly completely determined.

T. Kiang (**63**) has examined the problem of clustering of Abell's rich clusters of galaxies by adapting Neymann and Scott's model of uniform clusters to these objects.

The parameters in the model were determined from the variation of the index of clumpiness K^2 with the cell size z. Random realizations of the model so specified were then effected to produce (*i*) synthetic surface distribution and (*ii*) the variation with separation k of the coefficient of quasi-correlation, $Q(k;z)$ for 2 values of z, and these were then compared with their observed counterparts. Discrepancies of the same sort as found by Neyman and Scott

https://doi.org/10.1017/S0251107X00030571 Published online by Cambridge University Press

in their examination of the clustering of galaxies show up, namely (*i*) the synthetic surface distribution did not reproduce all the 'clumpiness' of the observed surface distribution and (*ii*) the two synthetic $Q(k)$ curves were close together whereas the observed curves for the same two cell-sizes were far apart. The present result on the clustering of Abell's objects, combined with Neyman and Scott's result on the clustering of galaxies and the phenomenon of sub-clustering (**64**) suggest that galaxies are clustered on all scales. This picture is in no way inconsistent with the apparent absence of clustering among radio sources when the great numerical disparity between radio sources and galaxies is remembered. Further, Kiang believes that while there is clustering on all scales, it does not take the form of physically distinct clusters. Kiang also points out that this picture of indefinite clustering naturally results from the mechanism of continual creation proposed by W. H. McCrea (**65**).

H. Neckel (**66**) finds that the brightness distribution within the galaxies plays a serious role in the determination of the optical thickness of the galactic absorption layer from the latitude variation of galaxy counts and from the mean surface brightness of the galaxies. A value of about $0^m.9$ is found for the photographic optical thickness of the absorption layer. General agreement is achieved between the hitherto different results of (1) Hubble's counts of galaxies, (2) the counts by C. D. Shane, C. A. Wirtanen and U. Steinlin (**67**), and (3) the observations of the mean surface brightness. The value of $0^m.45$ for the absorption at the galactic pole and the color excess $B - V = 0^m.05$ or $0^m.06$, which remains unchanged, lead to a value of about eight for the ratio between total photographic absorption and color excess.

C. D. Shane and G. E. Kron are determining the limiting photographic magnitudes of galaxy counts made with the 20-inch (51 cm) astrograph at the Lick Observatory. While not all of the final corrections have been applied, the average galaxy at the limit of identification is quite close to magnitude 19·0. Shane and Kron have also measured the color of several hundred galaxies in different galactic latitudes. Tentative discussion of only a fraction of the measures reveals a small or even negligible relation between latitude and color.

A new analysis of Hubble's galaxy counts has been carried out by G. de Vaucouleurs and G. Malik (**68**) who found serious bias in earlier analyses; in particular the half thickness of the galactic absorbing layer is $A_B = 0{\cdot}5$ magnitude (not 0·25 magnitude) in agreement with Shane's analysis of the Lick counts. An improved expression for galactic extinction as a function of latitude and longitude was obtained.

G. de Vaucouleurs (**69**) has derived distance indicators based on magnitudes and diameters for galaxies in small groups or clusters, and distances of 54 nearby groups have been established; these are in good agreement with distances from van den Bergh's luminosity classification.

G. C. Omer, T. L. Page, and A. G. Wilson (**70**) have intercompared three independent counts of the Coma cluster of galaxies. The three different surveys appear to be consistent with each other. The conclusion is reached that the cluster contains about 800 members to photovisual magnitude about 18·8 and has a radius of about 100′. A possible spatial density distribution is derived from the combined data.

A. G. Wilson studied the distribution of rich clusters of galaxies. Regularities in their distances (**71**) and angular separations (**72**) suggest the existence of larger scale structures than any presently recognized. Radio galaxies also appear to share cluster distributions (**73**) in the sense of indicating the existence of large scaled structures. The redshift distributions may be interpreted as indicative of a continuation of a Charlier type hierarchy up to organizations of the order of 500 megaparsecs.

F. Zwicky and his collaborators (**74-78**) have made extensive studies of the distribution of clusters of galaxies which have shown: (*a*) The largest open, medium compact and compact clusters of galaxies at all distances have the same indicative dimensions, (*b*) There is no evidence for any clustering of clusters of galaxies, all irregularities being accounted for by accidental fluctuations as well as the interference of interstellar and intergalactic obscuration and (*c*) The average size of the cluster cells occupied by rich clusters of galaxies, as determined from the distribution of 7000 clusters of galaxies is about 50 million pc, in close agreement with the value determined by Zwicky in 1938 from the distribution of the hundred nearest clusters then known.

Several investigations of individual clusters of galaxies have been carried out by members of Zwicky's group. R. Okroy (**79**) has investigated the Virgo cluster and confirmed a segregation effect: the number of galaxies per square degree increases towards the center for the more luminous galaxies, but decreases for the fainter galaxies. A similar result was obtained by T. Kwast (**80**) for the Hydra I cluster. K. Rudnicki and M. Baranowska (**81**) find the segregation effect in the clusters Zwicky 156–5 and 156–14, but not (**82**) in the cluster Zwicky 97–8 (= 127–2).

COSMOLOGY AND RELATED SUBJECTS

Relevant observational information on the physical conditions in intergalactic space now begins to become available. One of the most important newly discovered phenomena is cosmic background radiation whose significance has been discussed by R. H. Dicke, P. J. E. Peebles, P. G. Roll, D. T. Wilkinson (**83**). This radiation becomes observable at wavelengths below 20 cm. At longer wavelengths galactic and extragalactic emissions dominate the spectrum. The observed background temperatures are:

2·8 (±0·6) °K at 20·7 cm by T. F. Howell and J. R. Shakeshaft (**84**)
3·5 (±1·0) °K at 7·4 cm by A. A. Penzias and R. W. Wilson (**85**)
3·2 (±0·5) °K at 3·2 cm by P. G. Roll and D. T. Wilkinson (**86**)
3·22 (±0·15) °K at 0·26 cm by G. B. Field and J. L. Hitchcock (**87**),

determined from the excitation of interstellar cyanogen. These results suggest that the background radiation has a blackbody spectrum with a temperature close to 3°K. The discordant value

1·7 (±0·4) °K at 1·5 cm by W. J. Welch (**88**)

has quite recently been obtained. Additional observations obviously are needed to establish the nature of the background radiation beyond doubt.

G. J. Whitrow and B. D. Yallop (**89**) have discussed the problem of background radiation in homogeneous isotropic models in which account is taken of possible intergalactic absorption effects due to the finite extent of the galaxies and to intergalactic matter. The possible effect of relaxing the assumption that on the average the galaxies radiate uniformly in time is also considered in a preliminary way.

In objects with a redshift of 2, Lyman-α of hydrogen and the shortward region of the spectrum become accessible to ground based optical observations. If the redshift is cosmological, neutral hydrogen between the source and us will become observable, either as an absorption continuum extending shortward from the redshifted line to its zero-velocity wavelength if the intergalactic medium is uniform (J. C. Gunn and B. A. Peterson, **90**; P. A. G. Scheuer, **91**) or as discrete absorption features if the intergalactic hydrogen is concentrated in clusters of galaxies (J. N. Bahcall and E. E. Salpeter, **92, 93**). Gunn and Peterson find from the lack of strong absorption shortward of Lyman-α that intergalactic hydrogen accounts for less than 10^{-6} or 10^{-7} of the cosmological density to be expected if the acceleration parameter $q_0 = 1/2$. Thus, most of the hydrogen must be ionized if the discordance between the cosmological density and the density of matter in galaxies is to be explained as due to the presence of intergalactic hydrogen. G. B. Field, P. M. Solomon and E. J. Wampler (**94**) show that H_2

https://doi.org/10.1017/S0251107X00030571 Published online by Cambridge University Press

molecules also cannot contain a major fraction of the mass. The intergalactic gas then must be highly ionized and at temperature close to the limit of about 10^6 °K that has to be set according to G. B. Field and R. Henry (**95**) if the bremsstrahlung from the intergalactic medium is not to exceed the total flux in the X-ray region. It should be pointed out that a very small value of q_0 cannot be ruled out at present, but it is not suggested by any other evidence.

D. W. Sciama and M. J. Rees (**96, 97, 98, 99**) have made studies of the intergalactic medium in the light of recent observations of the X-ray background and the spectra of quasi-stellar objects with redshifts ~2. In the steady state model of the universe an intergalactic hydrogen gas of density $\sim 10^{-29}$ g cm^{-3} is required to have a kinetic temperature $\sim 10^6$ °K, which could plausibly be achieved by cosmic ray heating. If oxygen is present with its normal cosmical abundance, it could be detected in the spectra of sources with a redshift 2·2. However, the steady state model itself is not consistent with recent data on the redshifts of quasi-stellar objects, if these redshifts are cosmological in origin.

Whether the redshifts of quasi-stellar sources and objects is cosmological and whether they are correspondingly large distances is subject to doubt in view of the suggestion by J. Terrell (**100, 101**) that quasi-stellar objects are local, rapidly moving objects. The two different points of view have been discussed by F. Hoyle and G. R. Burbidge (**102**). At this time there is no conclusive argument in favor of one of the competing interpretations.

A. Sandage (**103**) has given an interim report on his recent work on the redshift-apparent magnitude relation for the brightest members of clusters of galaxies and for radiogalaxies. The results are mainly based on photoelectric photometry. The K term needed to correct the photometric data for the effects of redshift has been re-determined. The plot of redshift against the corrected V magnitude for the 1st ranked galaxy in clusters shows a linear relation with surprisingly small dispersion which emphasizes that the absolute magnitude of the brightest galaxy of a cluster is an exceedingly stable statistical parameter. The observed deceleration parameter will be very close to $q_0 = 1$. A correction must be applied, however, to the absolute magnitudes to account for the evolution of the stellar content for the individual galaxies during the light travel time. This correction gives $q_0 = +0{\cdot}2$ based on an evolutionary theory obtained from old star clusters. The uncorrected observations are consistent with a model with positive curvature, while the corrections lead to one with zero or negative curvature.

The redshift-apparent magnitude relation for the radio galaxies fits the relation for the brightest galaxies in clusters closely, although with somewhat larger scatter. The conclusion is that the radio galaxies do not differ significantly in luminosity from the first ranked cluster galaxies and that a galaxy must be supergiant in luminosity and presumably in mass to be a strong radio source.

G. de Vaucouleurs (**103a**) finds that local departures from linearity and isotropy in the redshift-apparent magnitude relation are confirmed by an analysis of improved and enlarged magnitude and velocity data. It follows that the value of the Hubble constant derived from nearby groups or the Virgo cluster is biased and probably too low.

H. Alfvén (**104**) has further studied the properties and evolution of a meta-galaxy containing equal amounts of matter and antimatter. He analyzed the properties of an 'ambiplasma' (containing ionized matter and antimatter) and showed that a magnetized ambiplasma (under the conditions assumed to exist in the universe now) should emit synchrotron radiation but no detectable gamma-radiation. He also suggested mechanisms for separating matter from antimatter. The possible formation of proto-galaxies from an 'ambiplasma' and their subsequent evolution into galaxies was treated by H. Alfvén and A. Elvius (**105**) and reported at the IAU Symposium 29. The annihilation of protons-antiprotons as a possible source of energy for certain astronomical objects was again discussed. A. G. Ekspong, N. K. Yamdagni and

https://doi.org/10.1017/S0251107X00030571 Published online by Cambridge University Press

B. Bonnevier (106) showed that the radio spectra to be expected from extragalactic objects deriving their energy from the annihilation of nucleon-antinucleons would be similar to radio spectra actually observed for quasi-stellar radio sources and strong radio galaxies. B. Bonnevier (107) studied some problems related to the early development of the metagalaxy in the theory of H. Alfvén and O. Klein. His solutions of equations previously derived by Alfvén and Klein indicated that an original contraction of the metagalaxy might be converted to an expansion in agreement with observed redshifts.

R. J. Dickens and S. R. C. Malin (108) find that observations of quasi-stellar sources and small-diameter galaxies show no differential aberration with respect to nearby stars. The result contradicts the Ritz theory of light propagation.

P. E. Kuustanheimo (109, 110, 111) has developed a new kind of linear gravitational theory in which the gravitational redshift may be non-conservative. This would explain a possible limb effect in the sun, and the route dependence of the redshift could be measured in the laboratory if the redshift experiments of Pound and Rebka based on the Mössbauer effect are repeated using photons not travelling vertically.

D. Sugimoto (112) explains phenomena in quasi-stellar sources by the nuclear instability of a star of about 200 $M_{\odot}$ that are formed by the rapid fragmentation of gas of $10^8 M_{\odot}$ in the nuclei of galaxies.

Zwicky (113) has discussed the discovery and some principal characteristics of previously unknown families of compact galaxies. He also has discussed a number of circumstances which will cause an entire compact galaxy to implode or, in some cases at least to liberate and to radiate energy at a much more rapid rate than an ordinary galaxy. He has observed differential redshifts in the spectra of some compact galaxies (114) that suggest an explanation in terms of Einstein's gravitational effect and the possibility that large redshifts are only in small part due to the cosmological effect.

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President of the Commission

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https://doi.org/10.1017/S0251107X00030571 Published online by Cambridge University Press

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APPENDIX I. OPTICAL DATA ON QUASI-STELLAR SOURCES

(Prepared by A. Sandage)

Introduction

There has been enormous activity in the study of quasi-stellar radio sources since the 1964 Hamburg meeting. It is now generally accepted that the name 'quasars' be applied to these objects and we shall adhere to this nomenclature in this report. Work on quasars can be conveniently divided into eight sections, touching the subjects of identification, redshifts, absorption lines, photometry, optical variations, interlopers ('radio quiet' quasars, sometimes designated QSG for quasi-stellar galaxies), the controversy of cosmological versus local distances, and theoretical studies of the structure of the sources.

The present summary is a partial literature review of papers appearing between 1963 and 1966. No attempt for completeness was made. It is further confined primarily to optical observations with only a few remarks on interpretation.

Identification

The first quasars were optically identified in 1960. This was achieved when radio positions of high precision became available through the work at the Owens Valley Radio Observatory on a list of high-flux-density sources of small angular diameter, as measured at Jodrell Bank. Direct photographs of several sources in this list were obtained with the 200-inch telescope. Matthews and Sandage (**1**) found that 3C 48, 3C 196, and 3C 286 appeared to coincide with starlike objects at the radio positions (which were accurate to better than $\pm$ 10″ arc in both coordinates). These three objects all had peculiar *U*, *B*, *V* colors compared to normal stars. This peculiarity of bright ultraviolet has been one of the main observational methods of optical confirmation of suggested identifications.

The fourth source to be identified was 3C 273 by Schmidt (**2**), who used a precise radio position due to workers at the Owens Valley Radio Astronomy Observatory and to Hazard, Mackey, and Shimmins (**2a**) at Parkes, who obtained the position by a lunar occultation. The 13th magnitude object was bright enough for Schmidt to obtain highly widened spectra of good quality from which he discovered the general property of redshifts (**2**).

The next three sources were found by Ryle and Sandage (**3**) using a two-color photographic method invented by Haro, where an ultraviolet and a blue image of each star in a given field is obtained on the same plate. These plates are searched for extreme ultraviolet objects. Sources 3C 9, 3C 216, and 3C 245 were discovered in this way. Photoelectric photometry confirmed the peculiar colors.

Schmidt and Matthews (**4**) identified 3C 47 and 3C 147 and confirmed from spectrograms that these were quasars.

By the middle of 1964 it was realized that quasars must be numerous. Estimates indicated that about 30% of the 3*C Revised Cambridge Catalogue* were objects of this type. Concentrated efforts of identification were then made at Owens Valley by Matthews and Wyndham, at Mt Wilson and Palomar by Sandage and Véron, at Cambridge by Longair (**5**) and later by Wills and Parker (**6**), and by Bolton and his co-workers at Parkes (**13**, **13a**, **14**).

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Sandage and Wyndham identified nine new sources in late 1964 (**7**) with 3C 93, 3C 208, 3C 279, 3C 287, MSH 13–011, 3C 345, 3C 380, 3C 446, and CTA 102, where 208 and 287 had previously been suggested by Longair (**5**). Bolton, Clarke, Sandage, and Véron (**8**) made the first identifications of fainter radio sources of the Parkes *Catalogue* where they found six sources to be quasars with peculiar colors and with coincident optical and radio positions.

The next identification list was that of Sandage, Véron, and Wyndham (**9**), where 21 quasars were suggested, 20 of which proved to be correct.

Hazard, Mackey, and Nicholson (**10**), Véron (**11**), and others added source identifications based on highly precise radio and optical positions and the coincidence of blue objects on the Palomar Sky Survey prints. Lynds, Stockton, and Livingston (**12**) identified 3C 351. A long new series of identifications of the Parkes radio catalogue objects was begun by Bolton, Kinman, and their co-workers. A number of identifications were suggested by Bolton and Ekers (**13a**). Bolton and Kinman (**13**) identified 12 new quasars, followed by Bolton *et al.* (**14**) for 15 additional quasars, and by Kinman, Bolton and Sandage (**15**) for an additional 16 sources. Scheuer and Wills (**16**) and Wyndham (**17**) published several identifications made from the *4C Cambridge Radio Catalogue*.

By the end of 1966 over 130 quasars were either positively identified or were highly probable suspects associated with blue optical objects.

Redshifts

The phenomenon of the redshift was discovered by M. Schmidt (**2**) through his interpretation of the spectrum of 3C 273. Greenstein and Matthews (**18**), following the lead of Schmidt, obtained the redshift of 3C 48 in 1963. Confirmation of Schmidt's redshift for 3C 273 was obtained by Oke (**19**) when he found the Hα line at λ 7590 Å using a spectrum scanner.

Following these initial discoveries, five independent groups began systematic observations of redshift for the identified sources as they became available. The principal observers in each group were M. Schmidt at Mt Wilson and Palomar, C. R. Lynds at Kitt Peak, E. M. Burbidge at Lick, T. D. Kinman at Lick, and Vera Rubin and W. K. Ford at the Carnegie Institution Department of Terrestrial Magnetism.

Schmidt and Matthews (**4**) obtained z values for 3C 47 and 3C 147. A list of five quasars with very large redshifts (3C 9, 245, 254, 287, and CTA 102) was published by Schmidt (**20**). These objects proved to be crucial because they established the existence of the C III line at λ 1909 Å, C IV at λ 1550 Å, and finally $L\alpha$ at λ 1216 Å for 3C 9. This was the first observation of the Lyman-α line, subsequently repeated many times on other quasars in 1966. The redshift of 3C 9 is $\Delta\lambda/\lambda_0 \equiv z = 2{\cdot}012$ with $L\alpha$ appearing at λ 3666 Å.

Oke obtained the redshift of 3C 286 (**21**) by identifying the line, which he had found with a scanner, at λ 3528 Å with C III (1909). E. Burbidge (**23**) found the redshift of MSH 14–121, which had been identified by Hazard, Mackey, and Nicholson (**10**). Lynds, Stockton, and Livingston (**12**) obtained redshifts for 3C 245, 279, 286, 334, 345, 351, 380, and 1252 + 11 using, for the first time, an image-intensifier spectrograph. Burbidge and Rosenburg (**22**) found the redshift for 3C 279, confirming the results of Lynds *et al.* (**12**).

Redshifts of six quasars (3C 334, 345, 380, 446, 208, and 0106 + 01) were then published by E. Burbidge (**23**). Schmidt (**24**) contributed a list of 14 redshifts for 3C 249·1, 277·1, MSH 03–19, 1252 + 11, MSH 14–121, CTD 141, 3C 204, 208, 181, 446, 270·1, 432, 454, and 1116 + 12. This was followed by Lynds and Stockton (**25**) for 1116 + 12, and Lynds, Hill, Heere, and Stockton (**26**) for 1217 + 02, 3C 215, 275·1, 261, 4C 39·25, 3C 138, 196, 4C 20·33, 0922 + 14, 0957 + 00, 3C 336, 186, 298, and 280·1.

Ford and Rubin (**27**) used an image-tube spectrograph to obtain redshifts for 1217 + 02, 3C 249·1, and 3C 263. Burbidge and Kinman (**28**) determined redshifts for 14 quasars

(3C 138, 0859–14, 4C 39·25, 1127–14, 3C 261, 1148–00, 4C 31·38, 4C 21·35, 1327–21, MSH 13–011, 1354 + 19, 1454–06, 3C 309·1, and 1510–08). Stockton and Lynds (**29**), and Burbidge, Lynds, and Burbidge (**30**) obtained the redshift of 3C 191 and showed that the spectrum has remarkable absorption lines in addition to the usual emission features.

Schmidt (**31**) published redshifts for 3C 232, 268·4, 288·1, 323·1, 454·3, and 4C 1·4 = PHL 1093. Finally, Lynds (**32**) published a long list of redshifts for 3C 2, 175, 207, 309·1, 454·3, 4C 21·35, 4C 29·68, 4C 37·24, 0056–00, 0122–00, 0159–11, 0350–07, 0403–13, 0736 + 01, 2146–13, 2216–03, PHL 658, PHL 1078, PHL 1093, PHL 1305, and PHL 5200.

A few redshifts are available for radio-quiet quasars (see a following section). Sandage, in a first discussion of the phenomenon (**33**), obtained redshifts for BSO 1, Ton 256, and Ton 730. Kinman (**34**) obtained a redshift for PHL 938, and Hiltner, Cowley, and Schild (**35**) published redshifts for Ton 1542, Ton 1530, together with values for 1217 + 02, 3C 249·1, 277·1, 281, 263, 1252 + 11, 0922 + 14, 0957 + 00, and PHL 1377. Sandage and Luyten (**74**), in their study of a single Haro-Luyten field, found redshifts for PHL 1127, 1194, and 3424, and showed that PHL 1027, 1070, 1072, 1222, 1226, 1237, and 3375 are also radio-quiet quasars, but with only one line visible on their spectra.

This list has 91 individual objects with redshifts, all of which are either radio quasars or radio-quiet quasars. The literature search for this tabulation is complete to December 1966.

Quasars with Absorption Lines

The detection of absorption lines in quasar spectra may prove to be important in unravelling the physics involved in the quasar phenomenon and in studying the intergalactic medium. Theoretical discussions by Bahcall and Salpeter (**36**), among others, suggest some of the possibilities.

Absorption lines have been found in a number of quasars. Some of the lines show little or no displacement relative to the emission lines and appear as central self-absorptions principally in $L\alpha$ and C IV 1550, but also occasionally in other lines. In other objects the lines are highly displaced from the emission components. Among the objects showing absorption are BSO 1 (**33**), PHL 938 (**34**), 3C 270·1 (**24**), 1116 + 12 (**37**), and 3C 191 (**25, 30**), where a large number of displaced lines are present. The most spectacular case is PHL 5200, where Lynds (**38**) has found extremely wide absorption 'bands' extending more than 20 000 km s^{-1} blueward of the C IV (1550), Si IV (1403), and N V (1243) emission lines. Furthermore, three velocity systems appear to exist in this object, as evidenced by three displaced components to many of the emission lines.

Absorption continua have been looked for shortward of $L\alpha$ in an effort to detect intergalactic hydrogen. Gunn and Peterson (**39**) and, independently, Scheuer (**40**) discussed this possibility in regard to Schmidt's spectrum of 3C 9 (**20**), where $L\alpha$ appears at λ 3666 Å. There is only a slight intensity jump, if any, below the $L\alpha$ line, a circumstance which allowed these authors to put very low limits on the density of intergalactic neutral hydrogen. A similar study by Field, Solomon, and Wampler (**41**), using scanner observations of 3C 9, failed to detect molecular hydrogen absorption in a band shortward of λ 1108 Å. They concluded that the density of H_2 was less than 4×10^{-9} molecules per cm^3, which is 8×10^{-6} of the expected cosmological density.

Photometry

Three-color *UBV* photometry has been obtained for many quasars. The peculiar position in the $U - B$, $B - V$ diagram was one of the original distinguishing features of the objects and helped in their first detection. The photometry has often been published in the identification papers as an aid in the confirmation. Two summary lists (**33, 42**) give the available

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photometry to January 1966. Additional photometry has been reported in references **13**, **14**, and **15**.

Analysis of the *UBV* data by McCrea (**43**), Kardashev and Komberg (**44**), and by Barnes (**45**) showed systematic correlations of the color indices with redshift. These were interpreted by Sandage (**42**) as due to features in the energy distribution being redshifted through the *UBV* filter bands, causing the systematic correlations. Lynds (**46**) and Strittmatter and Burbidge (**47**) extended the analysis to show that these features are undoubtedly the strong emission lines. The existence of these correlations, even with their moderately large dispersion, suggests that the underlying continuum radiation of quasars is statistically similar from object to object. The continuum extends at least to λ 1100Å, and is still rising in a plot of flux per unit wavelength interval versus wavelength.

Photoelectric spectrophotometry over a wavelength range λλ 3300–9000Å has been obtained for a small number of quasars by Oke (**48**) and Wampler (**49**). These authors find a relatively smooth continuum energy distribution upon which the strong broad emission lines appear.

Wide-band photometry in the infrared at 2·2 μ and 10 μ has been obtained for 3C 273 by Johnson (**50**) and Low and Johnson (**51**). This work shows that the energy distribution begins to climb toward high values at about 1 μ relative to a black body, fitting nicely onto the radio spectrum at 3 mm, which is now available for 3C 273 and 3C 279 from the work of Epstein (**52**) and Epstein, Oliver, and Schorn (**53**).

Optical and Radio Variations

Soon after the discovery of quasars, optical studies showed that some of the objects vary in optical radiation. Smith and Hoffleit (**54**) and Sharov and Efremov found that 3C 273 has varied by about 1 magnitude during the past 80 years. Source 3C 48 was also shown to vary (**1**) by about 0·4 magnitude during the three-year interval since its discovery. Further study revealed that 3C2, 43, 47, 196, 216, 245, and 454·3 (**55**, **56**) were also variable. A beautiful study by Goldsmith and Kinman (**57**) showed that 3C 345 varies by about 1 magnitude with a time scale as short as several weeks. The Burbidges (**58**) reported that the spectral lines, especially Mg II (2800), appear to vary in wavelength on the red wing in this object.

The most spectacular variation was recorded for 3C 446. Sandage found that the object had undergone an outburst of 3·2 magnitude sometime between September 1965 and June 1966. Photoelectric observations (**59**) showed the colors had also changed significantly during the outburst. Analysis of the data by Sandage, Westphal, and Strittmatter (**60**) showed that the color change was very probably due to the decreased influence of the C IV (1550) emission line on the total radiation at the maximum outburst phase. The emission lines apparently remained constant in absolute intensity while the continuum radiation increased. These results were confirmed with scanner observations by Oke (**61**) and Wampler (**62**). The light curve of 3C 446 is highly variable. Kinman, Lamla, and Wirtanen (**63**) followed the object for about 80 days between July and September 1966 and found variations of about 0·5 magnitude in ten days, with a total range of about 2 magnitudes. They also found that the light is 20% polarized, and that the plane of polarization varies from week to week.

Radio variations were first discovered in quasars by Dent (**64**) during his observations of 3C 273, 279, and 345 at 3·75 cm wavelength. Further data by Maltby and Moffet (**65**, **66**), Adgie *et al.* (**67**), Moffet (**68**), and others show that many quasars do indeed vary by large factors, and that the percentage variation is highly wavelength-dependent, decreasing toward longer wavelengths. There is, as yet, no indication that the radio and optical variations are coupled.

Radio-Quiet Quasars (QSG)

During a search (**33**) for blue objects associated with radio sources, using Haro's two-color method, a number of blue objects that imitated optical quasars appeared, but did not accurately

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coincide with the radio direction. These objects are apparently identical in superficial characteristics with the many blue objects found in previous searches of high galactic latitudes by many workers, e.g., Haro and Luyten (69). Photoelectric photometry of a special sample of highly ultraviolet objects, found by Sandage and Véron (70), showed that many of these objects were above the black-body line of the $U - B$, $B - V$ diagram, contrary to the situation for white dwarfs. Sandage (33) concluded that many of the Haro-Luyten objects were quasi-stellar but without radio emission. Zwicky states that he predicted the existence of such objects at the Hamburg meeting of the Union in 1964 and at the Galileo conference (71) in Padua in the same year.

Evidence that at least some blue objects were quiet quasars came from redshifts of BSO 1, Ton 256, and Ton 730 (33). The conclusions on the statistics, but not on the concept, were criticized by Kinman (72) and Lynds and Villere (73). Kinman (34) found that PHL 938 was radio-quiet and had a redshift of $\Delta\lambda/\lambda_0 = 1{\cdot}93$. Additional radio-quiet quasars were found by Hiltner, Cowley, and Schild (35). A study to improve the statistics was made by Sandage and Luyten (74) in a single Haro-Luyten field. Ten definite radio-quiet quasars were found, some with large redshifts. The surface density is estimated to be at least 0·3 QSG per square degree to $B = 18$ and perhaps as high as 3 QSG per square degree to $B = 19{\cdot}7$. This estimate to $B = 18$ is about 70 times the surface density of radio quasars to 9 flux units at 178 MHz. It is about ten times smaller than Sandage's first prediction.

Special faint optical surveys for new blue objects have been made by van den Bergh (75), Richter (76) and his co-workers, and others. It is not known what percentage of these objects will be quasi-stellar.

Special searches for radio emission at faint flux levels have been started by the Bologna group (78), by observers at Green Bank, at the University of Illinois, and at Parkes. Bolton surveyed the region near PHL 938 with the Parkes dish, but without success. Ton 256 and Ton 730 were looked for at Arecibo, but again with negative results.

It seems probable that radio-quiet quasars are not a new class of objects but rather are radio quasars near the faint end of the radio-luminosity function. Evidence for this view was presented by Sandage and Luyten (74) by showing that a very strong observational selection operates against finding quasars of small absolute radio power when optical identifications are made from existing radio catalogs. The total number of quasars is very large if the estimate of 3 QSG per square degree to $B = 19{\cdot}7$ is correct. There may be more than 100 000 of these objects over the sky to this optical limit.

The Issue of Local vs. Cosmological Distances

There is no definite proof that quasars are at the distances inferred by use of the Hubble law. Neither is there a definite disproof. A crucial experiment has not been performed in this matter.

Two major hypotheses have been discussed and many papers dealing with the subject have been published. The cosmological hypothesis assumes that Hubble's law applies and that the quasars are extremely distant objects partaking in the general expansion of the universe. The second hypothesis assumes the objects are local. If the redshifts indicate Doppler motion, the quasars have either been expelled from our own Galaxy or from a nearby system with velocities ranging from low values ($\Delta\lambda/\lambda_0 = 0{\cdot}153$ for 3C 273) up to 80% the velocity of light (3C 9 and others with $\Delta\lambda/\lambda_0 \simeq 2$). Another version of the local hypothesis asserts that the redshifts are not due to Doppler motion but to some unknown physical cause, unspecified.

The first serious suggestion of the local hypothesis was put forward by Terrell (79) on the basis that the linear size of objects must be extremely small if they vary in brightness on a short-time scale. A detailed discussion by Hoyle and Burbidge (80) treats the problem from

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a number of standpoints. Setti and Woltjer (81) discuss Terrell's suggestion that quasars are ejected from our Galaxy. These authors show that difficulties exist on Terrell's picture in that the total mass and energy involved in accelerating the objects to their observed velocities is very high. This is especially true if the number of quasars is as large as Sandage and Luyten suggest (74).

If the quasars are ejected from other nearby galaxies, and if the wavelength shifts are due to Doppler motion, then a large fraction of the objects should show blueshifts. Faulkner, Gunn, and Peterson (82) and Noerdlinger, Jokipii, and Woltjer (83) discuss the problem and conclude that in a sample of quasars that is complete to a given optical apparent magnitude there should be far more blueshifted objects than redshifted on the local hypothesis. Because no blueshifts have been found among the 91 objects surveyed, they reject this version of the theory.

A different version by Arp (84) attributes quasars *and radio galaxies* to daughter products of explosions of certain peculiar parent galaxies. The excess redshifts of the daughters relative to the parents are speculated to be caused by an unknown phenomenon. The chief difficulty is that radio galaxies are known (Sandage 85) to follow closely the Hubble law (log $\Delta\lambda/\lambda_0$ is proportional to apparent magnitude). These galaxies also show a linear decrease of angular diameter with increasing redshift. If, as Arp suggests, redshifts are not correlated with distance for radio galaxies, then the observed Hubble law and angular diameter relations cannot be explained unless the intrinsic properties of absolute luminosity and linear diameter are themselves regular functions of redshift, which seems quite implausible.

Adherents of the cosmological hypothesis point out that the absolute radio luminosity of quasars, computed with the Hubble law, are the same as the brightest radio galaxies such as Cyg A, 3C 295, and Her A, which are known to be at the Hubble distance. Furthermore, Heeschen (86) has shown that the radio surface brightness of quasars forms a continuous sequence with radio galaxies when plotted against absolute radio power computed with the Hubble law. This would not be the case if quasars violated the Hubble law.

The most direct observational evidence bearing on the general question is due to Koehler and Robinson (87). The data show that 3C 273 must be either imbedded in or beyond the Virgo cluster. However, this observation is not conclusive because certain versions of the local hypothesis suggest the same thing. What can be said with certainty is that the objects are not extremely local because of the absence of proper motion as measured by Luyten (88), Luyten and Smith (89), Jefferys (90), and Sanders (91).

What appears to be needed is a crucial experiment, such as the detection of absorption lines in the spectrum of a quasar due to a foreground cluster of galaxies. Alternately, the discovery of a quasar in a cluster of galaxies would be decisive. This latter test is known to be difficult for $\Delta\lambda/\lambda_0 > 0{\cdot}5$, and is negative in the case of 3C 48 and 3C 273 as shown by Sandage and Miller (92).

Controversy is likely to continue until some crucial experiment is devised.

Theoretical Models

Many models have been proposed, and a growing body of literature exists. A summary of the state of the problem in 1964 is given in the symposium volume on *Quasi-Stellar Sources and Gravitational Collapse*, edited by Robinson, Schild, and Schücking and published by the University of Chicago Press.

Early investigations were concerned with the nature of the outer regions producing the line spectrum. Greenstein and Schmidt (93), Osterbrock and Parker (94), Bahcall (95), Burbidge, Burbidge, Hoyle, and Lynds (96), Shklovsky (97), and others contributed to the subject.

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The origin of the continuum radiation, the problem of the small linear diameters, and of the high densities are other parts of the general dilemma. Field (98) suggested that the objects are newly-forming galaxies in the state of initial gravitational contraction, and that the energies now seen in the configuration could be accounted for by gravitational energy plus many supernovae. Ne'eman (99) suggested that the objects were left over as dense cores from the initial configuration of an inhomogeneously expanding universe.

Other suggestions for the high densities consider the end product of a dynamic evolution of star clusters. Ulam and Walden (100), Miller and Parker (101), and Gold, Axford, and Ray (102) have suggested that evaporation of stars cools the configuration, causing it to condense, evaporate more rapidly, and condense faster until stellar collisions occur, a process which releases the observed energy. Colgate (103) considers the energy to be due to supernovae. Alfvén (104) and Teller have discussed the possibility of matter and antimatter annihilation.

It is probably fair to state that many theoretical ideas concerning the interpretation of the observational data are in a state of flux.

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APPENDIX II. SPECTRA, INTERNAL MOTIONS AND MASSES OF GALAXIES

(Prepared by E. M. Burbidge)

Radial Velocities

The Reference Catalogue of Bright Galaxies, by G. and A. de Vaucouleurs (1), contains radial velocities and is thus the most modern compilation of velocities. Many of the entries are new ones, observed by the de Vaucouleurs at McDonald Observatory. Shobbrook (2) measured the radial velocities of 19 southern galaxies. Radial velocities of radio galaxies have been measured by Schmidt and Sandage; Schmidt (3) published results for 31 radio galaxies and gave also estimates of emission line intensities, which range from zero in two objects with absorption lines only, to the strongest emission lines, comparable with those in Cyg A. Sandage (4) published results for nine radio galaxies, for one of which data were also given on the velocity field (see below). Westerlund and Stokes (5) studied the optical properties of the radio galaxy PKS 0521–36; it is a highly luminous galaxy with $M_B = 21{\cdot}2$ and has an emission-line spectrum.

Rotation Curves, Masses, and Mass-to-Light Ratios

Density distribution, masses, and mass-to-light ratios were determined by means of rotation curves observed with a long-slit spectrograph at McDonald, Lick, Haute-Provence, and Asiago Observatories. The group consisting of the Burbidges, Prendergast, Rubin, and Crampin obtained results for NGC 3521, 6503, 1792, 613, 4826, 7331, 681, and 972 (6–13). Bertola measured the rotation mass, and mass-to-light ratio of NGC 3310 (14), and also studied the rotation of the Seyfert and radio galaxy NGC 1068 (15). Mme. Duflot measured the rotation of NGC 3034 (M82) (16).

A redetermination of the rotation curve of M33 was made by Brandt (17) by means of velocities of individual H II regions measured at Mt Wilson. Rotations were detected in the elliptical galaxies NGC 4621, 4697 by means of inclined absorption lines by King and

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Minkowski (18), thus showing that the inner parts of these ellipticals do possess angular momentum. Velocity dispersions were also measured in these two galaxies. Searle (19) measured the rotation of the radio galaxy NGC 1316 (Fornax A) by means of its absorption-line spectrum, and showed that it is rotating about its minor axis, in contradistinction to the situation in NGC 5128 (Centaurus A).

Determination of rotations and total content of neutral atomic hydrogen were made by means of 21-cm measures by a number of workers. Epstein (20) discussed all the data available in 1964, on 48 galaxies, of which 3 Sb's, 13 Sc's, and 13 irregulars showed measurable 21-cm emission. He discussed models to explain the observations in a following paper (21). Roberts and Höglund and Roberts measured the rotation of NGC 925 (22) in a region containing neutral H and lying outside the region covered by the optical measures; the rotation curve was found to continue on out into this region. Roberts measured 21-cm emission in the relatively distant galaxy NGC 5668 (23), and made a high-resolution study of M31 (24). Rotation curves and total masses were derived for NGC 55, 300, 2403, 3109, 4214, and 4244 by Seielstad and Whiteoak (25).

On the theoretical side, Pskovskii (26) has collected together the data on masses and has discussed the mass-to-light ratio for galaxies and obtained $L \propto \mathfrak{M}^{1.08}$ for spiral and irregular galaxies. Huang (27) used a more indirect argument based on the concept of the luminosity of spirals and irregulars being determined by the neutral H content. Brandt and Scheer (28) gave tables for calculating mass distributions, densities, and mass-surface densities from observed rotation curves. Wallace and Copeland (29) discussed the velocity field in a model spiral galaxy, and compared it with that of NGC 1084. Kinman (30) derived a model for the nucleus of M31 based on the luminosity profile, and showed that $\mathfrak{M}/L$ could be $\sim$50 in the center.

Non-Circular Velocity Fields in Galaxies

A study following up the work of Lynds and Sandage on M82 was made by Burbidge, Burbidge, and Rubin (31). It was shown that ejection of gas from the nucleus probably occurred in a cone about the axis of rotation. Non-circular motions were found in the nuclear region of M51 by Burbidge and Burbidge (32). NGC 2685, a spindle-shaped galaxy with helical structure about its major axis, was studied by Demoulin (33) who found that the gas in the helical windings was rotating about the long axis, as were the stars giving absorption lines in the spindle, while the spindle as a whole was also rotating about its minor axis.

The radio galaxy NGC 1275 was studied by Burbidge and Burbidge (34), who mapped out the velocity field of its main component and the component with a velocity displaced by 3000 km s^{-1}, discovered by Minkowski. Sandage (4) found that the radio galaxy NGC 305 is rotating and its emission lines reach maximum intensity 2000 pc outside the nucleus, suggesting a cone or jet-like distribution of gas. NGC 305 is an Sa galaxy; Minkowski (35) showed that NGC 1275 has Balmer absorption lines suggesting that it also is an Sa type. Münch (36) continued observations of gas in the nucleus of M31; the outflow along the minor axis amounts to a flux of 0·1 $\mathfrak{M}_\odot$/year at 100 pc distance from the center. Burbidge and Burbidge (37) measured the velocity field in the peculiar double galaxy NGC 4038–9; negative velocities occur predominantly in the dusty or upward-lying regions, suggesting outflow. Walker (38) discovered that the violet-displaced component in [O II] λ 3727 in M87 (Virgo A), noted in 1959 by Osterbrock, had in the spring of 1966 changed to a component shifted to the red of the central velocity by an approximately equal amount. He also mapped out four high-velocity turbulent gas clouds in the nucleus of the Seyfert and radio galaxy NGC 1068, and showed that a radial outflow of gas probably occurs in the inner parts, while rotation dominates outside 30″. In the bright Sb galaxy NGC 4736, pronounced 'bumps' were found on the rotation curve. NGC 3432, another galaxy with marked bumps on its rotation curve, was studied by Bertola (39).

Two peculiar multiple galaxies were discovered to show very large velocity differences, amounting to 2000–3500 km s^{-1}: NGC 4496, studied by de Vaucouleurs (40), and NGC 6438, studied by Sĕrsic (41). Both these indicate violent explosive events.

Gas streaming in barred spiral galaxies was studied theoretically by Freeman (42), and observations by de Vaucouleurs and himself gave evidence supporting the theoretical work; they indicate that gas flow occurs around the axis of the bar while stars have a retrograde mean motion. The intermediate barred spiral NGC 6181 was found by Burbidge, Burbidge, and Prendergast (43) to show a marked velocity peak at one end of the major axis of the bar.

Peculiar Galaxies; Compact Blue Galaxies

Zwicky and Humason (44) continued their work on spectra and other characteristics of interconnected galaxies and of galaxies in groups and in clusters. Redshifts and velocity dispersions were measured in a number of systems by Zwicky in a series of papers on compact galaxies and compact parts of galaxies (45, 46). In a plot of spectral type against morphological type, Zwicky found galaxies populating the hitherto empty part of the diagram, with compact elliptical-type structures and early spectral types.

Spectroscopic studies of four peculiar galaxies were made by the Burbidges and Mrs Rubin – Mayall's Object and IC 883 (47), VV 144 from Vorontsov-Velyaminov's catalogue of interacting galaxies (48), and NGC 2188 (49). VV 144 has a Seyfert-type spectrum and a long tail or jet.

Partly as a result of searches for quasi-stellar objects, some very compact blue galaxies have been discovered and investigated spectroscopically. Sandage (50) studied Ton 730 (a 'blue stellar object' from the Tonanzintla Catalogue). Kinman discovered a similar-looking object with a smaller redshift that has $M_B \approx -14$ and discussed its spectroscopic and optical resemblance to NGC 1569 and NGC 2366 (72). Zwicky (51) described spectra of several systems. Arp (52) discovered a very small condensed double galaxy, with an emission-line spectrum, an absolute magnitude for the two components of only $M_{pg} = -12{\cdot}7$ and $-12{\cdot}8$, and diameters of only 70 pc. In a plot of M_{pg} against diameter, the object lies between globular clusters and small galaxies like NGC 147.

Physical Conditions, Composition, and Distribution of Gas in Galaxies

Courtès and his colleagues have continued their studies of galaxies with very narrow-band filters in the light of Hα. Courtès, Viton, and Véron (53) studied NGC 1275, M82, NGC 4258, M51, and NGC 6946. Courtès and Cruvellier (54) studied the H II regions in M33. Hα emission extends right into the nucleus, as in NGC 4258. Véron and Sauvayre (55) studied NGC 2403, 2903, and 4490. Hodge (56) studied the distribution of Hα emission regions in eight irregular galaxies that resemble M82, and Baade and Arp mapped their positions in M31 (57, 58).

Burbidge and Burbidge (59) made a survey of the existence of and relative line intensities in ionized gas in the nuclei of 85 elliptical, SO, spiral, and irregular galaxies. The intensity ratio Hα/[N II] λ 6583 is < 1 in 100% of the E and 81% of the SO galaxies, and in 55% of the spirals, while this ratio is > 3 in 100% of the irregulars. This ratio is governed by the physical conditions of excitation in the gas, particularly the electron temperatures, but could be affected by the abundance ratio H/N.

A detailed study of the physical conditions and source of ionization in the Seyfert and radio galaxy NGC 1068 was made by Osterbrock and Parker (60). The electron temperature and density were derived, and it was shown that the most probable ionizing agent is 20 keV protons which are simply the ionized hydrogen in the moving clouds discovered by Walker, whose velocities are ~ 2000 km s^{-1}. Pacholczyk and Wisniewski (**61**) measured the infrared radiation in NGC 1068 and found a big excess over that in normal spiral galaxies so that it resembles the quasi-stellar object 3C 273.

Vorontsov-Velyaminov and Dibai (**62**) studied the hydrogen emission-line profiles in the nucleus of the Seyfert galaxy NGC 4151 and found two components, one with a velocity dispersion of 750 km s^{-1} and an electron density $N_e = 2 \times 10^3$ cm^{-3}, and one with 3500 km s^{-1} and $N_e \geqslant 10^7$ cm^{-3}. Dibai (**63**) found that the Seyfert galaxies NGC 1275, 3516, 3227, and 4051 all show two such components, while NGC 1068 had only a low-density component and NGC 7469 has only a high-density one.

Mathis (**64**) studied the He/H abundance ratio in the two gassy irregular galaxies NGC 4214 and IC 1569, which are the most distant objects in which this ratio has been measured. The values were in the same range in which lie determinations in our own Galaxy and in Local Group galaxies. Dickel (**65**) made a spectroscopic study of physical conditions in selected H II regions in the Magellanic Clouds.

Stellar Population of Galaxies

Deutsch (**66**) discussed critically the earlier work of Spinrad on the intensity of the blended Na I D lines as an indicator of the size of the red dwarf stellar population in the nuclei of K-type galaxies. Spinrad and Wood (**67**) measured the MgH intensity in cool stars and galaxies, and showed that dwarf stars must contribute to the integrated light in the nucleus of M31 and, to a lesser extent, probably in M32. Wood (**68**) gave the results of multicolor photoelectric photometry of galaxies, in which narrow-band filter measures of the light in and nearby to spectral features were made in order to build up a synthetic stellar population that would reproduce the measures. Philip and Sanduleak (**69**) used low-dispersion spectra of galaxies for spectral classification. Spinrad (**70**), in a review paper on normal galaxies, discussed the line strength ratios as population indicators, and suggested that strong-line K giants and strong CN giants like μ Leo might make an appreciable contribution to the integrated light of K-nuclei galaxies. On the theoretical side, Gratton (**71**) discussed the mass-to-light ratios of galaxies in relation to the population of evolved or 'dead' stars.

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APPENDIX III. REPORT OF THE WORKING GROUP ON GALAXY PHOTOMETRY

(Prepared by G. de Vaucouleurs, Chairman of the Working Group)

This report covers work on photometry and spectrophotometry of galaxies based on papers received since the Hamburg Meeting and, in particular, on replies to the Circular No. 4 of the working group.

Techniques and Instrumentation

Several new techniques and instruments have been introduced to speed up the tedious methods of photographic photometry.

D. Koelbloed (Amsterdam) has described a scanning isophotometer attachment to a Hilger microphotometer recording by means of electric sparks on 'Teledelthos' paper (**1**).

G. de Vaucouleurs, *et al.* (Texas) have described a double-beam, self-balancing isophotometer operating in either contour following or scanning modes and recording on either the paper chart of a slave x–y plotter or on a photographic plate (**2**).

A scanning 'Isodensitracer' built by Technical Operations Research, for radiography (**3**) could be applied to galaxy photometry.

Approximate isophotal contours have also been produced by composite printing of negative-positive pairs, an old technique recently revived for applications to galaxy photometry (**4, 5**).

A rigorous reduction program ('GALAXY 2') using digital techniques of 'numerical mapping' has been developed at the University of Texas and U.S. National Bureau of Standards to take advantage of the capabilities of large modern computers (**12**). A double-beam, two-coordinate, digitized microdensitometer in construction at the University of Texas will record automatically on punched paper tape the input (x, y and density) for this program. The system is designed to deliver accurate photographic isophotes (corrected for plate errors, with or without smoothing) and integrated magnitudes of galaxies on a mass production basis. Regular operations are expected to begin in 1967.

Detailed Photometry

Detailed surface photometry photographic isophotes (pg-i) or photoelectric scans (pe-s) has been reported as follows:

F. Bertola (Asiago) observed NGC 3432, 4485–90, 4605, 4618–25, 5005, 6503 (pg-i) to supplement spectroscopic rotation data (M/L ratio). The exponential decrease of luminosity in the outer regions of late-type spirals is confirmed.

P. W. Hodge (Seattle, Wash.) has continued his intensive studies of dwarf (E, I), lenticular (SO) and peculiar galaxies, on Mt Stromlo and Mt Wilson plates including NGC 128, 185, 1332 (**6**), the Sculptor dwarf (**7**), and bright and faint galaxies in the Fornax cluster (**8**) (pg-i with pe calibration), work in progress includes Local Group members NGC 6822, IC 1613 and the WLM galaxy (pe-s) and further surface photometry of SO, Irr II and spiral galaxies.

I. R. King (Berkeley) has continued his photographic studies of the brightness distribution in elliptical galaxies. Special attention is paid to maintaining a resolving power of 1″ or less in the central regions – a requirement for proper dynamical interpretation. The work is complete for NGC 2300, 4261, 4472, 4621, and 4697; and the results are being prepared for publication.

Additional material is being reduced for NGC 147, 185, 205, 221, 4365, 4374, 4382, 4406, 4486, 4552, 4589, 4636, 4649, 5846, 6166, 6703, and 7626; less complete material is available for NGC 404, 410, 524, 545–7, 584, 720, 1700, 3379, 4459, 4874, 4889, and 5322. These lists include all E's and round SO's whose internal velocity dispersions are known.

B. E. Markarian (Byurakan Obs., Armenian S.S.R.) reports that with the assistance of E. Y. Hovhannisian and S. N. Arakelian he has carried out detailed two-color photometry (pg-i) of 16 galaxies in the central part of the Virgo cluster (NGC 4371, –74, –88, 4406, –35, –38, –40, –58, –59, –61, –73, –77, –78, –86, 4501) (**9**).

P. Pishmish (Tonantzintla Obs., Mexico) indicates that she has started a four-color study (pg-i with pe calibration in *B*, *V*, *R*, *I*) of six edge-on galaxies (NGC 891, 4244, 4565, 4631 and 5904) and NGC 5128 in infra-red.

G. de Vaucouleurs and collaborators (University of Texas) have continued work on a 'Photometric Atlas of Bright Galaxies' (pg-i and pe-s) which will include about 100 of the brighter northern and southern galaxies. A detailed study of NGC 4486 (pg-i and pe-s) and its compact dwarf companion NGC 4486–B was completed. In collaboration with H. Ables, several Local Group dwarfs including the Sculptor and Fornax systems (pe-s) and IC 10 (**10**) have been observed in the *U*, *B*, *V* system. H. Ables (U.S. Naval Obs., Flagstaff) has started an intensive study of a dozen large, nearby galaxies observed at 21 cm and for which optical data are poor or lacking.

Integral Photometry

As part of work on vol. III, IV and V of the 'Catalogue of Galaxies and Clusters of Galaxies' (to be published in 1966–67) F. Zwicky, E. R. Herzog, C. Kowal and M. Karpowicz have estimated photographic magnitudes of some 10 000 galaxies on 18-inch Schmidt Schraffier films.

G. E. Kron and C. D. Shane (Lick Obs. and U.S. Naval Obs., Flagstaff) are continuing their photoelectric measurements (*P*, *V*) of integrated magnitudes to determine the limiting magnitude and magnitude scale of Zwicky's Catalogue and study galactic extinction. About 400 galaxies have been observed since 1964 with the Lick 120-inch (304 cm) and Flagstaff 40-inch (102 cm) reflectors.

R. R. Shobbrook (Sydney Univ.) measured in 1964–65 with the McDonald 36-inch (91 cm) reflector magnitudes and colors in the *U*, *B*, *V* system for about 30 galaxies in the zone $-20° < \delta < +5°$. These galaxies are in several groups for which he obtained radial velocities with the 82-inch (208 cm) reflector.

G. de Vaucouleurs and collaborators (McDonald Obs.) continued the reduction of *U*, *B*, *V* observations of some 550 galaxies with the 36-inch reflector in progress since 1960 (see 1964 report).

Multicolor Photometry

H. L. Johnson (University of Arizona) has published an eight-color photometry (*UBVRIJKL*) of the nuclear regions of ten bright galaxies extending to 3·4 μ. A stellar mixture including a large abundance of late K and M giants is necessary to explain the infra-red excess (**11**).

W. G. Tifft (University of Arizona) has prepared for publication narrow-band multicolor observations of galaxies made at Lowell Obs. in 1963–64.

S. van den Bergh and R. McClure (D. Dunlap Obs., Toronto) have started a seven-color intermediate band photometry of early type galaxies with a two-channel photometer on the 74-inch reflector. The objective is to obtain information on population content or luminosity from some combinations of color indices.

Spectrophotometry

E. Vandekerkhove (Uccle) has published values of relative gradients of 16 galaxies in the Virgo cluster (**13**) and is continuing work in about 50 objects measured on objective-prism spectra with the Uccle Obs. Schmidt telescope. R. G. Tull and G. de Vaucouleurs (McDonald Obs.) recorded in 1965 the spectra of 48 bright galaxies and 50 standard stars at 15 to 25 Å resolution with a photoelectric scanner at the Cassegrain focus of the 82-inch reflector. Energy distribution, equivalent widths (and incidentally radial velocities) are measured and will be analyzed to derive the spectral composition (population content) of galaxies at several stages of the classification sequence.

This report was prepared from information received on or before 8 August, 1966.

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APPENDIX IV. REPORT OF THE COMMITTEE FOR RESEARCH ON SUPERNOVAE

(Period covered from June 1964 to October 1966)

(Prepared by F. Zwicky, Chairman of the Committee)

Fourteen Observatories (eleven and three respectively on the Northern and Southern Hemisphere) have cooperated in the search for supernovae. During the period of 27 months 33 supernovae were found (**5, 6, 7**): one each by Arp, Gates, Haro, Hoffmeister, Yakimov, Lovas and Reaves, three by Rosino, four each by Chavira, Rudnicki, and Wild, five by Zwicky, and six by Kowal, all of them observers at the 14 observatories represented on the Committee for Research on Supernovae. This brings the total number of supernovae definitely recorded since 1885 to 184.

A circular letter no. 8 on the supernovae no. 141 (SN–1963s) to no. SN 170 (SN–1965i) was issued by the Chairman of the Committee on 20 July 1965 as well as a general review (**2**).

The brightest supernova found, SN 1964f ($m_p \sim 14{\cdot}0$), in this period appeared in NGC 4303 and is, incidentally, the last of three which have been discovered in this galaxy within 40 years.

Light curves and spectra of various supernovae have been published by a number of investigators (**8, 9, 10, 11, 12, 13**). None of the features in the spectra of the supernovae of the type I and IV have as yet been identified.

No emission of radio waves, cosmic rays or X-rays from one of the recent supernovae has as yet been observed.

https://doi.org/10.1017/S0251107X00030571 Published online by Cambridge University Press

A study of both the optical and the radio features of some of the remnants of past galactic supernovae by Minkowski (**3, 4, 14**) suggests that SN 1006 was an object of type I, SN 1054 cannot be assigned any type as yet, SN 1572 and 1604 are types I, the unobserved SN associated with the radio source Cas A to be classified as type III. η Carinae (according to Thackeray and Zwicky) was possibly type V.

No determination of the frequencies of occurrence of the various types of supernovae has as yet been possible with the exception of the frequency of objects of the type I in large nearby clusters of galaxies. This frequency is of the order of one supernovae per 300 years per average cluster galaxy whose luminosity lies within the first five magnitudes from the brightest galaxy.

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APPENDIX V. REPORT OF THE COMMITTEE ON THE MAGELLANIC CLOUDS

(Prepared by A. D. Thackeray, Chairman of the Committee)

1. *General*

Current plans for new equipment in the southern hemisphere, including both large and small telescopes, imply greatly extended research on the Magellanic Clouds in the 1970's. Publication of the Smithsonian Astrophysical Observatory's Atlas of the Large Cloud by Hodge and Wright (**34**) is an important event which will greatly aid both planners and observers. The Atlas contains 81 V charts and 80 B charts at 16"/mm (except for four in the bar at 4"/mm), with limiting magnitudes about 17·0 and 17·5 respectively. The V charts are marked with clusters and emission nebulae, the B charts with variables discovered at the Harvard, Republic and Greenwich Observatories. The introduction, itself a valuable summary of Large Cloud work, contains Tables listing all the variables, clusters etc. with bibliography and other essential data.

Bok (**10**) has written a valuable review article on the two Clouds as of December 1965 which of course presents a much more detailed picture than this report. A colloquium of optical and radio astronomers was held at Mt Stromlo Observatory (**48**) in May 1965. A summary of contributions by Shapley to Magellanic Cloud research has been given by Bok (**12**).

2. *Variables and the P–L Relation*

Accurate two-color photoelectric observations of 14 SMC and 13 LMC cepheids are reported in an important contribution by Gascoigne and Kron (**29**). The SMC *P–L* relation is $< V > = 17{\cdot}85 - 2{\cdot}97 \log P$, which agrees in slope with that found in the LMC by the Herstmonceux group. The colors are systematically bluer than Arp's SMC cepheids. The derived distances are 61 kpc (SMC) and 50 kpc (LMC). Dickens (**15**) reports 2-color photometry of 10 cepheids in Herstmonceux Field 2. The *P–L* relation was discussed at the Herstmonceux Conference on Stellar Evolution (**63**).

Wesselink (**57, 58**) has published results for 45 faint SMC variables, including five with periods shorter than one day, and magnitudes based on measures with objective grating. The predominance of periods less than two days in this rich region is striking. Hodge and Wright (**35**) have discovered 51 new variables in the LMC, while eight new variables in the wing of the SMC are reported by A. D. Andrews (**3**).

The Gaposchkins continue their studies of Harvard variables based on the Arp SMC sequence (**24, 25, 26**). They find that variables with sinusoidal light-curves ($M - m > 0{\cdot}3$) define a $P - L$ relation lying $0{\cdot}5\ m$ higher than the $P - L$ relation for normal cephoids (**24**). The general relationship of form of light-curve and period is similar to that found in the galaxy. Mrs Gaposchkin (**23**) finds the slope of the $P - L$ relation systematically steeper at the bright end than the faint. S. Gaposchkin (**28**) finds that at any given period the amplitude of a SMC cepheid tends to increase with maximum brightness. He has also studied 33 eclipsing variables in the SMC (**27**); he finds none brighter than $-5{\cdot}0$ (M_{pg}) while relative to the known SMC cepheids they appear to be five times rarer than in the Galaxy.

Gascoigne (**48**) discusses cepheids and stellar birth-rates and stresses the rarity of Cloud cepheids in clusters and associations.

Arp's SMC sequence is being re-observed at Boyden (C. J. Butler) and Radcliffe (P. J. Andrews) Observatories. At Boyden cepheids in two LMC fields and one SMC field are being observed by four-color photometry to 18th magnitude (**4**). Van Genderen (Leiden) is studying SMC cepheids on the basis of plates taken by Arp.

The LMC cepheid HV 953 has been studied over a 60 year span by Janes (**40**) who finds the period fluctuating rather than progressively lengthening.

Arp (**6, 7**) has derived light-curves of cepheids in two colors in NGC 1866, based on Radcliffe plates secured in part by Thackeray. The colors, amplitudes and light curves are essentially independent of period (ranging from 2·64 to 3·53 days).

Short-period variability in some bright LMC supergiants has been looked for in vain by Bok *et al.* (**13**). Spectra of S Dor during a record deep minimum (from which it has not yet recovered) have been described by Thackeray (**52**).

3. *Radio and Gaseous Components*

Detailed results of 21 cm surveys with the 210 ft (64 m) Parkes telescope have been published for the LMC by McGee and Milton (**44, 45, 46, 48**) and for the SMC by Hindman and Balnaves (**31, 32, 33, 48**).

McGee detects 52 large H I complexes in the LMC. He attributes the very complicated velocity pattern to two pairs of spiral arms in planes differing by about 20°. The bridge between SMC and LMC has been resolved with the Parkes equipment into patchy condensations.

Hindman has given further details of the double-peaked 21cm profiles in the SMC. The pattern is attributed to expanding shells; the absence of a non-thermal component associated with supernova shells is to be noted and may perhaps be due to an ageing effect. He has found the first evidence of a rotation curve for the SMC with turn-over points and a rather surprisingly large velocity gradient; the maximum gradient is in p.a. 55°, similar to the major axis of Lindsay's distribution of clusters.

Westerlund and Mathewson (**61**) identify Henize nebulae N49, 63A, 132D in the LMC with non-thermal sources and attribute them to remnants of Type II supernovae.

Broten (**48**) has surveyed the LMC at 11 cm with the Parkes telescope. Over 50 sources are found, with the strongest coinciding with H II regions. Mills (**48**) reports preliminary observations of the Clouds with the EW arm of the Cross radio telescope at 408 MHz.

The H I content of the Clouds is listed for comparison with that of other galaxies by Epstein (**16**).

Dickel (**14**) has determined electron densities and masses of 8 LMC and 1 SMC H II regions from low-resolution scans with results that are matched by many galactic H II complexes (larger and less dense than the Orion nebula). Feast (**19**) in a complementary investigation based on coudé spectra, determines electron densities and masses of 36 LMC and 2 SMC nebulae from measures of the [O II] 3726/3729 ratio combined with Michigan measures of Hα surface brightness; three nebulae are common to Mrs Dickel's list. The general conclusions are similar. Feast's densities run higher, partly at least because his analyzing slit was very much narrower; his total masses run smaller.

Aller and Faulkner (**5**) compare 30 Dor and Eta Car nebulae by photoelectric spectrophotometry; abundances (He/H, O/H), electron temperatures and densities are compared. No differences in abundance ratios greater than 40% can be found. Mathis (**47**) has also studied the inner regions of 30 Dor with results that resemble galactic nebulae fairly closely. Faulkner (**17**) in a further study of 30 Dor compares surface brightness in Balmer lines with radio fluxes. He derives $R = 7$ for the ratio A_v/E_{B-V}.

Feast (**18**) has observed spectra of ten planetaries and finds a rotation curve for the Cloud similar to that from Population I stars. The velocity dispersion is 22 ± 7 km s^{-1}. This program is being continued and Feast has now material on 37 planetaries (both Clouds). Webster (**48**) gives preliminary results of velocities of Cloud planetaries. Bok *et al.* (**11**) have measured radial velocities of nine emission nebulae in the bar of the SMC for comparison with the 21 cm velocities.

A third list of 446 emission-line objects in the LMC discovered on ADH objective prism spectra is given by Andrews and Lindsay (**2**).

4. *Clusters*

Gascoigne (**30**) has completed a major program on color-magnitude diagrams of nine Cloud globular clusters down to $V \sim 19{\cdot}5$. Among these he recognizes three types: (1) NGC 1466, 2257 (both containing known RR Lyr variables) and 1841 have arrays like that of Tifft for NGC 121, and all are similar to galactic halo clusters; (2) Lindsay 1, Kron 3 and NGC 339 (all SMC) have no blue horizontal branch despite blue integrated colours and are regarded as of intermediate age; (3) NGD 2209, 2231 and Hodge 11 (all LMC) differ in having a very weak (or no) giant branch but many faint blue stars; this type has no known galactic counterpart. Gascoigne (**48**) has also measured integrated colors of 60 Cloud globulars and confirms the two-fold grouping in color; there is an almost complete absence of colors $(B - V)$ between 0·30 and 0·60.

Arp (**6, 8**) has completed his study of the *c–m* array of NGC 1866 which contains many red giants ($B - V = +0{\cdot}6$ to $+1{\cdot}5$) despite its early-type integrated spectrum. He assigns an age a little less than 10^8 years and finds some evidence in favour of evolutionary tracks predicted for stars of mass $5\,M_\odot$. There appears to be a progressive reddening of giant branches of globular clusters in SMC, LMC and the solar neighborhood. Hodge and Sexton

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(36) have listed 457 new clusters in the LMC. Lindsay (41) has commented on the classification of some objects listed as clusters by Lynga and Westerlund. Lindsay (42) has also identified most of the 366 NGC objects in the LMC region on ADH plates. He lists 26 (almost entirely in the outer regions) as galaxies.

Renewed attempts at measuring radial velocities of Cloud globulars are being made at the Radcliffe Observatory.

5. *General Field*

(*a*) *c–m arrays and photometry*

Woolley and Epps (64) have studied colors of stars down to about 16·5 *m* (two magnitudes fainter than an earlier proper-motion study) and conclude that in the relevant LMC field the great majority of stars with $B - V$ between $+ 0{\cdot}5$ and $+ 1{\cdot}5$ are foreground. Basinski *et al.* (9) have derived a *c–m* array down to $V = 15{\cdot}0$ for a dense region of the SMC. They find numerous stars with $B - V < + 0{\cdot}4$ (approximately equally divided into groups $-{\cdot}4$ to 0 and 0 to $+{\cdot}4$ and some stars with $B - V > + 1{\cdot}20$). They also attribute stars of intermediate color to the foreground. The same team have continued to study NGC 1929–37 (LMC). According to a preliminary report by Bok (48) the core of the region is dominated by blue stars, while further out (after allowance for foreground stars) some yellow-red stars appear which may represent evolved stars expelled from the central core. Hodge (37) has published a corrected p–e sequence and *c–m* array for 938 stars in the LMC.

UBV photometry of LMC supersupergiants is being undertaken by P. J. Andrews. Walraven (55) is also working on multi-color photometry of Fehrenbach stars. He has observations on his system of 365 and 274 stars in the region of SMC and LMC respectively of which at least 45% are Cloud members.

Westerlund (48) divides each of the Clouds into four sub-systems according to age, partly on the basis of colors.

(*b*) *Spectroscopy*

Hutchings (39) has published measures of Hγ equivalent widths for 149 Cloud supergiants (O to K5). The variation with spectral type shows a maximum near F0. Approximate distance moduli (corrected for absorption) of 18·2 (LMC) and 18·3 (SMC) are derived. Przybylski (49) has carried out a curve of growth analysis of the brightest known LMC member, HD 33 579, and finds $\Delta \log N$ (Fe, Cr, Ti/H) relative to the Sun of $- 0{\cdot}2 \pm 0{\cdot}2$. J. A. Williams (62) has also studied the metal/H ratio of long period Cloud cepheids by means of four-color intermediate band photometry. He finds no significant differences in the metal indices for either Cloud and the solar neighborhood. L. F. Smith (50) has classified 41 Cloud WR stars through narrow band photometry and some spectra. The order of decreasing luminosity appears to be WN7–8–6 (rare)–WC5– WN5. Dessy is obtaining spectra of the brightest Cloud stars at 42 Å/mm for inclusion in an Atlas of Spectra in collaboration with the Jascheks.

(*c*) *Radial Velocities*

Fehrenbach (20) has recapitulated his group's lists of stars with large and small velocity in the direction of the LMC. Fehrenbach *et al.* (20) have published radial velocities of 111 stars in a central region of LMC of which 29 are attributed to the Cloud. Fehrenbach (21) reported at IAU Symposium no. 30 on further progress in this program and on the extension of his survey to regions between the Clouds and between LMC and Galaxy where several high velocity stars have been found. Florsch and Carozzi (22) have found 33 high-velocity stars between the Clouds of which they regard 21 as probable members.

Slit spectra of all the later type LMC members, $m < 12$, revealed by Fehrenbach's survey are being obtained at the Radcliffe Observatory. Thackeray (53) has published two instances of high-velocity galactic subdwarfs and it is clear that the objective prism velocities are not a completely sure criterion of Cloud membership. Radcliffe slit spectra of SMC stars are also being secured for improved radial velocities.

Wayman (56) has proposed a technique for separating foreground stars among the later types through narrow-band photometry.

Gollnow (48) has reviewed the general problem of observed radial velocities in the Clouds.

(*d*) *Polarization and Absorption*

Visvanathan (54, 48) has published his polarization measures of 30 LMC stars. His discussion suggests that the Cloud is seen nearly face-on with a magnetic field related to Cloud structure. The polarization is correlated with color excesses derived from Radcliffe photometry and spectra. Hutchings (38) has published details of his important discovery of 4430 Å absorption in both Clouds. The correlation of strength and color excess is similar to that found for galactic stars.

Wesselink (59) has further discussed selection effects due to absorption in the discovery of variables. He is inclined to attribute the displacement of the LMC centre of rotation from the bar to heavy absorption distorting the optical picture.

7. *Summary of Trends and Future Needs*

The comparison of the Clouds with each other and with the Galaxy, particularly as regards cepheids and the *P–L* relation, continues to be of fundamental interest. Extensive statistics of cepheid periods and light-curves may have encouraged early belief in differences in composition, which would serve as a key to evolutionary theory. The differences sought, however, have become elusive. For example, the 'unusual' galactic cepheid TV Cam resembles the SMC cepheids in its light-curve, and was at one time thought to display abundance anomalies in its spectrum. These are now attributed to low turbulent velocity by Abt *et al.* (1).

Further study of the *P–L* relation could be planned to examine questions of *tilt* of the two systems, especially in view of Hindman's model of the SMC viewed nearly edge-on. It would be logical if further plans, especially in the choice of fields were coordinated with this problem in mind together with provisions for an adequate degree of overlap.

Uncertainty in the masses of the Clouds, arising largely from uncertainty in their tilts (see Bok (10)) should be resolved in order to clarify the problem of tidal interactions between the Clouds and Galaxy. Kerr (48) discusses such interactions as possibly associated with the warped H I galactic plane, north-south asymmetry in the H I rotation curve, and the high-velocity thin H I clouds observed at Leiden ($l^{II} = 120$, $b^{II} = +40$).

The complexities of radio patterns revealed by the Parkes telescope have posed many problems whose solution depends in part on the slower approach of optical astronomers. Visvanathan's work on optical polarization deserves to be prosecuted.

Narrow-band photometry could be pushed to fainter limits. Hβ photometry could be used for improved distance moduli; Hutchings' Hγ equivalent widths refer only to the brightest supergiants and may frequently be affected by shell absorption or superposed emission.

The luminosity function in different parts of the Clouds is an important datum in evolutionary theory. It has been discussed by McCuskey (43) in the light of former star-counts. There are many suggestions of bursts of local star formation in regions up to 1 kpc across. Even at magnitude 15–16 the contribution of galactic foreground can be very serious and statistical corrections may be misleading. Multicolor photometry at this level would probably offer the safest criterion of membership. For the brightest stars, Fehrenbach's survey supplemented by slit spectra is leading to a fairly complete census.

It is now generally accepted that both Clouds contain Populations I and II. But our knowledge of Population II components is severely limited. Gascoigne's *c–m* arrays of globular clusters underlines the recognized need for radial velocities – an especially difficult problem for the red globulars. Continuation of Dessy's search for long period variables is required and is being attempted at the Radcliffe Observatory.

Perhaps the most neglected field in recent Cloud research has been the search for novae. Several must have been missed since the abandonment of the Harvard patrols in the last decade. A small resumption has been begun by Sterling (51) in association with the Radcliffe Observatory. With many telescopes capable of following up a discovery, the importance of immediate blinking of search-plates, with accurate information on position and nearest bright star cannot be overstressed.

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APPENDIX VI. INVESTIGATIONS IN EXTRAGALACTIC ASTRONOMY MADE IN THE U.S.S.R. DURING 1964–66

(Prepared by B. Vorontsov-Velyaminov)

Photometry, Colorimetry, Polarization

Markarian, Oganesian and Arakelian made a detailed photometry and colorimetry of E and SO galaxies (1) and of spiral galaxies (2) in the Virgo cluster. The principal regularities observed in the distribution of brightness and color in the images of galaxies were noted. E and SO galaxies were studied: NGC 4374, 4406, 4435, 4458, 4459, 4461, 4473, 4477, 4478, 4486, and spirals: NCG 4371, 4388, 4402, 4438, 4440, 4501. The main features of their structure were noted. Kalloghlyan (3) measured photographically the surface brightnesses of bars of nine brighter SB galaxies. He found the mean value to be $20^m.9$ per square second of arc and concluded that this brightness is constant, which was confirmed by the comparison of the angular dimensions of the bars with the integrated brightness of many SB galaxies. Later Kalloghlyan and Tovmassian (4) made a two-color photometry of 50 SB galaxies and classified their nuclei from the point of view of their structure. Besides, Tovmassian (5) from the observations of 20 SB galaxies discussed the distribution of nuclei depending on their structure. Kalloghlyan (6) performed also the two-color photometry of the interacting galaxy NGC 3656 and described the structural peculiarities of this double system.

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Artamonov, Vorontsov-Velyaminov and Dibai (7) published the isophotes of the spiral galaxy NGC 2861. Vorontsov-Velyaminov (8), using the photographic measurements of stellar magnitudes of 200 galactic nuclei made by Gorbatschev (9) and the published photoelectric measurements of galaxies, compiled a catalog, which gives for 173 nuclei their apparent and absolute magnitudes, surface brightnesses, and luminosities per unit volume. They all are similar to the corresponding characteristics of Zwicky's compact galaxies. The luminosity of the nuclei increases with the luminosity of galaxies. Gorbatschev (10) studied the distribution of absolute luminosity in the nuclei of NGC 1300, 4051, 4040 and 4548 and, using Spinrad's model of the M31 nucleus, calculated the density distribution and the masses of these galaxies. Vorontsov-Velyaminov's group obtained the isophotes for several peculiar and interacting galaxies (in press).

Gagen-Torn (11) from the photographic and photoelectric observations studied the polarization distribution in NGC 3077, which points to the presence of dust in this galaxy. Dombrovsky (12) detected photoelectrically polarization in the nuclei of M51 and NGC 1068. Dibai and Schahovskoy (13) measured polarization in the nuclei of the Seyfert galaxies, but found it only in the radiogalaxies NGC 1068 and 1275.

Morphology of Galaxies

Vorontsov-Velyaminov described some new morphological types of galaxies, which show their large variety and the repetition of some 'peculiar' forms. Vorontsov-Velyaminov and Davydov (15) from the photographs with interference filters found a difference in the distribution of hydrogen and of [O III] in M82. Gurzadian (16) explained the presence of the hydrogen absorption lines in the spectrum of M82 not by the presence of numerous hot stars, but by the light absorption, by interstellar hydrogen inside this galaxy and by the presence of relativistic electrons. Markarian (17) studied ten irregular galaxies, which he considered to belong to the M82 type. He concluded that the discrepancy between the colour and the spectrum cannot be accounted for by the influence of dust and suggested that the early type of their spectra were due to some unusual emission. Ambartsumian (18) analyzing the data on the galaxies of M82 type concluded that they are young and that their luminosity increases in the course of time. The relationship between the physical state of the nucleus and the evolutionary phase of the galaxy was discussed. Markarian (19) also investigated other galaxies with anomalous spectral characteristics as regard their type and drew up a list of them. The conclusion was drawn that the peculiarly blue color of their nuclei is due to the additional ultraviolet emission of unusual nature. Vorontsov-Velyaminov (20) described eight types of peculiar nuclear regions and established that hot nuclei with traces of spiral structure occur among a third of the galaxies of SAB and SB families. Some of their physical characteristics were determined. Vorontsov-Velyaminov (21) showed that the structure of the flat component of many galaxies is in favor of the presence of magnetic-like phenomena: loops, eight-forms, intersections of the arms, etc. However, some data do not confirm the magnetic forces hypothesis. Zasov (22) found 13 galaxies where the layer of dark matter is inclined to the equatorial plane and suspected this inclination in 17 galaxies. To explain this he turns to the hydrodynamical interaction of the layer with a current of intergalactic gas outflowing the galaxy.

Ambartsumian, Iskudarian, Shachbazian and Sahakian (23) described the powerful associations of 30 Doradus type in the LMC. They call them superassociations. The latter are most frequent in the supergiant Sc and in irregular galaxies. A list of galaxies with superassociations is given. Markarian (24) quoted examples of isolated chains of six and more galaxies. The calculation of the probability of an accidental formation leads to the conclusion that the majority of the chains must be real physical systems. Karachenzev (25) studied the distribution

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of galaxies and the structure of the supercluster in Hercules. He (**26**) has also found 165 dwarf galaxies in the Virgo cluster and established their statistical relation to the bright galaxies S and E.

Richter and Sahakjan (**27**) discovered 54 remote blue objects and studied their distribution. Vorontsov-Velyaminov (**27a**) showed that the number of globular clusters relate neither to luminosity nor to mass of the galaxy, though generally there are less globular clusters in small galaxies.

Statistics and Kinematics of Galaxies and of QSS

The Morphological Catalog of galaxies (MCG) provides an exhaustive source for statistical investigations and for the compilation of observational programs. Now with the publication of the II and IV volumes this catalog, compiled by Vorontsov-Velyaminov and Arhipova (**28, 29**), is complete. It gives the coordinates, integrated and surface brightness, dimensions, inclination, description and all other known data for 34 000 galaxies 15^m and brighter to the north of $\delta = -33°$. Among them 1765 interacting, 4700 double and multiple systems are noted. Zvyagina (**30**) from the counts of faint galaxies in small areas around galaxies of 13^m to 14^m finds that statistically more than a half of them have dwarf companions. The number of galaxies with increasing number of companions drops quickly. Denisjuk (**31**) discussed the possibility of finding the orientation of an elliptical galaxy in space with respect to the observer. Roslyakova and Gainullina (**32**) gave a theoretical interpretation to the fact that the symmetry planes of bright E galaxies tend to pass through the center of compact clusters. Agekjan and Sumsina (**33**) found a connection between momenta of apparent and real sphericity of galaxies in 90 clusters. The squares of the sphericity are different, sometimes negative. This points to the preponderance of orientation or to the existence of needle-like galaxies. Veltman (**34**) in his papers, based on the Schuster law, constructed the phase and hydrodynamical models with radially elongated velocity distribution. In the last case the dispersions of velocity are expressed through hypergeometric functions.

Karachenzev concludes that the clusters Virgo (**35**) and Coma (**36**) are not stable. From counts of 54 000 galaxies in the region of the North Galactic Pole he (**37**) finds, using the angular diameters, that the average density of Metagalaxy is $1{\cdot}2 \times 10^{-31}$ g cm^{-3} and makes the inference that the new galaxies are formed in the lapse of time. Pskovsky (**38**) estimated the density and mass of the Coma clusters ($4 \times 10^{14} M_{\odot}$) and, accepting that the clusters occupy 1% of the whole volume, evaluated the density of the Metagalaxy as 7×10^{-30} g cm^{-3}. Karachenzev (**39**) determined the ratio of the virial mass to luminosity for multiple galaxies and clusters and concluded that the non-stability of systems increases with their luminosity. He believed this to be akin to the expansion of the Metagalaxy. Zasov (**40**) studied the correlation of the distance moduli with the red shift of galaxies taking into account the influence of the latter on the apparent luminosity. He has found that the second order term in the relation describing the deceleration of expansion equals $-2{\cdot}2$ (from the luminosity of the 10th galaxy in clusters). Pskovsky (**41**) established the connection of optical limunosity with radio index and obtained the luminosity function of normal galaxies in the photographic and in the radio region. He (**42**) studied the correlation of radio luminosity with the spectral index and linear dimension and obtained the radio-luminosity distribution which proved to be monotonic. Zasov and Ozernoi (**43**) determined the luminosity function of QSS for different models of the Universe in radio and optical frequencies. The continuous transition of the function from radio galaxies to the quasi-stellar radiosources points to their genetic connection.

Spectra and Spectrophotometry of Galaxies and QSS

Dibai and Pronik investigated spectrophotometrically the Seyfert galaxies NGC 1068 (**44**), 1275 (**45**) and others (**46**); Dibai and Vorontsov-Velyaminov (**47**)—NGC 4151; and Dibai,

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Esipov and Pronik (48)–NGC 5548. They calculated the physical conditions in the two systems of gas in all these nuclei and the probable excitation mechanism. Dibai and Pronik (49) made also the spectrophotometry of QSS 3C 273 and determined the physical parameters in its gaseous envelope. Dibai and Esipov (50) measured the red shift in the spectrum of 3C 345 and noticed the changes of the profile of Mg II line. They detected Hα emission in the nucleus of NGC 4486, estimating its gas content and obtained (52) the spectra of ten faint blue objects in high galactic latitudes. Object Tonanzintla no. 256 has a spectrum similar to that of the nuclei of the Seyfert galaxies. Pronik (53) obtained the spectrophotometric characteristics of QSS CTA-102 and estimated the mass of gas to be above $10^6 M_\odot$.

Supernovae

Dibai, Esipov and Pronik (54) studied the energy distribution in the spectra of Chavira and Rosino 1965 supernovae. Kukarkin (55) and Ambartsumian (56) noticed the very high frequency of supernova I outbursts in giant spirals of late types and Pskovsky (57) gave the characteristics of an object near radiosource 3C 386 considering it as being a supernova of anno 1230.

Cosmogonic Hypotheses

According to Pickelner's hypothesis (58) the spiral arms appear when the primordial gas in the center is contracting with a subsequent propagation of a condensation wave along the magnetic tube. Their thickness depends on the star density in the disk. This explains the difference in the arm structure in the galaxies of the Sa, Sb and Sc types. The propagation of the condensation wave in the gas cloud which surrounds the galaxy can explain the formation of the tails and of the connecting filaments in the interacting galaxies. Another possibility of their formation was pointed out by Gerschberg (59). It is the twisting of the magnetic field with the relative rotation of galaxies which lie on one and the same tube of force lines. Sb galaxies require the absence of differential rotation and according to Pickelner (60), the explosion in a gaseous proto-galaxy pushes the gas off center creating the homogeneous sphere of old stars. The flow of gases to the ends of the bar, rings and other structures is also explained.

Notice. In this review there are not included: cosmology, radioastronomical studies of galaxies, theoretical speculations concerning QSS, as well as discoveries and photometric observations of supernovae.

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