28. COMMISSION DES NEBULEUSES EXTRAGALACTIQUES

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MEMBRES: Arp, Baum, Bigay, Bondi, Dessy, de Vaucouleurs, D. S. Evans, Gascoigne, Holmberg, Hoyle, Lemaitre, B. Lindblad, McCrea, McVittie, Markarian, Mills, Morgan, Sandage, Mlle Scott, Shane, Thackeray, Whitford, Whitrow, Zwicky.

La Commission a une Sous-Commission: 28*a*.

INTRODUCTION

Because no *Report* for this Commission was prepared for the General Assemblies of 1955 and 1958, the amount of material submitted for this report is fairly extensive. Also, radio astronomy has reached out into the extra-galactic realm, with very important results; an All-Union S.S.R. Conference on cosmology was held in Moscow during 1957, with the transactions published in 1959; and a Sub-Commission for the Magellanic Clouds was established in 1958. These newer developments, plus the steady advance of extra-galactic researches in the optical region, have resulted in an impressively large number of publications. To keep this report within reasonable bounds, the following abridgement procedure was adopted:

(*a*) Specific references to papers published before 1958 are omitted; in general, these earlier papers may be easily located in the later references listed.
(*b*) The longer descriptive summaries of past, present, and planned future work, submitted by some members, were very briefly (and doubtless incompletely) abstracted, but with explicit references to all work published since 1957, or in press toward the end of 1960.
(*c*) The large amount of work done could not be reviewed completely in any critical way in the short time available; instead, this account is mainly bibliographical with occasional comment.

The authors of this report realize the inadequacy of such treatment in many cases, but it seemed the only feasible way to try to cover the field from a broad viewpoint. Completeness can hardly be expected under these circumstances, and we can only hope that errors of omission, or of commission, are not at a significant level.

OPTICAL REGION

Individual Galaxies, Groups, and Clusters. The physical properties of galaxies in general have been described in detail by de Vaucouleurs (**1**). This author (**2**) also has determined isophotes and colors for the Magellanic Clouds, M 31 and M 33.

The colors and integrated magnitudes of NGC 5194 (M 51) and NGC 5195 have been measured by Markarian (**3**). He also has investigated M 31, 32, 33, 51, and 101 in six colors in order to separate the integrated luminosities of stars of different spectral classes and thus to obtain an idea of the stellar contents of these galaxies.

Mayall and Morgan (**4**) have made a spectroscopic investigation of the peculiar irregular galaxy M 82. It has an early-type spectrum combined with a reddish color, which was interpreted as due to a great complex of dust clouds in the system.

Absolute surface intensity measurements for fifteen elliptical galaxies and for nine spirals and barred spirals in the Virg cluster have been made by Martha Liller (**5**) and for three So galaxies by H. M. Johnson (**5a**).

The emission lines in galaxies, especially the λ 3727 line of [O II], have been studied by

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Minkowski and Osterbrock and by Osterbrock (**6**), particularly for NGC 1052, 4486 (M 87), and 4278. The mechanism of emission is still not clear, although the available data tend to rule out planetaries in favor of hot blue stars like those in globular clusters. The Burbidges (**7**) have investigated the apparent distortion, or different inclination, of the dust lane in NGC 5866, and have compared it with the central H I distorted disk of our Galaxy revealed by the 21-cm radio observations. Jensen (**8**) has worked on the distribution of light around the nuclei of the spiral galaxies NGC 4258 and NGC 7331. Isophotes in the ultra-violet, blue, and red were derived. Evans and Wayman (**9**) have measured the radial velocities of the southern galaxies NGC 1365, 6769, 6770, 6771, and IC 5152. The first four have velocities ranging from +1640 to +4070 km/sec, but the velocity of IC 5152 is only 60 km/sec. Isophotal contours, integrated magnitudes, and dimensions for a number of southern galaxies have been published by Sérsic (**10**).

The rotational motions and deduced masses of galaxies have been the subject of a number of investigations, especially by E. M. and G. R. Burbidge. They (**11**) have observed rotational velocities in NGC 5128 and found a mass of $2 \times 10^{11} M_{\odot}$. With K. H. Prendergast (**12**), they found for NGC 2146 a mass of $1{\cdot}8 \times 10^{11} M_{\odot}$ and a mass/light ratio of 3; for 1068, $2{\cdot}7 \times 10^{10} M_{\odot}$ and 2; and for 5055, $7{\cdot}6 \times 10^{10}$ to $5{\cdot}5 \times 10^{10} M_{\odot}$, depending on the distance adopted, and 2 or 2·8 respectively. They also have obtained similar data, not yet published, for NGC 5005 (**13**), and for 4676 (**14**), which is a peculiar double, possibly interacting, system about 4° from the center of the Coma cluster. G. de Vaucouleurs (**15**) has observed the velocities of outlying nebulosities of the Large Magellanic Cloud. If the distance modulus of the Cloud is 19·0, the deduced mass is $(2{\cdot}5 \pm 0{\cdot}6) \times 10^{10} M_{\odot}$, and the mass/light ratio is about 6. The ratio of neutral hydrogen to total mass is 4 to 5%. The same author (**15a**) has also determined the rotation and mass for NGC 55.

The Burbidges (**16**) have also obtained rotation-curves for the nuclear regions of the barred spirals NGC 1097 and 1365, for which they deduced masses of the nuclei of 0·5 to $1{\cdot}3 \times 10^{10} M_{\odot}$ and 2·2 to $3{\cdot}4 \times 10^{10} M_{\odot}$, repectively. A general review of the problem of the ratio of mass to light densities for galaxies has been published by Münch (**17**).

The rotation curve in the immediate vicinity of the nucleus of M 31 has been investigated by Lallemand, Duchesne, and Walker (**18**) by their new electronic camera technique. The highest nuclear velocity, 87 km/sec, occurs at a distance of 2″·19, after which it falls away rapidly and is presumed to be very nearly zero at 8″, beyond which it rises again. H. M. Johnson (**18a**) had previously studied this nucleus on plates taken at the Cassegrain focus of the McDonald 82-inch telescope.

Galaxies with bars (NGC 936, 7723, 7479, 1023) are the subjects of a colorimetric investigation by Kalloglian (**19**). The bars are bluer than the other parts of the galaxies, and the bars of SB0 and SBa galaxies are redder than those of type SBb. In the latter, the color changes along the bar.

Ambartsumian (**20**) has interpreted galaxies that are radio sources as those whose nuclei are dividing, but in which the separation is incomplete. He considers that the division of a nucleus, and the formation of spiral arms and of connecting filaments, are inter-connected processes.

Schahbasson and Iskudarian (**21**) have found several galaxies of abnormally blue color. The latter (**22**) has discovered a new system of the Sculptor type at $\alpha = 5^{h}\ 55^{m}{\cdot}7$, $\delta = +7^{\circ}\ 46'$ (1950). Dolidze (**23**) at Abastumani Observatory has begun a spectroscopic survey of galaxies with a 70-cm objective prism, and he has found several galaxies in which Hα is bright in the nuclei. Rostovskaja (**24**), using the Palomar Sky Atlas, has investigated the types of the blue-color galaxies discovered by Haro. It was found that the majority of these galaxies belong to the E to Sa classes, and that fifty per cent of them have bright lines in their spectra.

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The theory of a distribution of matter in the form of a flattened system has been worked out by Brandt (**25**), who has applied it to M 31 and to the Galaxy.

The particle dynamics of a galaxy have been investigated by P. O. Lindblad (**26**) with an electronic computer, by which he traced the development of spiral structure of several hundred individual particles. The main mass was assumed to stay in an unperturbed state of rotational symmetry. The free mass-points were considered to move in the principal plane of symmetry and to have a total mass of $10^7 M_\odot$. Resonance perturbations from two kinds of agents are considered. One is the dispersion ring and the other a density wave resembling the bar of a barred spiral. (Certain instabilities occur, causing the formation of spiral structure.) Double galaxies also were studied, and it was found that matter may be ejected from them to large distances, under certain conditions.

Idlis has written a series of papers on the dynamics of galaxies (**27**). In particular, he calculated the masses of the Magellanic Clouds, their relative orbits and their orbits about the Galaxy. He suggests that the Clouds might be the result of a collision between the Galaxy and NGC 55 Agekian (**27a**) has studied the action of irregular forces in galaxies in connection with their evolution. Two evolutionary sequences and four evolutionary stages of galaxies are distinguished.

The possible formation of spiral arms through the action of radiation pressure on dust particles was briefly discussed by Evans and Wayman (**28**).

The dynamical theory of galaxies also has been treated in a monograph by Ogorodnikoff (**29**). This work includes the author's own researches on the statistical mechanics of galaxies. In particular, he believes that sometimes the original form of a galaxy may be that of a 'needle'.

Extra-galactic Super-novae. The Palomar super-nova search, under the general direction of Zwicky, has continued to yield valuable results: it is a co-operative project with the Steward Observatory in Tucson, Arizona, and the Berne Observatory in Switzerland; initially, the Lick Observatory also participated. Humason and Gates (**30**) have published details of six super-novae found in 1959. Since then, eleven more have been discovered, of which nine are due to Humason and one each to Kearns and Wild, as shown in the following table:

Super-novae found in 1959–60

Galaxy	Type	R.A. (1950)	Dec.	First Obs.	m_{ph}	Nucl. Dist.	Found by
		h m	° ′	1959		″ ″	
Anon	Sbc	2 47·2	− 0 43	Dec. 26	18·5	30 E — 20 N	Humason
				1960			,,
Anon	Sa	12 04·6	+17 16	Feb. 20	17·0	7 W — 13 N	,,
Anon	Sa	12 32·2	+ 9 10	Feb. 20	16·0	3 E — 3 S	Kearns
NGC 4321	Sc	12 20·4	+16 06	Feb. 21	18·0	75 E — 20 S	Humason
Anon	SBc	8 17·4	+21 02	Mar. 20	16·0	12 E — 30 S	,,
NGC 4496	SBc	12 29·1	+ 4 12	April 17	12·0	37 E — 33 N	,,
Anon	Sc	11 29·3	+18 40	April 19	17·5	17 E — 17 S	,,
NGC 4096	Sc	12 03·5	+47 45	June 16, 18	14·5	67 E —114 S	See note*
Anon	SBb	12 24·4	+48 34	June 16, 18	19·0	5 E — 11 S	Humason
NGC 4375	Sc	12 22·2	+28 50	June 16, 18	18·5	37 E — 17 N	,,
Anon	SBc	22 37·7	+34 08	June 16, 18	19·0	13 W — 8 S	,,

*Wild, Humason, (*H.A.C.* no. 1488)

Large-Scale Features. A most important observational advance was made by Baum and Minkowski (**31**), who extended measurements of magnitude and of redshift to a value of $z(=\Delta\lambda/\lambda)$ of 0·46 for a very faint galaxy. Minkowski used a precise position of the radio source 3 C 295 to identify the brightest member in the cluster designated 1410 + 5224, and to measure spectroscopically the large redshift of the [O II] emission line normally at λ3727.

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Baum previously had studied the cluster by his photo-electric technique (**32**), and had deduced essentially the same value of the redshift. The presently available photo-electric data refer to the following clusters: Virgo ($z = 0{\cdot}004$), Coma ($z = 0.022$), Cor. Bor. ($z = 0{\cdot}072$), 1055 + 5702 ($z = 0{\cdot}134$), 0925 + 2044 ($z = 0{\cdot}192$), 0024 + 1654 ($z = 0{\cdot}29$), 1448 + 2617 ($z = 0{\cdot}36$), 1410 + 5224 ($z = 0{\cdot}46$). When interpreted in terms of the uniform models of the universe, these data suggest a value of -1 for the acceleration parameter $(\ddot{R}/R)_0/(\dot{R}/R)^2{}_0$, where R is the scale factor and the suffix zero refers to the present time. Baum considers that this result indicates that the steady-state theory is unacceptable, because this theory predicts a value of $+1$ for the acceleration parameter.

E. Holmberg (**33**) has published an investigation of 300 galaxies for which he gives total magnitudes and colors. His detailed statistical analysis dealt with such matters as absorption within galaxies, a pronounced correlation between absolute magnitude and surface brightness for 'normal' galaxies in the Virgo cluster, and advocacy of the point of view that double galaxies and physically-related groups have been formed by the disintegration of a single parent galaxy. A similar suggestion regarding the formation of associated galaxies was made in the previously-cited work of Ambartsumian (**20**). Bigay (**34**) has published V magnitudes and $B-V$ and $U-B$ colors for twenty galaxies.

Vorontsov-Velyaminov (**35**) has issued the first part of his catalogue and *Atlas of Interacting Galaxies*. It contains 355 objects.

Agekian (**36**) has analyzed the published counts of galaxies by means of his generalization of Ambartsumian's method in the theory of fluctuations. He concluded that the majority of galaxies form groups of eight members.

The classification of more than 600 galaxies has been carried out by W. W. Morgan (**37**), on the basis of the correlation, previously noted by him and Mayall, between the degree of central concentration of luminosity and the integrated spectrum of the brightest inner parts of a galaxy—and also with its color. This classification included all galaxies brighter than the 13th magnitude and north of declination –25°. S. van den Bergh (**38**) has proposed a classification of spiral and irregular-type galaxies based on the correlation between absolute luminosity and the degree of development of the spiral arms.

An elaborate system of classification for galaxies has been worked out by de Vaucouleurs (**39**); it makes use of a three-dimensional representation. The same author also has studied the photographic dimensions of galaxies (**40**). In this connection, Vorontsov-Velyaminov (**41**) has concluded that it is impossible to compare the linear dimensions of elliptical and spiral galaxies, and he proposes that the diameters of the latter be defined by the spiral structure. He also has investigated many ring galaxies (**42**). G. and A. de Vaucouleurs (**43**) have reported a second survey of bright galaxies south of declination −35°. Descriptions, classification, and a few new radial velocities are included. Much of the work was done with the 74-inch telescope at Mount Stromlo. Magnitudes and colors of galaxies on the U, B, V system also have been published by de Vaucouleurs (**44**).

Zwicky's five-volume catalogue of positions and apparent magnitudes of about 40 000 galaxies brighter than magnitude 15 has reached the stage where the first volume is being printed. Zwicky concludes that the accompanying analysis provides evidence that: (*a*) most galaxies belong to clusters, (*b*) there are obscuring dust clouds between galaxies, (*c*) there are no clusters of clusters of galaxies, and (*d*) there is a breakdown of Newton's and Einstein's laws of gravitation at distances of several millions of light years, amongst other results. In unpublished work, Zwicky and Humason have obtained new spectroscopic data on redshifts, velocity dispersions, and spectral characteristics of double, multiple, and cluster galaxies. For such objects, Zwicky would expect a luminosity function with a maximum, but not for galaxies in general. He thinks the latter would include increasing numbers of low population systems, some with as few as 1000 stars, which have been found in a continuing search for dwarfs.

Vorontsov-Velyaminov (**45**) also finds, from his investigation of interacting galaxies, that tidal forces are insufficient to account for these objects. He suggests that some unknown force of a non-gravitational nature must be involved.

Neyman and Scott (**46**) have continued their statistical researches on the distribution of galaxies, with the basic material being counts previously published by Shane and Wirtanen. Their analysis considers that the observed distribution results from a stochastic process stationary in the spatial coordinates and either stationary or expanding in time. Rejection of the hypothesis of stationarity could imply that a part of the redshift represents expansion. The analysis has been refined to include selection effects: a corollary result is a normal luminosity function with a dispersion of 1 magnitude for galaxies with redshift observed. They have derived formulae to estimate velocity dispersion in clusters (**47**) and also for field galaxies (**47a**). Lovasich, Mayall, Neyman and Scott (**47b**) have applied the stability test to 15 groups and 7 clusters, including Coma with additional velocity data of Mayall (**48**). The results indicate instability, expansion or contraction, and suggest presence of intra-cluster absorption. Page (**49, 49a**) has refined the statistical treatment of double galaxies and extended it to 52 systems, including all appropriate measures of velocity in the Humason, Mayall and Sandage catalog. The average mass of spirals in 14 systems is $2 \times 10^{10} M_{\odot}/h$, that of ellipticals in 27 systems is $(60 \pm 10) \times 10^{10} M_{\odot}/h$. Using the magnitudes available, some of them of low accuracy, he obtains a mean ratio of mass to light in solar units of $(0{\cdot}3 \pm 0{\cdot}2)h$ for spirals and $(94 \pm 27)h$ for ellipticals (h is the Hubble constant in km/sec/10^4pc).

An overall review of the problem of extra-galactic distances and the resulting value of the Hubble parameter H (Hubble 'constant') is due to McVittie (**50**), who found $143 < H < 227$ km/sec/Mpc on the basis of the data available up to mid-1956. Holmberg (**33**) obtained 134 ± 6 km/sec/Mpc. S. van den Bergh (**51**), by a discussion of all available distance-indicators similar to McVittie's, concluded that $100 < H < 145$ km/sec/Mpc. Sérsic (**52**), from a correlation between the diameters of H II regions in galaxies and the type of the galaxy, $120 < H < 130$ km/sec/Mpc. Larger distances and smaller values of H are favored by Sandage (**53**), who used two distance criteria only, namely, the brightest stars in galaxies and the novae. The calibration for the former method by objects in the Galaxy was provided by three stars and, for the second, by eleven novae (**54**). Sandage's value for H is 75 km/sec/Mpc. This value was used by Oort (**55**) in his determination of the average density of matter in space, for which he found $3{\cdot}1 \times 10^{-31}$ gr/cm^3.

In another statistical investigation of the dynamics of clusters of galaxies and the spatial distribution of their members, Scharov (**56**) has analyzed the clusters in Coma, Cancer, and Hydra, by means of the counts previously published by Zwicky. In each cluster, he found the galaxies distributed in three zones: a nucleus, a constant density zone, and a corona. This distribution is similar to that of the stars in a globular cluster, and does not resemble that of an isothermal gas sphere.

Limber and Matthews (**57**) have discussed again all the available data on Stephan's Quintet. They conclude that the system is indeed in dynamical equilibrium and is not disrupting, as was suggested by E. M. and G. R. Burbidge (**58**). G. de Vaucouleurs (**59**) concluded that the group consisting of NGC 45, 55, 247, 253, 300, and 7793 is an association of galaxies in a state of expansion. He also has discussed the stability or otherwise of a number of other clusters (**60**), has reviewed the evidence for the existence of a Local Super-cluster (**61**) and proposes to explain the non-linearity and anisotropy of the velocity field among the brighter galaxies by the hypothesis of differential rotation and expansion in the super system (**61a**).

RADIO REGION

Continuum. A number of detailed studies have been made of the radio continuum emission from individual systems. These include M 31, M 33, NGC 5128, and NGC 1316. In the case of M 31, a division of the emission into discoidal and coronal components, similar to those of the Milky Way, has been found by Brown and Hazard (**62**) and by Large, Mathewson, and Haslam (**63**). The emission of M 31, however, is significantly less, and the total volume of its radio corona is substantially greater. M 33 has a radio corona comparable in size to that of the Milky Way, and in emissivity to that of M 31.

Both NGC 5128 and NGC 1316 are abnormally strong radio emitters having absolute radio magnitudes some 5 to 6 magnitudes brighter than M 31. Little information is available on NGC 1316 because of its greater distance, although in its general features it appears to resemble, according to Shain (**64**), NGC 5128. This system has been the subject of several investigations and some very interesting results have been obtained. The radio corona appears to consist of two separated concentrations more or less symmetrically situated on either side of the galaxy. The separation between the centers of these concentrations may be between 50 and 200 Kpc, depending on the distance for the galaxy adopted by the several observers, Wade (**65**) and Bolton and Clark (**66**). The situation appears similar to the well known case of Cygnus A, although NGC 5128 has an intense emitting region approximately coincident with the band of dust that crosses its nucleus. Twiss, Little, and Carter (**67**) have found that this central source also may be resolved into two symmetrically situated components. The cause of this duplicity is not clear at present, but some unpublished surveys for diameters have suggested that this feature may be fairly common among strong extra-galactic sources. Mills and Minkowski (**68**) and Dewhirst (**69**) have noted that some radio sources may be identified with close pairs of galaxies, but it is not yet known whether they are also double in the radio region.

Several investigations have been made of clusters of galaxies and of the collection of brightest galaxies sometimes referred to as the local 'Super-galaxy' or 'Super-cluster'. Hill (**70**) and Shakeshaft and Baldwin (**71**) have shown that radiation formerly attributed to the latter is more likely to be associated with a galactic feature.

A detailed study of the Coma cluster by Large, Mathewson, and Haslam (**72**) has indicated that any excess radiation associated with it probably originates in a few peculiar galaxies of the cluster. Similarly, search for identifications of radio sources with clusters showed that in many cases excess emission at the cluster position most likely originated in a single peculiar galaxy: no clear evidence could be found for inter-galactic emission. To summarize, it appears that the evidence favors radio emission of clusters only from a few members, but the possibility of a cluster radiating as a whole cannot yet be excluded; more high resolution studies are needed for more clusters.

Radio Luminosity Function. This has been an outstanding problem since the first observations of extra-galactic radio emission. Optically bright and close galaxies have been observed to exhibit a low radio emission, comparable to that of the Milky Way, whilst the brightest radio sources at high galactic latitudes have been identified with faint and distant galaxies. This situation has led to the use of the terms 'normal' and 'radio' galaxies to describe the two apparently distinct types. However, Mills and Minkowski's (**68**) systematic searches for identifications, which involve large numbers of radio sources, have suggested that no clear distinction can be made. Thus, a galaxy chosen at random may have any radio emission between the extremes observed, with the probability of finding a given emission falling rapidly and monotonically as the emission exceeds that of the 'normal' nearby spirals.

B. Y. Mills found that such a luminosity function is quite adequate to explain qualitatively the preponderance of distant objects of high luminosity among the observed radio sources, provided the rate of decrease in probability (i.e. in space density) is not too great. The two luminosity functions derived by him do not differ greatly in form, and both are adequate to account for the high-latitude radio sources, within the rather large observational uncertainties. An important conclusion is that analysis of source counts alone is not a very effective method in cosmology. At most the method may hope to differentiate between steady-state and evolutionary universes.

H I 21-*cm Emission.* Following earlier detailed studies of M 31 by van de Hulst, Raimond, and van Woerden and by M. Schmidt, the Leiden group has extended its work to other systems: to M 32 by Wentzel and van Woerden (**73**), in which a search for H I was negative, but inconclusive; to M 33 and M 101 by Louise Volders and by van de Hulst (**74**); while van Woerden and Heidmann (**75**) found that total H I mass and rotational velocity may be estimated for systems out to 10 Mpc.

For the spirals observed, the intensity distribution of the hydrogen mass and of velocities over the system was derived and plotted. The estimated ratios of hydrogen to total mass are: 1% (M 31), 5% (M 33), and 2% (M 101). M 33 also has been studied by Nannielou Dieter (**76**), who obtained a larger apparent extent of the spiral than did Volders and van de Hulst. H I emission has also been observed from NGC 253, 4236, 6822, and IC 1613; a summary of these and other cases has been made by van de Hulst (**77**).

Cooper *et al.* (**78**) have detected 21-cm radiation from nine galaxies, and Heeschen (**79**) has observed radio emission at 68·2 and 21·4 cm, also from nine galaxies. The latter found a well-defined correlation between color and absolute magnitude.

Muller (**80**) was unable to detect 21-cm radiation from the Coma cluster, while Field (**81**) was unsuccessful in detecting inter-galactic neutral hydrogen, from a search for absorption effects in the spectrum of the radio source Cygnus A. Finally, a most important negative result was the failure by Davies and Jennison (**82**) to observe the Cygnus A redshift originally obtained by Lilley and McLain. Unpublished work by McClain confirms the spuriousness of the original observations.

COSMOLOGICAL THEORY

Much attention has been devoted to the theoretical calculation of observable relations predicted by uniform models of the universe. These investigations consist mainly of detailed expositions and amplifications of results found in the textbooks, such as that by McVittie (**83**). Mattig (**84**) has dealt with the three relativistic models in which the pressure and the cosmical constant are zero. He calculated the exact relations between apparent bolometric magnitude and redshift. He also derived the formula for the total number of light sources as a function of apparent magnitude, correct to the second order in the redshift. The number problem has been also treated by Davidson (**85**) for optical sources in the general model of relativity theory and for the steady-state model. The same question was discussed by McVittie (**86**) from the point of view of the number of radio sources per unit volume. The possibility of the disappearance of radio sources during the course of the history of the universe is also allowed for. The number of radio sources, when these are regarded as due to collisions between galaxies, was analyzed by Priester (**87**) for the three model universes treated by Mattig and for a classical Newtonian universe by Harrower (**88**).

Davidson (**89**), Lamla (**90**), and van der Borght (**91**) have all worked out in detail the theory of the relation between observed apparent magnitude and the redshift (the *K*-correction). The analogous relation between observed flux-density and redshift for radio sources was discussed by McVittie (**92**).

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The question of the dependence of the angular diameters of sources of radiation on such other observables as the redshift is the subject of a paper by Florides and McCrea (**93**), who concluded that the differences between the predictions of the steady-state model and the relativistic models are of the order $(1+z)^{-1}$, where z is the redshift. In view of the present attainment of a redshift of 0·46, this factor can no longer be regarded as differing only slightly from unity. The problem of angular diameters is also treated by Davidson (**94**).

The total background radiation from optical and from radio sources in a Milne universe was worked out in detail by McVittie and Wyatt (**95**). A more general treatment is due to Metzner and Morrison (**96**), and more work on problems of this type is being carried out by G. J. Whitrow.

Among investigations of a more general character, the problem of the evolution of a uniform model universe was discussed by Bonnor (**97**). Davidson (**98**) has studied the interpretation of the steady-state theory by relativistic cosmology. He used the notion of a statical superposition of a symmetric mass concentration, or rarefaction, on a medium that is in a steady state. Hoyle (**99**) has tried another approach to the formulation of gravitational theory in the steady-state theory. He introduced a scalar function of position, in place of the vector used earlier, to represent the creation process. Thus, he showed that a particular solution of the resulting field-equations gives rise to the steady-state model of the universe. Bondi and Lyttleton (**100**) have considered, in the steady-state theory, the effects of a postulated electrical unbalance due to a difference of charge between electrons and protons. Hillas and Crankshaw (**101**) have, however, shown experimentally that, if such an unbalance exists, it must be at least one hundred times smaller than is required by Bondi and Lyttleton's theory. Hoyle (**102**) has, nevertheless, pursued the investigation further by introducing considerations of matter and anti-matter.

McCrea (**103**) has proposed that there is an implicit indeterminacy in cosmology, which arises from a postulate that every part of the universe interacts with every other part.

Schücking and Heckmann (**104**) have published a brief account of their investigations on non-homogeneous models of the universe.

COSMOLOGY: STUDIES IN THE U.S.S.R.

The following report was abridged from a more complete one prepared by A. L. Zelmanov, and communicated by E. R. Mustel, Vice-President, Astronomical Council, U.S.S.R. Academy of Sciences. The condensation consisted of deleting descriptions and references to works published prior to 1958, as was done for the preceding parts of this *Report*.

D. Ya Martynov (**105**) studied the reliability of the observational data in extra-galactic astronomy and found that a number of effects, which distort the determinations of the integrated magnitudes of the galaxies, make unreliable the elucidation of fine details of the redshift dependence upon the distance, and the theoretical deductions based upon these details, in particular the determination of the acceleration of the Meta-galaxy expansion.

J. A. Smorodinsky (**106**) found by comparing the relativistic equations (without the cosmological term) for the homogeneous isotropic universe with the observational data, that the latter (in spite of some authors' opinions, for example, Sandage and Baum) can be represented, if an open model is accepted.

G. P. Pskovsky (**107**), using A. L. Zelmanov's results for the redshift dependence upon the distance in the relativistic anisotropic non-homogeneous universe (in the linear approximation), analyzed preliminarily the redshifts of 310 extra-galactic nebulae and determined the anisotropy of deformation of the Meta-galaxy.

M. F. Shirokov (**108**) proposed a version of the relativistic model of the homogeneous isotropic universe with negative pressure, analogous to the model suggested by McCrea.

E. M. Lifshitz (109) confirmed his previous results on the gravitational stability of the relativistic expanding universe.

E. M. Lifshitz and I. M. Khalatnikov (110, 111) investigated in detail the different types of the singularities in the cosmological solutions of Einstein's equations for the anisotropic non-homogeneous universe.

A. L. Zelmanov (112, 113) developed a mathematical formalism for the relativistic theory of the anisotropic non-homogeneous universe (the method of chronometric invariants), and deduced with its aid general equations of the theory and a number of conclusions concerning the temporal behaviour of an arbitrary region of the anisotropic non-homogeneous universe.

In connection with the above-mentioned theory, the following result, proved in the case of empty homogeneous isotropic models, was discussed: the spatial volume of the universe can be finite in one system of reference and infinite in another system, with the space-time of the second system representing a part of the space-time of the first system (114). The same author introduced a formalism for obtaining an approximation to the relativistic theory of the anisotropic non-homogeneous universe by means of the non-relativistic mechanics and the non-relativistic theory of gravitation: the quasi-newtonian approximation (115, 112) and the earlier deduced non-relativistic equations of the mechanics of a continuous medium in the co-moving co-ordinates. This formalism was applied by I. D. Novikov (116) to a number of anisotropic homogeneous models.

A. L. Zelmanov (115), comparing the gravitation laws of Newton and Einstein, found that the sources of the non-relativistic gravitational paradox are, firstly, the idea that the velocity of gravity propagation is infinite, and, secondly, the idea that the gravitational field of a mechanical system is independent of the energy of interaction of its parts.

By postulating the law of gravitation as admitting the statistical equilibrium state for the universe as a whole, J. P. Terletzky (117) continued to develop the Boltzman fluctuation hypothesis and his own deductions; according to these, the gravitational interactions increase the probability of strong fluctuations in large volumes.

K. P. Staniukovitch (118) confirmed and developed his earlier conclusions, according to which the infinite hierarchic structure can never reach the state of statistical equilibrium, while in every finite region, the entropy is increasing. The polemics with I. R. Plotkin is contained in (118) also.

I. R. Plotkin (119), in considering the universe as a system consisting of an infinite number of particles, developed the conclusions previously obtained by him, according to which the law of entropy growth for such a system—and even the conception of entropy—is senseless, and found the above-mentioned law to be altogether inapplicable to the systems consisting of a very (even excessively) large number of particles. The papers by this author also contain the polemics with K. P. Staniukovitch.

G. M. Idlis (120, 121) considered the properties of the Meta-galaxy as a typical habitable cosmical system.

G. J. Naan (122) and A. L. Zelmanov (123) examined such general problems of cosmology as the problems of definition, content, and foundations of cosmology, the extrapolation problem in cosmology, etc.

The present report and the references are not exhaustive.

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INTRODUCTION

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

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

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