TRANSACTIONS OF THE
INTERNATIONAL ASTRONOMICAL
UNION
VOL. XVI A (REPORTS 1976)
PART 3

REPORTS ON ASTRONOMY

PUBLISHED AND DISTRIBUTED FOR

ΨAU

D. REIDEL PUBLISHING COMPANY
DORDRECHT-HOLLAND / BOSTON U.S.A.

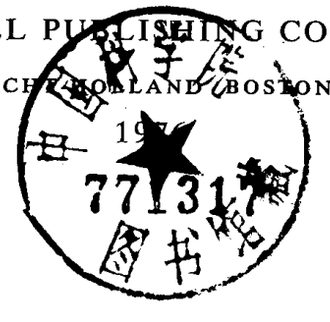
INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS
INTERNATIONAL ASTRONOMICAL UNION
UNION ASTRONOMIQUE INTERNATIONALE

TRANSACTIONS
OF THE
INTERNATIONAL ASTRONOMICAL UNION
VOLUME XVIA - PART 3

REPORTS ON ASTRONOMY

Edited by
G. CONTOPOULOS
General Secretary of the Union

D. REIDEL PUBLISHING COMPANY
DORDRECHT-HOLLAND/BOSTON-U.S.A.



ISBN 90-277-0741-3

Published on behalf of
the International Astronomical Union
by
D. Reidel Publishing Company, P.O. Box 17, Dordrecht, Holland

Sold and distributed in the U.S.A., Canada, and Mexico
by D. Reidel Publishing Company, Inc.
Lincoln Building, 160 Old Derby Street, Hingham,
Mass. 02043, U.S.A.

Printed in The Netherlands

TRANSACTIONS
OF THE
INTERNATIONAL
ASTRONOMICAL UNION

VOLUME XVIA – PART 3
REPORTS

INTRODUCTION

The reports on Astronomy, 1976, have been arranged into three Volumes of moderate size and as much as possible homogeneous contents. The Commission Reports have been divided as follows:

VOL. XVIA-1

Commissions

4	Ephemerides
7	Celestial Mechanics
9	Instruments and Techniques
14	Fundamental Spectroscopic Data
15	Physical Study of Comets, Minor Planets and Meteorites
16	Physical Study of Planets and Satellites
17	The Moon
19	Rotation of the Earth
20	Positions and Motions of Minor Planets, Comets and Satellites
21	Light of the Night-Sky
22	Meteors and Interplanetary Dust
31	Time
49	The Interplanetary Plasma and the Heliosphere
5	Documentation
6	Astronomical Telegrams
38	Exchange of Astronomers
41	History of Astronomy
46	Teaching of Astronomy
50	Identification and Protection of Existing and Potential Observatory Sites

VOL. XVIA-2

Commissions

8	Positional Astronomy
10	Solar Activity
12	Radiation and Structure of the Solar Atmosphere
24	Photographic Astrometry
25	Stellar Photometry and Polarimetry
26	Double Stars
27	Variable Stars
29	Stellar Spectra
30	Radial Velocities
35	Stellar Constitution
36	Theory of Stellar Atmospheres
42	Close Binary Stars
45	Spectral Classifications and Multi-band Colour Indices

VOL. XVIA-3

See the Contents for this volume, p. VII.

It is hoped that the present system will allow a wider circulation of the separate Volumes to Members of the IAU and other scientists interested in particular topics of astronomical research.

Still it was necessary to adopt the utmost conciseness in the Reports. Otherwise, in view of the considerable increase of the astronomical activity (including the work of physicists, chemists and other non professional astronomers) each of the three volumes could well be more than double its present size.

In view of this restriction the various Presidents of Commissions reacted in different ways. Some have reviewed the recent research in the area of their Commissions, giving only a few general references, others have provided extensive references but little description of the published work. However, in most Commissions' Reports I found a wealth of useful and exciting information that would be valuable for research workers in any field of Astronomy.

I want to thank all Presidents of Commissions and their Colleagues who took part in preparing the various Commissions' Reports.

G. CONTOPOULOS
General Secretary

Athens
January 31, 1976

CONTENTS

28. GALAXIES

PRESIDENT: E. B. Holmberg.
VICE-PRESIDENT: B. E. Markarian.
ORGANIZING COMMITTEE: F. Bertola, J. Bolton, G. R. Burbidge, R. D. Davies, K. C. Freeman, M. S. Roberts, J. L. Sérsic, S. van den Bergh, B. A. Vorontsov-Velyaminov, B. E. Westerlund.

The present account refers mainly to research work published in the period 1973–1975. Due to the limited space available, and the rapidly increasing number of contributions in the field of Commission 28, it has not been possible to write an all-inclusive report. As in the previous IAU volumes, the report is not intended as a repetition of the summaries given in the *Astronomy and Astrophysics Abstracts*. In stressing the importance of certain areas of research, the personal views of the writer(s) cannot be entirely avoided.

On account of the great diversification in the field of extragalactic research it has seemed appropriate to divide the responsibility for this report among astronomers who are actively working in the various areas. Where possible, references are given by the numbers in the above-mentioned *Abstracts*; for papers published after 1975.01.01 commonly-used abbreviations for journals are used and volume numbers alone without years.

Attention may be called here to the numerous meetings and symposia that have been held during the past three years, or the proceedings of which have been published during this period. The First European Astronomical Meeting, held under the auspices of the IAU, convened in Athens 1972, and the proceedings have been published in three parts; extragalactic problems are confined to the third volume, 'Galaxies and Relativistic Astrophysics' (11.012.010). A part of the Second European Meeting, held in Trieste 1974, was devoted to problems connected with galaxies (proceedings in press). The Third European Astronomical Meeting, on the subject 'Stars and Galaxies from Observational Points of View', was held in Tbilisi 1975; in the extragalactic field the lectures referred to the structure of galaxies, the missing mass in galaxies, and observational aspects of the evolution of galaxies.

IAU Symposium No. 52, on 'Interstellar Dust and Related Topics' (10.012.022), includes some papers on dust in galaxies. Symposium No. 55, on 'X- and Gamma-Ray Astronomy' (09.012.002), gives reports on extragalactic X-ray sources. Symposium No. 58, on 'The Formation and Dynamics of Galaxies' (12.012.005), covers a number of important problems: the nature of the intergalactic medium, the redshift problem, the nuclei of galaxies, the gravitational interaction between galaxies, and the spiral structure of nearby galaxies. Symposium No. 63, on 'Confrontation between Cosmological Theories and Observational Data' (12.012.004), presents a review of observational aspects of cosmology in the light of current theories. Finally, IAU Symposium No. 69, dealing with the 'Dynamics of Stellar Systems' (1975), among other things compares theory and observations as regards the dynamics of galaxies of different types.

Among other important meetings, attention is again called to the 'Conference on the Role of Schmidt Telescopes in Astronomy' (08.012.014), jointly sponsored by the European Southern Observatory (ESO) and the British Science Research Council (SRC); the proceedings include some papers referring to the extragalactic field. A subsequent 'ESO/SRC/CERN Conference on Research Programmes for the New Large Telescopes' (11.012.021) deals with a number of extragalactic observational problems. Extragalactic observations outside the optical region have been discussed at the 17th and 18th Herstmonceux Conferences (10.011.020, 12.011.038).

1. GALAXIES IN GENERAL

A. *Survey Work; Catalogues*

Two new large Schmidt telescopes, in the first place intended for survey work, have been installed in the southern hemisphere during the past three-year period. The ESO 1-m telescope became operational at la Silla, Chile, towards the end of 1972. About one year later, the 48-in Schmidt telescope of the British Science Research Council started observations at Siding Spring, N.S.W., Australia.

It was decided that the ESO telescope should first undertake a fast survey in a blue waveband: II a-O plates combined with a GG 385 filter. The survey is referred to as the ESO (B) Survey (also termed the 'Quick Blue Survey') and covers 606 fields distributed at 5° centers from −90° to −20° decl. The limiting magnitude for a 1-h exposure is approximately $21^{m}.5$. A systematic search of the survey plates is carried out at the Uppsala Observatory. The three lists completed till now (12.113.033-034, third list in press), which refer to more than 100 fields, include galaxies down to a limiting diameter of about 1'.0, in addition to all disturbed galaxies that are recognizable on the plates. The lists give coordinates, diameters, position angles, and descriptions. Later on it is intended to collect all the data, with the addition of apparent magnitudes, in one final extragalactic catalogue for the southern sky. Preparations are also being made to produce an atlas of peculiar and disturbed galaxies. The UK SRC telescope will first be used for a survey based on sensitized III a-J plates, the exposures being centered on the same 606 fields as those mentioned above. A first list (in press) of 'A Catalogue of Southern Peculiar Galaxies from the U.K. Schmidt Survey', referring to 36 fields, has been prepared by Arp and Madore. On a photograph reaching B = 23 a study of 3000 faint galaxies has been undertaken by Dodd and colleagues (*Monthly Notices Roy. Astron. Soc.* **171**, 329). – Accounts of present and future surveys with the southern Schmidt telescopes have been given by West (11.032.048, 11.041.023), by Cannon (11.032.049), and by Reddish (*Observatory* **95**.85).

A very comprehensive and detailed catalogue, based on the Palomar Sky Survey prints, has been published by Nilson (10.158.072). The 'Uppsala General Catalogue of Galaxies' gives information on about 13 000 galaxies down to a limiting diameter of 1'.0 and north of decl. −2°.5. The data include, among other things, coordinates, diameters, position angles, morphological types, and magnitudes; additional information is presented in detailed notes. The catalogue furnishes a material very suitable for statistical analyses.

'The Revised New General Catalogue of Nonstellar Astronomical Objects', published by Sulentic and Tifft (10.003.155), presents revised data for the 7840 objects of the NGC. The revision is based on the Palomar Sky Survey prints, with the addition of plates obtained from a number of southern observatories. The catalogue supplies a collection of basic data that are urgently needed by the observers.

For 821 galaxies of the 'Reference Catalogue of Bright Galaxies' optical positions, with an accuracy of a few seconds of arc, have been determined by Gallouet and colleagues (10.158.024); the list is a continuation of a previous paper with positions for 745 objects (05.158.076). The Palomar Sky Survey prints have been used by Corwin (10.158.137) to derive revised classifications for 1200 bright galaxies. The new results show good agreement with the earlier de Vaucouleurs types.

Valuable information on the sky survey has been presented by Lund and Dixon (09.041.014) in 'A User's Guide to the Palomar Sky Survey'.

Finally, attention is called to the plans announced in a circular letter by R. S. Dixon to compile a master list of the over 200 000 non-stellar optical objects known at the present time. A study is being made of the desirability of preparing and distributing full-size, clear plastic overlays for all of the Palomar Survey photographs, showing all these non-stellar objects.

B. *Measurements in the Optical, Infrared, Radio and X-Ray Regions*

In the past three years a considerable amount of work has been devoted to photometry of galaxies in the standard optical wavelength bands. Since most of these investigations will be

included in the subsequent report by the Working Group on galaxy photometry and spectrophotometry, only a few comments on general problems will be given here.

Attention is recalled to the interesting comparison of electrographic, photographic and photoelectric results that has been made by Ables and Ables (08.158.026); the three different techniques were compared by studying the luminosity profiles derived for the galaxy NGC 4881. The dependence of magnitude on the aperture used in photoelectric measures has been studied by Kron and Shane (11.158.012) in the first of a series of papers on the magnitudes of galaxies. In a paper on the techniques of galaxy photometry Tifft (10.158.041) has discussed a new method for rapid estimation of nuclear magnitudes by iris photometry of photographic plates.

It has become apparent that a large fraction of the luminosity from many extragalactic objects is emitted at infrared wavelengths, a fact that has been emphasized by Stein (*Publ. Astron. Soc. Pacific* **87**, 5) in a summary of recent revelations of infrared astronomy. Among observations in the near-infrared we may recall the spectrophotometry by Barbon and D'Odorico (08.158.003) of the nuclei of NGC 221, 224, 3115, 4151 and 4406, also the measurements by Barbon and Capaccioli (10.158.146) of NGC 3628. The heavily obscured object Maffei 2 has been investigated by Spinrad *et al.* (09.158.052); combining optical, near-infrared and radio observations they concluded that the object is a Sbc spiral with a probable distance of 5 Mpc. In the far-infrared region, we wish to recall the observations by Rieke and Low (08. 158.057; *Astrophys. J.* **197**, 17; *Astrophys. J.* **199**, **L13**; *Astrophys. J.* **200**, L67) of a considerable number of extragalactic sources. Several observers have measured galactic nuclei: NGC 253 (09.158.066), NGC 253, 3034 (09.158.145; *Astrophys. J.* **198**, L65), NGC 1068, 4151 (11.158.005). A list of the numerous observations of the nucleus of the important Seyfert galaxy NGC 1068 has been given by Jones and Stein (*Astrophys. J.* **197**, 297), together with a discussion of the origin of the infrared emission.

The largest number of contributions is to be found in the field of radio astronomy. Due to overlap with the Report of Commission 40, the following account will be restricted to the most important of the recent developments.

A very important field of research has been opened up by the arrival of the high-resolving synthesis radio telescopes. Attention will in the first place be called to the comprehensive extragalactic program initiated by means of the Westerbork telescope. This instrument consists of ten fixed and two movable 25-m disks, and is operated as an Earth-rotation aperture synthesis telescope. The results published by van der Kruit, Oort and Mathewson (08.158.067), by Allen and Raimond (08.158.011), and by van der Kruit (10.158.087-088) give, together with earlier results, data for 44 large spiral galaxies, among them all fourteen spirals brighter than Harvard magnitude 10.5 above decl. +15°. A summary and general discussion of the results, and a list of the objects, has been presented by van der Kruit (10.158.089). All the observations are studies of the radio continuum brightness distribution at 1415 MHz (bandwidth = 4 MHz). The radio maps in many cases give detailed information about the three components that can usually be distinguished: nucleus, base disk, and spiral arm system. The nuclei of Seyfert galaxies appear to be the strongest radio emitters, about 100 times stronger than the nuclei of most normal galaxies; NGC 598 and 2403 exhibit exceptionally weak nuclei. As regards the observed spiral structure, the radio ridges are displaced towards the inner edges of the optical arms, thus confirming the conception of compression regions due to the action of density waves. Additional observations with the Westerbork telescope have later on been published by Allen, Goss and van Woerden (10.158.119), by Rots and Shane (11.158.014), and by Israel and van der Kruit (11.158.082). An up-to-date summary of the Westerbork work has been given in a report by van der Laan (12.033.036).

The twin-element interferometer of the Owens Valley Radio Observatory has been used for synthesis observations of neutral hydrogen emission in spiral galaxies. A number of different observers have investigated Maffei 2 (09.158.001), NGC 6946 and IC 342 (09.158.005), NGC 2403 and 4236 (09.158.085), NGC 5194 (09.158.039), NGC 7640 and IC 2574 (10.158.027), IC 10 (11.158.010), and NGC 5236 (12.158.113). Detailed maps of the H I distributions and of the radial velocity fields lead to a number of interesting conclusions.

A program of high-resolution observations at 5 GHz of extragalactic radio sources has been in

progress at the Mullard Radio Astronomy Observatory. The eight elements of the Cambridge Earth-rotation synthesis system have been connected to provide 16 independent interferometer spacings, with a maximum of close to 5 km. The results obtained for 48 objects have been presented by Pooley and Henbest (12.141.083). The very detailed maps are accompanied by a table of important physical parameters. In a separate paper, Hargrave (12.158.037) has given the results obtained for M 82.

Among the traditional 21-cm hydrogen line studies of external galaxies the numerous results obtained by means of the Nançay radio telescope may be noted. The results refer to all types of objects, from type E to type Ir I galaxies. The investigations are published in *Astronomy and Astrophysics*. Attention may also be called to the long series of neutral hydrogen observations of external galaxies made by the Jodrell Bank telescopes. Reports have been given by Lewis and Davies (10.158.083-084), and by Dean and Davies (*Monthly Notices Roy. Astron. Soc.* **170**, 503).

In the X-ray region the main interest has been focussed on the results obtained from the *Uhuru* satellite, launched by NASA in 1970. The observational data have been published by Giacconi and colleagues in 1972 (08.142.101) and 1974 (11.142.035), the latter contribution being 'The Third *Uhuru* Catalogue of X-Ray Sources'. With a nearly complete sky coverage, the total number of sources has grown to 161. Although most of these objects are of galactic origin, the number of known extragalactic sources has been greatly increased. The Magellanic Clouds are near enough to allow the resolution of a number of individual sources. The intrinsic X-ray intensity of NGC 224 seems to be about the same as the total emission of all the Milky Way sources, whereas the well-known radio galaxy NGC 5128 has an intensity about ten times greater. Other intense sources are found among the Seyfert galaxies, as NGC 1275 and 4151, and among the clusters of galaxies. The total emission is for the giant clusters 10 to 100 times greater than would be expected from the combined contributions of the member galaxies, an indication that the X-rays may possibly originate in an intergalactic medium inside the clusters. For quite a number of the high-latitude sources the identifications of optical counterparts are still uncertain.

Other observations of extragalactic X-ray sources have been made by instrumentation carried on the *Copernicus* and on the *OSO-7* satellites. Results have been presented by Rapley and Tuohy (12.159.001), and by Markert and Clark (*Astrophys. J.* **196**, L55).

More details about extragalactic X-ray sources may be found in the Report of Commission 48.

C. *Luminosities and Masses*

The revision of the extragalactic distances makes necessary a zero-point correction to all previously published absolute magnitudes and log masses of galaxies. A report on the new distance scale, and on the Hubble parameter, is found in a subsequent chapter.

In an investigation by Sandage (08.160.008) the luminosities of E and S O galaxies in the Virgo and Coma clusters have been analyzed as a function of the $U-B$ index. There appears to exist a very pronounced correlation between magnitude and color, the linear relation extending over an interval of 8.5 mag. The analysis leads to an accurate determination of the difference in distance modulus between the two clusters, a result that agrees with the difference expected from the redshifts.

In a statistical study of integrated properties of galaxies measured in the 21-cm line Balkowski (10.158.076) has compiled a list of the luminosities, as derived by different methods, for 149 individual objects.

The luminosity function of galaxies has been studied by Holmberg (11.158.066) by means of the Palomar Sky Survey prints. By a statistical procedure, 174 physical groups of galaxies have been picked out; the groups are centered on prominent spiral systems, and are thus comparable to the Local Group and the M 81 group. The distribution of the absolute magnitudes, as based on redshift distances, seems to be well represented by an exponential curve for the E-SO-Ir galaxies, and a normal error-curve for the Sa-Sb-Sc spirals. Whereas the former curve rises continuously down to the observational cut-off, the luminosities of the spiral galaxies appear to have a definite lower limit.

The luminosity function for members of the Coma cluster has been studied by Rood and Abell (09.160.004). Two sets of independent magnitude measures appear to be in good agreement. As in the previous case, it seems possible to represent the magnitude distribution with an exponential curve with a hump (excess due to spiral galaxies?) in the brighter luminosity classes.

As regards the masses of individual galaxies, the traditional method based on the internal velocity field as determined by optical or 21-cm observations has been applied to a number of objects. NGC 224 has been studied by Emerson and Baldwin (10.158.074); NGC 598 by Warner, Wright and Baldwin (10.158.001); NGC 4321 by van der Kruit (10.158.145); NGC 224, 3031, 5457 by Roberts and Rots (10.158.006). Detailed mass models have been derived by Nordsieck (10.158.044) for 17 galaxies. All these papers also give valuable theoretical contributions, as studies of the problem of non-circular motions.

The internal radial-velocity dispersion method (virial theorem) has been applied by Richstone and Sargent (08.158.018) to NGC 221, and by Morton and Chevalier (09.158.008) to a number of E galaxies. The method has been applied also to the nucleus of NGC 224 by Morton and Thuan (09.158.056). An interesting variation of the virial theorem has been successfully used by Hartwick and Sargent (11.158.101) to determine the mass of NGC 224 from the motions of its globular clusters.

The list by Balkowski (10.158.076) gives information on the total masses (and the hydrogen masses) for all galaxies measured up to 1973. An attempt to determine the statistical distribution function for the masses of galaxies has been made by Holmberg (11.158.066).

The ratios of mass to luminosity obtained for galaxies of different morphological types have been analyzed by Chiao and Reinhardt (09.158.006), also by Balkowski in the above-mentioned paper. The variation of mass-luminosity ratio with distance from the nucleus of a spiral system has been discussed in several of the papers listed here. It has in most cases been found that in the outer disk the ratio is independent of the central distance. The observed correlation between mass-luminosity ratio and $B-V$ for spiral galaxies has been compared with theoretical relations for model galaxies by Sargent and Tinsley (12.158.016).

Attention is called to the current discussion on possible massive halos surrounding galaxies. The existence of such halos would considerably increase the masses, and the mass-luminosity ratios, as derived by the traditional methods. It has been argued by Einasto *et al.* (12.158.022), by Ostriker *et al.* (12.158.107), and by Freeman *et al.* (*Astrophys. J.* **198**, L93), that available observations indicate the presence of heavy coronas, the mass of a spiral galaxy possibly increasing linearly with radius out to very great distances. Contrary to these results, Burbidge (*Astrophys J.* **196**, L7) has shown that there is no unambiguous dynamical evidence for massive galaxy halos.

D. *Composition, Structure and Dynamics*

During the past three-year period a considerable number of investigations have been published on the contents, structures and velocity fields of galaxies of different types.

Attention may first be called to some results obtained for elliptical galaxies. Repeated attempts have been undertaken to try to detect 21-cm emission from neutral hydrogen in E galaxies, all with negative results. References are made to papers by Gallagher (08.158.064), by Bottinelli, Gouguenheim and Heidmann (09.158.114), by Knapp and Kerr (11.158.113), by Huchtmeier, Tammann and Wendker (*Astron. Astrophys.* **42**, 205), and by Shostak, Roberts and Peterson (*Astron. J.* **80**, 581). The elliptical members of the Local Group offer an opportunity for detailed studies of content and structure. By means of interference filters it has been possible for Ford, Jenner and Epps (10.133.005) to identify 26 planetary nebulae in NGC 185, 205 and 221. According to Hodge (09.158.157), NGC 205 has an anomalous color distribution due to the presence of O and B stars in the central area; twelve dark nebulae have been identified with a distribution similar to that of the OB stars. The eight globular clusters found in NGC 205 are about 2 mag. fainter than the clusters of NGC 224. It has been suggested by Hodge (09.158.159) that contaminating populations of young stars may be present also in other E galaxies, thus offering an explanation of the relation between absolute

magnitude and integrated color found by Sandage (cf. prec. sect.). The structure of the Fornax dwarf system has been investigated by Hodge and Smith (11.158.019) by means of photo-electric surface photometry and counts of resolved stars; the counts show an excellent agreement with King's cluster model. Positions are listed for six globular clusters. The physical characteristics of giant stars in the Draco dwarf system have been studied by Hartwick and McClure (*Astrophys. J.* **193**, 321) by means of intermediate-band photoelectric photometry; the observations lead to certain conclusions concerning the metal content of the stars. It has been shown by van den Bergh (08.158.118, 10.158.132, 12.158.012) that the three new dwarf companions to NGC 224 earlier found by him are resolvable; the brightest stars have magnitudes comparable to those of stars in the outer regions of NGC 185. As regards objects outside the Local Group, it may be noted that spectral scans by Spinrad (08.158.090) and by Faber (09.158.027) of about 30 elliptical galaxies of widely different magnitudes confirm the previously indicated trend: intrinsic colors and line strengths are closely correlated with absolute magnitude at all luminosities. For the purpose of studying the evolution of the stellar population, new models for E galaxies have been constructed by a number of investigators: van den Bergh (08.158.071), Tinsley (08.065.096), Hillel (10.158.107), Rose and Tinsley (11.158.100), Larson (11.151.009), Larson and Tinsley (12.158.065).

Going over to the domain of spiral systems, we note the increasing interest for studies of the nuclei of these galaxies. Recent photometric and spectroscopic analyses of nuclei have been made for NGC 224 by Joly and Andrillat (09.158.126), for NGC 3031, 4826, 5194 by Warner (10.158.102), and for a number of galaxies by Alloin (10.158.025, 12.158.004) and by Alloin and Sareyan (12.158.003). Infrared observations of spiral nuclei have been summarized in a previous section. Various attempts to construct models in accordance with the observational data for the stellar population in the nucleus of a normal spiral galaxy have met with difficulties, possibly on account of the presence of gas and dust in the nuclear region. The earlier comparison of the nucleus with an elliptical galaxy appears to be of questionable value. For recent discussions of synthetic models we refer to Andrillat *et al.* (08.158.012), Baldwin *et al.* (09.158.094), and Joly (11.158.105). A serious problem is presented by the rapid and complex motions of stars and gas that have been observed in spiral nuclei, more recently by Rubin, Ford and Kumar (09.158.063) for NGC 224, by Ulrich (08.158.108) for NGC 1614, and by Anderson (11.158.033) for NGC 4151. The observations in many cases indicate high-velocity expulsion of gas from the nuclear parts. The physical causes of the violent activity in a spiral nucleus are still not fully understood. A review of current ideas about the nuclei, and a detailed list of references, has been published by Saslaw (12.158.084).

As regards the disks of spiral galaxies, the distribution of luminous matter is discussed in the subsequent report by the Working Group on galaxy photometry and spectrophotometry. The increasing number of 21-cm surveys have given detailed information about the extension and structure of the H I distribution. As a rule, the H I clouds extend far beyond the optical boundaries. Recent high-resolution observations have been reported for NGC 3031, 4258, 5194 by Oort (09.158.120), for NGC 598 by Wright (09.158.014), and for NGC 224 by Guibert (11.158.009). The mean H I space density is apparently more or less independent of the morphological type, in contrast to the total mass density which decreases along the sequence from SO to Sc and Ir I; cf. Kellman and Black (10.158.045).

Special interest has been devoted to two types of objects in the spiral disk: dust clouds and H II regions. The general properties of the dust distribution are well known: high concentration towards the principal plane of the galaxy, and condensations more or less coinciding with the basic spiral pattern. The dust clouds are observed by their obscuration and polarization effects; examples are given by the analyses by van Genderen (09.158.038) and van den Bergh (*Astron. Astrophys.* **41**, 53) of the dust distribution in NGC 224 as found from the magnitudes of cepheid variables and from the colors of globular clusters, and by the polarization measurements by Elvius (10.158.092) for a number of galaxies. For the various parts of a given galaxy the dust-to-gas ratio may be more or less constant: the absorption seems to be roughly proportional to the H I density. The bright H II clouds in a spiral system, which may be identified on Hα interference-filter photographs, are generally located in or near regions of high obscuration. Investigations on H II regions in external galaxies have been made by a number of observers,

and results are now available for more than 100 galaxies. A review of the studies of H II regions, and a complete list of all observational data available up to 1974, has been published by Hodge (12.131.554); the review includes an analysis of the spatial distribution of H II and its relation to galactic structure. Valuable information on obscurations and hydrogen clouds has been assembled by Lynds in the publication 'An Atlas of Dust and H II Regions in Galaxies' (1974). The atlas presents image-tube photographs of 41 spiral systems, representing all the types of the morphological sequence.

At this place attention may be called to the systematic search for extragalactic supernovae that is being made at the Palomar Observatory by Kowal and collaborators. During the period 1973–75 a total of 83 new supernovae has been reported (10.125.011, 12.125.022, *Publ. Astron. Soc. Pacific* **87**, 401).

A 'Bibliography on the Structure of Galaxies' has been published by Brosche, Einasto and Rümmel (12.002.037). This compilation is intended to serve as a basic list of references for studies of the inner structure of galaxies.

As regards the dynamics of galaxies, we wish to refer to the subsequent report on observed velocity fields by the newly formed Working Group on internal motions in galaxies, also to the recent IAU Symposium No. 58 on 'The Formation and Dynamics of Galaxies'. The proceedings of this meeting (12.012.005) present a detailed account of different problems related to the dynamics of galaxies, a report that will not be repeated here. A few notes may be added on recent contributions on the problem of the origin of spiral structures.

In a series of papers, the evolution of spiral arms has been discussed by Contopoulos (09.151.033, 10.151.023, 12.012.005, *Astrophys. J.*, in press). The analyses refer to the particle resonance in spiral galaxies and the properties of the density waves. Further discussions of the density-wave theory have been published by Wielen (12.151.018), by Mark (12.151.035), by Woodward (*Astrophys. J.* **195**, 61), and by Roberts, Roberts and Shu (*Astrophys. J.* **196**, 381). A general discussion on spiral structure has taken place at the Royal Astronomical Society (*Observatory* **94**, 266). Observations of the dynamics of spiral arms in individual objects have been made by a number of investigators, among them van der Kruit (NGC 4321, 10.158.145), Guibert (NGC 224, 11.158.009), and Tully (NGC 5194, 11.158.133).

Further data on the dynamics of stellar systems are found in the report of Commission 33.

E. *Tidal Disturbances and Eruptive Phenomena*

A partial disintegration of a stellar system may be effected by two mechanisms: disruption by outside tidal forces, or ejection of matter by an internal release of energy. The two cases are treated together, since the observational evidence does not always permit a clear distinction between the two types of events.

A list of peculiar galaxies and interacting pairs and groups in the southern sky has been published by Sérsic (11.158.067). It may be recollected that the ESO-Uppsala survey of the southern sky (cf. section A) includes all disturbed galaxies that are recognizable on the plates.

Photometric and spectroscopic observations of double and multiple interacting galaxies have recently been reported by Arp and Kormendy (08.158.119), King and Kiser (09.158.060), Graham and Rubin (10.158.002), Arp (10.158.014,080), Chincarini and Heckathorn (10.158.101), and Stockton (11.158.006,103). The observations refer to galaxies with conspicuous disturbances, among them objects from Vorontsov-Velyaminov's 'Atlas and Catalog of Interacting Galaxies', and from Arp's 'Atlas of Peculiar Galaxies'.

It has been noted that interacting systems have a tendency to be aligned in chainlike configurations. However, a theoretical analysis by Turner and Sargent (10.160.032) leads to the conclusion that chance formations of multiple galaxies that in projection look like chains ought to be comparatively frequent.

A valuable contribution to our knowledge of tidal interactions between galaxies has been presented by Toomre and Toomre (08.151.039, 10.151.038). The bridges and tails that result from close encounters have been studied by analyses of theoretical disk models. It is shown that after the passage of a small-size companion the outer portions of the primary galaxy may be

deformed into a double-sided spiral arm structure; an encounter with an equal or more massive object may produce a long tail on the far side of the primary, and a transfer of matter on the near side. Striking reconstructions have been made of four specific interacting pairs, among them NGC 5194-95. Similar theoretical analyses have been undertaken by Lauberts (11.151.052). The loss of orbital energy has been computed for close encounters between spherical bodies, also the exchange and loss of mass.

Radio observations of interacting galaxies have been reported in a number of papers. According to Wright (11.158.059), who has made a survey of 44 interacting systems, no anomalous radio properties have been detected, which may be interpreted as evidence against a nuclear ejection origin of the observed deformations.

As regards galaxies with explosive internal activities, some new information is available for NGC 3034 and 5128. The nature of the emission from the filaments of the former object has been discussed by Van Blerkom, Castor and Auer (09.158.009), and by Mathis (10.158.004). The results of high-resolution observations of radio intensity and polarisation of the inner parts of NGC 5128 have been reported by Price and Stull (10.158.028); the X-ray spectrum has been studied by Tucker and colleagues (09.158.057).

Attention has again been directed towards objects of type Ir II, a class that according to Krienke and Hodge (12.158.137) probably consists of explosive and post-explosive galaxies, in addition to galaxies distorted by gravitational interaction. Studies of NGC 5195 have been made by Spinrad (09.158.144), and by Warner (11.158.087). A number of Ir II systems have been studied by Chromey (12.158.144). Observational evidence for an explosive event in the peculiar galaxy NGC 1569 has been presented by de Vaucouleurs *et al.* (12.158.183); this is an interesting case since the object probably is to be referred to type Ir I.

An isophotometric and photographic atlas of peculiar galaxies has been published by Schanberg (10.158.150). The atlas gives information on 63 single galaxies and 28 multiple systems which show distortions caused by internal explosions or by tidal interactions.

F. *Clusters of Galaxies*

During the past three years a considerable fraction of the total work in the extragalactic field has been devoted to clusters of galaxies. Most of the contributions deal with the following problems: the internal structure, the redshifts of cluster members, the possible existence of intergalactic mass, and the distribution of clusters in extragalactic space.

The apparent distributions of galaxies in and around a number of clusters have been determined by galaxy counts down to different limiting magnitudes by Bahcall (09.160.015, 10.160.008,039, 11.160.008), Noonan (11.160.011), Austin and Peach (11.160.022), and others. The analyses lead to determinations of the total extension of each cluster, also of the spatial distribution of the cluster members. In many cases the latter distribution seems to be adequately represented by an isothermal-gas-sphere model. Luminosity segregation, with the brighter cluster members more centrally concentrated than the fainter members, appears to be present in some clusters; this concentration supposedly indicates a corresponding segregation in mass.

New determinations of redshifts for cluster galaxies have been reported by a number of investigators, among them Rood *et al.* (08.160.005), Tifft (08.160.004, 09.160.001), Tifft and Gregory (09.158.058). The number has increased at a fast rate; for each of the Virgo and Coma clusters the redshift list now includes more than 100 objects. It has traditionally been assumed that, apart from the excessive dispersion, the statistical distribution of the redshifts in a cluster would offer no special problems. A contrary view has been expressed by Tifft (11.160.007, and other papers), who has found indications of a very complex redshift field in the Coma cluster: in the redshift-magnitude diagram the galaxies appear to lie in bands sloping to fainter magnitudes at higher redshifts; in the bands the galaxies tend to be distributed according to morphological type. The significance of Tifft's interpretation has been doubted by other investigators, among them Barnothy and Barnothy (11.160.014).

The attention has remained focused on the well-known and still unsolved problem of the 'missing mass' in clusters: if the individual masses are based on the conventional mass-

luminosity ratios, even on somewhat increased ratios, the combined mass provided by the members of a cluster would be far too small to account for their mutual association. In a series of papers (cf. 12.160.029), Rood has studied the empirical properties of the mass discrepancy in groups and clusters of galaxies. The possibility, touched upon above, of reducing the velocity dispersion by assuming a non-Doppler redshift component will be further discussed in a subsequent chapter on anomalous redshifts. The presence of large amounts of intergalactic matter within the cluster would also remove the dilemma by providing the necessary mass to bind the cluster.

The models constructed for a gravitationally bound cluster generally utilize intergalactic gas, although intergalactic dwarf stars, dust and black holes have also been suggested. The material must be in a form that does not violate the observational data available. According to 21-cm observations, neutral hydrogen does not seem to be present in clusters in an amount sufficient to account for the missing mass. As an example, we may refer to the results reported by De Young and Roberts (11.160.013) for a number of clusters. It has been suggested, however, that the amount of gas may be larger than that inferred from the observations if the hydrogen is concentrated in high-density clouds that are optically thick to 21-cm radiation (cf. Smart, 09.160.016). The possible upper mass limits of an ionized medium have been discussed by a number of investigators, among them Holberg *et al.* (09.160.013) and Davidsen *et al.* (10.160.040). The general conclusion is, that the measurements of Ly-α, X-ray and radio emission seem to rule out cluster models that are bound by an ionized gas. Since it is not possible to give here a detailed account of the numerous investigations on the hidden mass in clusters, we beg to refer to the complete summary of the present research situation that has been published by Tarter and Silk (11.160.029). We may cite the final conclusions by these writers: the missing mass could possibly be a mixture of dwarf stars, high-density clouds of neutral and molecular hydrogen and a small amount of hot, ionized gas; a mixture of this type would prove the most difficult case to substantiate or invalidate observationally.

In conclusion, a short account is given of the efforts that have been made to try to determine the spatial distribution of clusters of galaxies. It may not be necessary to emphasize the cosmological importance of these efforts, the framework of the clusters presumably reflecting the general arrangement of galaxies in space.

The investigations have necessarily been based on the two catalogues available, by Abell (1958) and by Zwicky and collaborators (1961-68). On account of the unavoidable observational selection, an effect that increases very fast with increasing distance, the analyses have in the first place been concerned with the projected distribution of the clusters over the sky. As is well known, the earlier results point in two directions: an approximately random distribution, or a distribution dominated by superclustering tendencies. A result of the latter type has been reported by Bogart and Wagoner (09.160.022) from a nearest-neighbor statistical test based on Abell's catalogue; an analysis of the distribution of the angular distances from a cluster to its neighbors seems to indicate a superclustering tendency. A similar conclusion has been reached in an investigation by Hauser and Peebles (10.160.024), also based on Abell's clusters; the results obtained by a special method of analysis developed by Peebles are interpreted as direct evidence for the existence of superclusters. According to Holmberg (12.160.013), who has made an analysis of the Zwicky catalogues, the previous investigations have not paid sufficient attention to the disturbances produced by the local, small-scale variations in galactic absorption; for distant clusters also by the absorption (or selection effect) that is apparently caused by nearby clusters. If these disturbances are taken into account, all available observational data seem to be in perfect agreement with the assumption of an essentially uniform cluster distribution, also with the assumption of a random distribution for the dust clouds in the galactic absorption belt.

2. COMPACT GALAXIES, QUASARS AND RELATED OBJECTS

(P. Nilson)

A. *Survey Work. Identifications*

A compilation of all published identifications of extragalactic radio sources was made by Véron and Véron (12.141.075). The list contains 4022 entries for 2882 different radio sources published in 232 papers. The authors will keep the list up to date and it is available from them on request.

Kraus and Gearhart (*Astrophys. J.* **80**, 1) published a list of redshifts and radio spectral indices at 408–1415 MHz and 1415–6500 MHz for 179 QSOs. Identifications of 135 sources from the NRAO 5 GHz survey were made by Johnson (12.141.064). More than half were quasars or quasar-like objects.

Katgert *et al.* (09.141.022) made a 1415 MHz survey at Westerbork to detect radiation from blue stellar objects. Out of 99 objects four were detected and another four suspected to radiate near the detection limit. A second deep survey at 1415 MHz was made by Katgert and Spinrad (12.141.054). 14 sources were identified with galaxies and five with possible quasars.

In spectroscopic surveys in the fields of 77 4C objects and of 120 faint blue objects in the PHL and LB catalogues, Schmidt (12.141.079 and 12.141.080) found in total 83 quasars.

Khachikian and Weedman (12.141.104) compiled an atlas of 71 Seyfert galaxies. A collection of 37 spectra was presented.

New BL Lac type candidates have been proposed by several observers. Attention is called to papers published by Le Squéren *et al.* (08.122.087), Carswell *et al.* (10.141.080 and 11.141.123), Khachikian and Weedman (11.158.089), Crovisier *et al.* (11.158.301), Disney (12.158.309), Hagen-Thorn and Semenova (12.158.310), Pollock (*Astrophys. J.* **198**, L53) and Usher *et al.* (*Astrophys. J.* **198**, L57).

Optical positions of the first 507 objects in Markarian's lists were measured by Peterson (10.158.094). The accuracy is of the order of a few seconds of arc. Some corrections to the original Markarian lists were noted.

B. *Photometric Investigations. Variability*

The photometric history of OJ 287 was studied by Visvanathan and Elliot (09.123.032) for the period 1894–1973. Angione (09.141.098) obtained historical light curves of 20 quasars and three Seyfert galaxies from Harvard plates. The photometric history of PKS 0537 – 441 since 1892 was investigated by Liller (11.141.088) and of PKS 0048 – 097 for the years 1921–1955 by Usher *et al.* (12.141.072). The quasar ON 231 (W Comae) was studied by Pollock *et al.* (11.141.002) on blue plates from the period 1931 to 1952.

A large number of investigations have been concerned with BL Lac type objects. A discussion, principally dealing with BL Lac and OJ 287, has been published by Kinman ('Variable Stars and Stellar Evolution', *IAU Symp.* **67**, 573). Observations of BL Lac have been made by, among others, Rieke (08.141.032), Bertaud *et al.* (09.122.052), Visvanathan (09.141.007), Weistrop (09.141.031), Weistrop and Goldsmith (10.122.028), Folsom and Miller (10.122.140), Evseev *et al.* (10.122.184), Milone (12.158.317) and Véron (*Astron. Astrophys.* **41**, 423). Ekers (*Astron. Astrophys.* **38**, 67) made 21-cm observations from March 1971 to Sept 1972 and found variations in intensity and polarization.

Crane and Warner (09.141.010) studied optical variations of OJ 287, ON 231 and OQ 208. Visvanathan and Elliot (09.141.020), Goldsmith and Weistrop (09.141.045) and Frolich *et al.* (10.122.138) investigated the variability of OJ 287. Miller *et al.* (10.122.139) reported rapid optical variability of AP Lib. Andrew *et al.* (12.158.301) made nine-colour photometry of AP Lib and PKS 0521–36. I Zw 187 was studied on Harvard plates by Hall and Usher (09.158.037). The object shows a BL Lac type behaviour, with a total amplitude in the variations of $2^{m}.1$.

Selmes *et al.* (*Monthly Notices Roy. Astron. Soc.* **170**, 15) made optical monitoring of 36