34. COMMISSION DE LA MATIERE INTERSTELLAIRE ET DES NEBULEUSES PLANETAIRES

PRÉSIDENT: Professor B. Strömgren, The Institute for Advanced Study, School of Mathematics, Princeton, New Jersey, U.S.A.

VICE-PRÉSIDENT: Dr S. B. Pikelner, Sternberg Astronomical Institute, Moscow, U.S.S.R.

MEMBRES: Aller (L. H.), Andrillat (H.), Andrillat (Y.), Behr, Bok (B. J.), Chvojková, Courtès, Divan, Dunham, Elvius (A. M.), Gehrels, Goldworthy, Greenberg, Gurzadian, Güttler, Hall (J. S.), Haro, Hatanaka, Henize, Hiltner, Herbig, Johnson (H. M.), Kahn, Kaplan (S. A.), Keer, Kharadze, Khavtasi, Kipper, Lambrecht, Liller, McCrea, Martel-Chossat, Menon, Minin, Minkowski, Münch (G.), Osterbrock, Pottasch, Razmadze (N. A.), Rosino, Rozhkovski, Safronov, Savedoff, Schalén, Schatzman, Schmidt-Kaler, Seaton, Serkowski, Sharpless, Shklovsky, Sobolev, Spitzer, Takakubo, Thackeray, van de Hulst, van Woerden, Vanýsek, von Hoerner, Vorontsov-Velyaminov, Westerhout, Whitford, Zirin.

INTRODUCTION

The present report is based to a large extent on reports by members of the Commission. This material is gratefully acknowledged, and, in particular, thanks are due to Dr R. E. Gershberg and Dr V. I. Pronik who prepared an extensive report on work relating to Commission 34 in the U.S.S.R.

A number of books, and survey and review papers dealing with problems of interstellar matter and planetary nebulae have appeared since 1961:

V. A. Dombrovski, *Trudy. astr. Obs. Leningrad. gos. Univ.*, **19**, 88, 1962.
R. E. Gershberg, *Voprosy Kosmogonii* (Moskva), **8**, 180, 1962.
M. Greenberg, *Ann. Rev. Astronomy and Astrophysics*, **1**, 267, 1963.
M. Greenberg, *Proc. Int. School of Physics 'Enrico Fermi', Cosmic Rays, Solar Particles and Space Research*, p. 227, Academic Press, New York, 1963.
G. A. Gurzadian, *Planetary Nebulae*, Moscow, 1962.
J. S. Hall and K. Serkowski, *Stars and Stellar Systems*, Vol. 3, ed. K. Aa. Strand, Chapter 16, Univ. Chicago Press, 1963.
S. A. Kaplan and S. B. Pikelner, *The Interstellar Medium*, Moscow, 1963.
E. E. Khatchikyan, *Voprosy Kosmogonii*, **7**, 333, 1961.
H. Lambrecht, *Zur quantitativen Spektralanalyse des interstellaren Gases*, Leipzig, J. A. Barth, 1964.
V. I. Pronik, *Voprosy Kosmogonii*, **8**, 191, 1962.
K. Serkowski, *Advances in Astronomy and Astrophysics*, ed. Z. Kopal, **1**, 289, Academic Press, New York and London, 1962.
S. Sharpless, *Stars and Stellar Systems*, Vol. 3, ed. K. Aa. Strand, Chapter 12, Univ. Chicago Press, 1963.
L. Woltjer (Ed.), *The Distribution and Motion of Interstellar Matter in Galaxies*, Benjamin, New York, 1962.

PLANETARY NEBULAE

As a result of an Hα survey of the southern sky, Henize (1) has discovered 202 objects tentatively classified as planetary nebulae. Of these, 134 are classed as probable planetaries on the basis of resolution of the nebular disc or the presence of forbidden lines in the spectrum.

https://doi.org/10.1017/S0251107X00015078 Published online by Cambridge University Press

Westerlund has photographed the new objects in Henize's list as well as a number of previously known planetaries in Hα light with the 74-inch reflector of Mt. Stromlo Observatory.

10 new planetary nebulae have been found by Apriamashvili (**2**) near the galactic center. Vorontsov-Velyaminov (**3**) has described 60 planetary and peculiar nebulae found in the Palomar Atlas. Co-ordinates of 61 starlike planetaries have been determined by Franzman (**4**). Kohoutek (**5**) has found 20 new planetaries through an examination of the Palomar Atlas. Vorontsov-Velyaminov (**6**) has published a catalogue of 600 planetary nebulae.

Perek has prepared a preliminary edition of a catalogue of planetary nebulae. The catalogue data include position 1950·0, identification chart, galactic co-ordinate, dimension, surface brightness, total magnitude, classification and information concerning the central star.

Henize and Westerlund (**7**) have investigated objects in the Small Magellanic Cloud classified by Lindsay as planetary nebulae. Analysis on the basis of Hα photographs with the Mount Stromlo 74-inch reflector for 11 resolved objects brighter than $M_{pg} = -3^{m}.0$ has led to masses from 2 to 33 solar masses, so that it seems unlikely that the objects in question are planetary nebulae. The data indicate an upper limit to M_{pg} for planetaries in the Small Magellanic Cloud at $-3^{m}.0$ in agreement with O'Dell's results for galactic planetaries. Henize and Westerlund estimate that the Small Magellanic Cloud contains approximately 300 planetary nebulae. In the Large Magellanic Cloud, Henize and Westerlund have determined blue and red magnitudes for 42 planetary nebulae and derive an upper limit to M_{pg} equal to $-3^{m}.0$. The total number of planetaries in the Large Magellanic Cloud is estimated to be about 400.

Distances of planetary nebulae have been determined by Gershberg (**8**) on the basis of radio emissions, and by Metik and Pronik (**9**) according to the amount of the interstellar absorption. Khromov (**10**) has discussed the space distribution of planetaries. O'Dell (**11**) has applied the method proposed by Shklovsky for the determination of the distance of a planetary nebulae from measured value of the angular radius and the Hβ intensity to 131 planetaries. The Hβ intensities had been measured by Collins, Daub and O'Dell (**12**), and by O'Dell. The size distribution of the planetaries is studied as well as the position of the central stars in the luminosity-temperature diagram.

The problem of masses of planetary nebulae has been discussed by Turchaninova (**13, 14**), Gershberg (**15**), Khromov (**16**) and by Metik and Gershberg (**17**). O'Dell (**11**) found an average mass of 0·14 solar masses, in good agreement with a value previously derived by Shklovsky.

Observations of intensities of emission lines of planetary nebulae have been published by a number of investigators: Turchaninova (**13**), Vorontsov-Velyaminov, Dokutchaeva and Archipova (**18**), Metik and Gershberg (**17**), Osterbrock, Capriotti and Bautz (**19**), Capriotti, Collins, Daub and O'Dell (**20, 12, 21, 22**), Y. and H. Andrillat (**23**), Aller and Faulkner, and Bowen, O. C. Wilson and Aller (**24**), Razmadze (**25**). Walker and Aller have determined emission line intensities in a number of planetaries using a Lallemand image tube at the coudé focus of the Lick Observatory 120-inch telescope, with considerable gains in sensitivity and scale and without loss of accuracy in comparison with conventional photometry. Radio emission of planetary nebulae has been observed by Kuzmin, Salomonovich and Udaltsov (**26**).

The hydrogen recombination spectrum of planetary nebulae has been considered in a number of theoretical investigations, and comparisons of theory and observation have been made. O'Dell (**22**) compared observed intensity ratios of the Balmer lines with the values according to the recombination theory, deriving corrections for interstellar absorption from a comparison of Balmer and Paschen emission lines arising from the same upper energy state. The observed Balmer decrement appears to be flatter than the decrement predicted from recombination theory. It is concluded that collisional excitation is probably important in IC418 and NGC7027. Capriotti (**27**) calculated the emission in the Balmer and Paschen lines taking into account the effect of self-absorption in the Balmer lines. Comparison with observations shows that the self-absorption effects are unimportant. From a study of the excape of $L\alpha$ radiation from a planetary nebula, Osterbrock (28) concluded that the population of neutral H in the 2p state, excited by $L\alpha$ absorption, is too small for appreciable self-absorption in the Balmer lines to occur.

Pengelly (29) has made recombination calculations allowing for nl degeneracy, similar to those in earlier work by Burgess and Searle, but with an infinite number of states, while Pengelly and Seaton (30) show that collisional nl→nl' transitions become important for $n \geqslant 15$. Seaton (31) considers the populations of highly excited states taking into account collisional n→n′ transitions. W. Clarke is undertaking a study of the combination spectrum of hydrogen taking all levels into account up to $n=60$ and $l=59$.

Zanstra (32) has discussed the problem of the determination of the total number of ultra-violet quanta ($\lambda < 911$ Å) emitted by the nuclear star from the emission line spectrum of the planetary nebula. Results are given for 13 nebulae.

Osterbrock (33) discussed the expected satellite-ultra-violet emission spectrum of a typical planetary nebula, using available estimates of element abundances, collision cross sections and temperatures.

Saigusa (34) investigated theoretical models of planetary nebula and studied the dependence of the optical thickness upon temperature, dimension and dilution factor for the ultra-violet radiation. Turchaninova (13, 14) calculated models of four planetary nebulae on the basis of distributions of the absolute surface brightnesses and determined the L_c-radiation field. Sobolev (35) and Ivanov (36, 37, 38) obtained exact solutions for a set of problems of radiative diffusion into planetary nebulae. Khromov (39) investigated the $L\alpha$ radiation pressure and concluded that its role in determining forms of planetary nebulae is negligible. Pleshkova (40) studied the $L\alpha$ diffusion into media with different temperature gradients. Hummer and Seaton (41, 42) investigated the ionization and structure of planetary nebulae and collisional cooling for the case of pure hydrogen nebulae, and extended the study to include problems of the ionization of helium (43). Gurzadian (44) studied the mechanism of the splitting of $L\alpha$ quanta.

Nikitin (45) and Nikitin and Yakubovski (46) investigated spectra of C II, N III and O IV with a view to analysis of planetary nebulae. Boyarchuk, Gershberg and Pronik (47) published a compendium of equations, graphs and nomograms for quantitative analysis of the spectra of emission objects. O'Dell (22) derived the helium-hydrogen abundance ratio for a number of planetary nebulae.

Problems of the central stars of planetary nebulae were studied in a number of investigations: Seaton and Gebbie (48), O'Dell (49), Turchaninova (50), Gurzadian and Hovhanesian (51).

Chudovicheva (52) has measured angular expansions of the planetary nebulae NGC6853 and NGC7662. O'Dell (53) studied NGC4997 spectroscopically and derived an expansion velocity of 15 km sec^{-1}.

The variability of spectra of planetary nebulae has been discussed by Pronik (54) who studied the effect of a non-stable corpuscular radiation from the nuclear star and by Khromov (55) who investigated the consequences of variations of the ionizing radiation from the nucleus.

Osaki (56) investigated the formation of condensations at the interface between He III and He II regions. Daub (57) studied the pressure-electron temperature relation of matter in planetary nebulae and found that it is significantly influenced by free-free transitions of hydrogen and cooling by forbidden line radiation. This influence tends to inhibit the formation of condensations.

Gurzadian (58) discussed the problem of the forms of planetary nebulae in relation to the presence of dipole magnetic fields.

The role of shock waves in the process of formation of a planetary nebula through expulsion of matter from a star was studied by Klimishin (59).

Chvojková and Kohoutek (**60**) studied the expulsion of equatorial shells from a contracting star under the influence of magnetic fields and discussed the possible role of such a mechanism in problems of the relation between planetary nebulae, novae and variable stars. Relations of planetaries and novae were further considered by Kohoutek (**61**).

DIFFUSE NEBULAE

The spectrum of the Orion Nebula in the region 9000–11 000Å has been described by Yessipov and P. V. Shcheglov (**62**). Yessipov (**63**) has measured infra-red lines of [S III] in bright diffuse nebulae. Gagen-Torn (**64**) has carried out an absolute spectrophotometry of NGC281 with glass filters and has investigated the distribution of electron temperature and the degree of ionization of oxygen and derived the mass of the nebula.

Cruvellier has utilized an interference spectrophotometer at the coudé focus of the 193-cm reflector of the Observatoire de Haute-Provence for determination of high-resolution profiles of the O II emission doublet 3726Å–3729Å.

Parijski (**65**) has constructed a model of the Orion Nebula on the basis of observations at 8·3 cm. Radio observations of a number of diffuse nebulae leading to estimates of densities, masses and distances of the objects were made by Kuzmin and Noskova (**66**) and by Zin Jun Khao (**67**).

Mathis (**68**) has studied the intensity ratios of $H\alpha$, $H\beta$ and $H\gamma$ in the diffuse nebulae M8, M20, NGC604 and the Orion Nebula. The observations cannot be fitted by the predicted nebular recombination spectrum modified by interstellar reddening; the observed $H\alpha/H\beta$ ratio is too large by about 0·07 in the logarithm. There is no indication of self-absorption effects. These results are similar to those found by Osterbrock, Capriotti and Bautz for planetary nebulae (cf. the previous section). The mean He/H ratio in the nebulae was found to be 0·11, and the average deviation from the mean was only six per cent. Waughan has studied the line profile of the He I line at 10 830Å in the Orion Nebula with a resolution of 50 000 in an effort to detect He^3.

Vandervoort (**69, 70, 71**) developed a theory of the formation of an H II region about a star of early spectral type that forms abruptly in an infinite homogeneous medium of atomic hydrogen, and utilizing the developed technique he constructed a model of the Orion Nebula (**72**) compatible with the observational data; the age of the Orion Nebula was estimated to be about 2×10^4 years.

Yada (**73**) has made a detailed study of the radiation field in a model nebula illuminated by a central star, assuming the nebula to consist of a pure-hydrogen gas H II region surrounded by an H I region containing hydrogen gas and dust particles. The results are applied to problems of the Orion Nebula.

Field and Partridge (**74**) discussed the stimulated emission in the 3·04 cm fine structure-line of hydrogen in diffuse nebula, calculating the effect of $L\alpha$ in exciting the $2P_{3/2}$ level of neutral hydrogen. An observational test of the 3·04 cm emission would lead to an estimate of the degree of $L\alpha$ trapping in diffuse nebulae.

A number of investigations deal with diffuse emission nebulosities that have a connection with a previous super-nova outburst.

Moroz (**75**) has measured the flux of radiation from the Crab Nebula in the 1–2 micron region and has shown that the continuous spectrum from 0·3 to 2 microns may be represented by the law $I \sim \nu^{-1.5}$. An absolute measurement of flux from the Crab nebula at 3·2 cm has been carried by Lazarewski, Stankevich and Troitski (**76**), while Soboleva, Prozorov and Parijski (**77**) have obtained the distribution of the radio brightness and polarization at centimeter waves. Pronik (**78**) has considered the excitation of gaseous filaments in the Crab nebula and concluded

https://doi.org/10.1017/S0251107X00015078 Published online by Cambridge University Press

that their radiation may be caused by high energy particles emitted by the amorphous part of the nebula.

On the basis of 21 cm observations, Sholomnitski (**79**) has found two H I clouds associated with the Cygnus loop and has determined their mass to be 400 solar masses.

During a survey for the optical identification of galactic radio sources in the southern sky by Westerlund, two possible super-nova remnants were identified.

A series of investigations of NGC6618 suggest that a super-nova outburst occurred within the nebula. Photometric and spectrophotometric investigations of NGC6618 have been carried out by Gershberg and Pronik (**80**), by Gershberg, Yessipov, Pronik and Shcheglov (**81**) and by Rozhovski, Gluskov and Jakusheva (**82**). Photometric charts have been obtained, the density and the mass have been calculated, and the interstellar absorption and distance of the nebula determined. The visual continuum is due to two-quanta emission while [S III] line emission contributes to the infra-red radiation. Polarization of the light of NGC6618 was investigated by Rozhkovski and Jakusheva (**83**). Parijski (**84**) compared the optical emission of NGC6618 with the radio emission and found that the radio center of the nebula is covered by optically absorbing matter. Questions concerning an exciting center of NGC6618 have been discussed by Pronik (**85**); cf. also (**81**) and (**82**). Gershberg (**86**) showed that the assumption of a super-nova outburst within NGC6618 about 3×10^4 years ago will explain the morphological features of the nebula, such as the filament system, the concentration of dark matter toward the center and a 'running-away' of the exciting stars.

Moriyama (**87**) has discussed the problem of the intense radio radiation from NGC6618 in comparison with the observed Hα intensity, and, in a general way, the problem of radio emission from H II regions with special regard to the nature of the exciting stars.

Gershberg (**88**) has considered possible causes of the association of Hα–emission with filamentary nebulae that are remnants of super-nova outbursts.

Wesselink (**89**) has confirmed photo-electrically the strong polarization found by Thackeray of the light of the halo surrounding η Carinae.

Parker (**90**) has analyzed spectrophotometric observations of individual filaments in the Cygnus loop, and some other possible super-nova remnants, and shown that interpretation of their spectra in terms of collisional excitation and ionization leads to a model in which the temperature may vary from 15 000° to 100 000° across the width of the filament.

Reflection nebulae are the subject of a number of investigations. Dorschner and Gürtler (**91**) have published a catalogue of reflection nebulae, containing about 50 new objects found from inspection of the Mount Palomar Sky Atlas. A. Elvius and Hall have continued and expanded a joint program of photo-electric study of the nebulosity in the Pleiades (**92**). Polarization observations have been made in more than 70 regions. The data indicate that the polarization of the nebulosity in regions close to bright stars is radial and independent of the direction of the filaments (electric vector perpendicular to the line connecting the star and the region in question), and that it is usually less than 5 per cent. The polarization of regions more than 5′ south of Merope has its electric vector roughly perpendicular to the direction of the filamentary structure of the nebulosity; it is usually between 5 and 10 per cent. The polarization of transmitted light, as observed by measures of stars in the same area, is usually nearly parallel to the filaments. Color measures have been made in 16 regions, each 27″ in diameter. The nebulosity near Merope and Maia is considerably bluer than these stars. The color index generally increases with distance south of Merope; at a distance of 15′ the nebulosity has about the same color as Merope.

Polarimetric observations of the reflection nebulae NGC2245, 2247 and NGC2261 have been made by Parsamyan (**93**).

https://doi.org/10.1017/S0251107X00015078 Published online by Cambridge University Press

Rozhkovski (**94**) has carried out a photometric analysis of 5 typical reflection-nebulae and has found their radiation in almost all cases to be in agreement with a theory based on a model of a homogenous sphere with a small radius imbedded in a large cloud. He has evaluated a mean size of the particles in the nebulae and found a dependence upon the spectral class of the illuminating star. In studies of the reflection nebula NGC2268 and of the northern part of the Trifid Nebula, Rozhkovski (**95**) found abnormal colors and photometric features. Minin (**96**) has determined optical characteristics of reflection nebulae.

Problems of cometary nebulae and associated T Tau stars are dealt with by Dibye (**97**), who shows that the main morphological features of the cometary nebulae can be understood as the result of convergent shock waves at an H I – H II boundary; the increase of pressure and density in the convergent wave is related to T Tau star formation. Gershberg (**98**) considered the conditions leading to a compression in the H I region and the formation of gravitationally stable protostars.

Khatchikyan and Kalloglyan (**99**) have studied the polarization of the cometary nebula NGC2261 (Hubble's variable nebula) and have shown that the polarimetric picture is invariable and radial relative to R Mon while the photometric picture of the nebula is variable.

M. T. Martel and Rousseau have carried out photo-electric and photographic studies of NGC2261 (magnitudes, colors and polarization measures). H. M. Johnson (**100**) has investigated NGC2261 and plans to continue the work through proper motion studies of star-like masses in the nebula.

Diffuse emission nebulae in both Magellanic clouds have been studied by Faulkner and Aller at Mount Stromlo Observatory and its field station. They used a spectrum scanner to measure the principal spectral lines, and when possible the integrated monochromatic brightnesses. A special effort was made to study the ratio of hydrogen to helium in these objects. The ratios He/H and O/H seem to be smaller in the Magellanic clouds than in our Galaxy, but not by a large factor.

DISTRIBUTION AND PHYSICAL STATE OF INTERSTELLAR GAS

Dunham is carrying out a survey of the interstellar H and K lines of calcium in the spectra of B stars, using the 32-inch camera of the coudé spectrograph at Mount Stromlo Observatory. The dispersion is 6·7Å per mm, and the survey includes 120 stars between $4.^{m}0$ and $9.^{m}0$ within 5° of the galactic plane and between longitudes $l^{II} = 170°$ and $l^{II} = 20°$.

Münch and Unsöld (**101**) showed that α Oph at a distance of only about 18 pc as well as neighboring stars have weak interstellar Ca II lines originating in a nearby cloud about 1 pc in diameter which is related to the large Ophiuchus complex of interstellar matter.

Herbig has found two new interstellar lines of CH in several early-type stars at 3137·53Å and 3146·00Å, and the identification of 3143·17Å with CH (as proposed by Feast and by McKellar and Richardson) has been confirmed by the wavelength agreement and by the appearance of the two expected fainter features. The R(0) line of the 4–0 band of CH^+, predicted by Morton and Douglas, has been found in ζ Oph at 3447·08Å. The second member of the He I $2^3S - n\,^3P°$ series at 3187Å has been found in absorption in θ^1 Ori.

Using spectra taken with the coudé spectrograph of the 120-inch reflector at Lick Observatory (2Å per mm), Herbig has made an effort to detect interstellar lines of CO^+, NH_2, OH, OH^+, NH, CN^+, and SiH in a number of bright, reddened early-type stars, but the results have been negative. A search for interstellar Li I was made by Herbig at 6707Å, with emphasis on reddened stars seen through nebulae that contain T Tau stars, or through clouds in which the absence of nearby hot stars might be expected to lead to a lesser degree of ionization of Li. The result, however, was negative.

https://doi.org/10.1017/S0251107X00015078 Published online by Cambridge University Press

Walker has made photo-electric intensity measures of the 4430Å diffuse interstellar band (**102**) and has investigated the correlation of 4430Å intensity and interstellar reddening in different galactic longitude regions.

Unsöld (**103**) showed that diffuse interstellar absorption bands such as the 4430Å band might be produced by metallic spheres, small compared to the wavelength, for which the real and the imaginary part of the refraction index are small compared to 1 and about equal to $-\sqrt{2}$, respectively. The Drude-Lorentz theory connects the frequency of a band with the electron density and the band-width with the conductivity of the metal. Van de Hulst has generalized Unsöld's analysis to the case of metallic ellipsoids and finds that small deviations from the spherical form cause broadening of the absorption band, an effect that might make it difficult to account for the observed line profiles.

H. Wilkens (**104**) has studied the dependence of the strength of interstellar absorption lines on the stellar distance.

McNally has investigated the equilibrium of CH and CH^+ in interstellar space. Weinreb, Barrett, Meeks and Henry (**105**) have detected the 18-cm line of interstellar OH in absorption in the radio spectrum of Cas A. Gould and Salpeter (**106**), and Gould, Gold and Salpeter (**107**) have carried out an extensive theoretical investigation of the problem of the interstellar abundance of the hydrogen molecule. Through an analysis of the various processes which determine the concentration of H_2 in an H I cloud, they conclude that the most important mechanism for forming molecular hydrogen is association on the surface of interstellar grains, a process previously considered by McCrea and McNally, and others. Dissociation of molecular hydrogen occurs largely through random encounters of the H I cloud with O and B stars. A balance results in which the molecular abundance is roughly comparable with the atomic hydrogen abundance, the ratio being in the range 0·1 – 10, almost independent of the height above the galactic plane. It is suggested that molecular hydrogen contributes appreciably to the mass near the galactic plane, and that this contribution narrows the gap between the observed density of visible stars plus atomic hydrogen gas and the density determined from analysis of stellar motions at right angles to the galactic plane.

Lambrecht and K.-H. Schmidt (**108**) have discussed the various mechanism of formation and dissociation of molecular hydrogen in interstellar space and have emphasized the dependence of the resulting H_2 abundance upon the assumed diameter law of the dust particles. When direct determinations of the H_2 abundance, from extra-terrestrial observations or otherwise, become available, it should be possible to determine the mean diameter of the interstellar dust grains.

Gould and Harwit (**109**) have examined the possibility of detecting interstellar molecular hydrogen through observation of vibrational lines at wavelengths of 2·22 and 2·12 micron emitted by molecular hydrogen located in H I regions just outside the boundary of H II regions. They conclude that such radiation might be measureable from the ground or with balloon-borne instruments.

Thackeray has carried out work on multiple structure of interstellar lines with the Radcliffe coudé spectrograph. The measured radial velocities support the concept of an inner spiral arm seen tangentially towards Norma, but general conclusions regarding spiral structure in this direction are hampered by the presence of local expansions similar to those found by Münch in the northern sky.

Comparison of results obtained through observations in the optical region and through 21 cm observations has been carried out in a number of investigations. Takakubo (**110**) measured the interstellar absorption lines in ϵ Ori with very high dispersion (1·0Å per mm) and discussed the profiles with reference to the 21-cm profiles observed in the direction of the star. Howard, Wentzel and McGee (**111**) have investigated the correlation between the radial velocity and

https://doi.org/10.1017/S0251107X00015078 Published online by Cambridge University Press

line intensity of interstellar lines deduced from optical and radio techniques, limiting the material to stars with single optical line components, and with galactic latitude $b > 15°$. The standard deviation of the differences between the H I and Ca II radial velocities is found to be 3 ± 1 km per sec. The analysis of the intensities indicates an interstellar sodium-to-hydrogen abundance ratio equal to its value in the Sun, while the corresponding average calcium-to-hydrogen ratio is found to be 60 times smaller than the solar value.

Van Woerden at Mount Wilson and Palomar Observatories is carrying out a study of the interstellar Ca II lines at dispersions 1·1 and 1·9Å per mm for stars brighter than $4{\cdot}5^m$ and 6^m, respectively. The velocity resolution attained (2 to 4 km/sec) closely approximates that in his previous 21-cm line work. In some stars the Ca II components correspond closely with features in the 21-cm profiles, while in some cases Ca II components are found that have no hydrogen counterpart.

Schmidt-Kaler and van Schewick investigated the region of the OB association I Mon and its surroundings on the basis of optical and 21-cm observations. From proper motions an expansion age of 2×10^6 years is derived. The 21-cm emission components belonging to the association were interpreted by Rohlfs and Girnstein (**112**) in terms of an expanding shell with an expansion velocity of 23 km/sec and a mass of $2{\cdot}6 \times 10^5$ solar masses; an expansion age for the shell equal to $3{\cdot}8 \times 10^6$ years is derived.

Sorotchenko (**113**) has studied the distribution of neutral and ionized hydrogen in Cygnus. Optical studies of the central regions of the galaxy have been made, guided in a general way, by the radio-astronomical results. Moroz (**114**) has tried to find the galactic nucleus in the infra-red. Using a Fabry-Pérot étalon and an image converter, Shcheglov (**115**) has found extremely wide Hα emission lines of nebulosities in the direction of the galactic center indicating an expansion velocity of 200 km/sec.

During the last three years great progress has been made in the study of distribution, physical state and motion of the interstellar hydrogen gas on the basis of radio-astronomical observations. Much of this work is discussed in the Draft Report of Commission 40 (Radio astronomy) which we refer to in this connection.

The 21-cm work at the Leiden Observatory (cf. Draft Report Commission 40) has been concerned with problems of the central region (Rougoor), the region between 3 and 10 kpc (W. W. Shane), the redetermination of the galactic rotation curve (G. P. Smith), test for systematic radial motion in the galactic disk (Braes), the OB associations II and I Mon (Raimond), and high-velocity clouds (Muller, Oort and Raimond, G. P. Smith and W. W. Shane). The Leiden Observatory 21-cm results regarding the transition region between disk and halo and their relation to problems of the dust distribution are discussed by Oort (**116**).

The 21-cm work at the Radiophysics Laboratory, Sydney, is also discussed in the Draft Report, Commission 40. It has dealt with the large-scale structure and the motions of neutral hydrogen (Kerr), and the results of a low-resolution (beamwidth $2°{\cdot}2$) survey of the whole visible sky (McGee, Murray, Milton). Radio continuum studies at the Radiophysics Laboratory include a survey of the southern milky way at 1440 Mc (Mathewson, Healey and Rome) and surveys at 75 and 20 cm along an extensive section of the southern milky way (Hill, Komesaroff, Westerhout).

The radio-astronomical research on interstellar matter at the Kapteyn Astronomical Laboratory, Groningen, has included a study of the general structure of the interstellar medium in the solar neighborhood based on 21-cm observations at intermediate galactic latitudes, obtained at Dwingeloo Radio Observatory.

Profiles observed in seven latitude zones have been published by Van Woerden, Takakubo and Braes (**117**). Takakubo and Van Woerden have analysed these profiles into components and find that almost all intermediate-latitude profiles can be represented by the supposition of a few gaussians. Takakubo has discussed the kinematical properties of the profile components which may be tentatively identified with interstellar clouds. The interstellar Ca II line profiles generally agree quite well with the 21-cm profiles. Takakubo has further used the profile components in a discussion of interstellar cloud models. He finds that the observations may be reproduced by uniform spherical clouds with the following characteristics: radius 3 pc, density 14 H atoms per cm^3, fraction of space filled 5 per cent, number of clouds along a line of sight 11 per kpc, mass 55 solar masses. However, it is emphasized that caution with regard to the interpretation is required because the angular size of the clouds is comparable with the antenna beamwidth. This work has been summarized and discussed by Blaauw (**118**). A program of investigation of neutral hydrogen at high galactic latitude (H I in the solar neighborhood and in the galactic halo) is being carried out by Blaauw, Schwarz and Tolbert jointly with Muller, Oort and Raimond at the Leiden Observatory. Habing is making a study of hydrogen in the outermost arms of the galaxy, and early results have been communicated by Blaauw (**119**). Van Woerden has made a redetermination of the total mass of neutral hydrogen in the galaxy and finds a value of 7×10^9 solar masses. The largest amount of hydrogen is found in the Perseus arm. The revision enhances the similarity between the galaxy and M31.

The Groningen work includes studies of neutral hydrogen in special regions. A few associations are being studied in great detail on the basis of observations made at Dwingeloo. These include the Orion region (Van Woerden (**120**)), II Sco (Van Woerden and Schwarz), I Per (Schwarz and Van Woerden) and a region south of h and χ Persei (Hack, Van Woerden and Blaauw, cf. Blaauw (**121**)). The latter investigation suggests that large amounts of interstellar gas have been driven away from the region of the double cluster, the momentum having been provided by the radiation of OB stars in the association and by super-novae of type II.

Investigations based on 21-cm observations carried out in the U.S.S.R. include studies of the neutral hydrogen distribution in the outer parts of the galaxy (Lozinskaya and Kardashov (**122, 123**)) and around the galactic nucleus (Ryzhkova, Yegorova, Gosachinski and Bystrova (**124**), Yegorova (**125**)). Parijski (**126**) has analysed observations of the galactic center at different wavelengths and obtained results on the structure of the galactic nucleus. The nature of the source of excitation of the interstellar gas within the galactic nucleus is discussed by Zin Jun Khao (**127**).

Clark, Radhakrishnan and Wilson (**128**) have obtained 21-cm absorption spectra for 12 radio sources and have analysed the observed absorption line profiles in terms of the properties of the absorbing interstellar clouds. They estimate the temperature, the densities, the radius and the total mass of the type of clouds in question. Typical values are 50°K, 20 H atoms per cm^3, 13 pc, and 10^3 solar masses. The number of such relatively cool and dense clouds along a line of sight is found to be about 0·8 per kpc, and the relative volume filled near the galactic plane is about 0·01.

Theoretical calculations of interstellar gas temperatures which take into account the effect of heating by cosmic ray particles, in particular the soft cosmic rays, were carried out by Getmanzev (**129**). Hayakawa, Nishimura and Takayanagi (**130**) investigated the excitation and ionization in the interstellar hydrogen gas by suprathermal particles, of which protons of energies between 0·1 Mev and 10 Mev are assumed to be the major component. The energy spectrum of the suprathermal particles is estimated by extrapolation to lower energies from data on cosmic rays. For H I clouds fairly good agreement is found with the observed mean temperature of about 120°K.

Gershberg has investigated the problem of the temperature of the intermediate region between H II and H I regions (**131**). The L_c radiation field has been calculated with due regard to the diffuse radiation, and the mean energy of the photo-electrons has been evaluated as a function of optical depth. It is shown that the submillimeter emission by O I atoms is about

https://doi.org/10.1017/S0251107X00015078 Published online by Cambridge University Press

equally effective in cooling the interstellar matter as the forbidden emissions of C II and Si II ions.

Theoretical calculations concerning non-thermal radio emission have been carried out by Razin (**132**). Kardashov (**133**) has studied the radio emission spectrum emitted during the evolution of a radio source.

The probability for two-photon transitions between superfine structure levels of the 1s-state of the hydrogen atom has been calculated by Demidov (**134**) and found to be much less than the transition probability for 21-cm emission.

EXTINCTION AND THE DISTRIBUTION OF INTERSTELLAR DUST

Schoenberg (**135**) has published a catalogue of 1456 dark nebulae north of declination $-36°$. The basic observational material consists of the Ross-Atlas of the Northern Milky Way and E. E. Barnard's Lick-Atlas of the Milky Way. The catalogue gives 1950 co-ordinates, area, shape and absorption. A statistical discussion of the material gave the result that the dark nebulae are flattened objects with the smallest extension in the direction toward the center of the galaxy, the largest in the direction of galactic rotation. The average absorption of the catalogue objects is $0{\cdot}7^{m}$.

B. T. Lynds (**136**) has published a catalogue of dark nebulae containing 1802 objects and compiled from a study of the red and blue prints of the Palomar Observatory Sky Atlas. Positions, area and estimates of the opacity are given. Statistics on the basis of the catalogue data show that the dark clouds listed cover 1368 square degrees of the sky. The distribution of area for clouds of intermediate opacity shows a maximum between 0·01 and 0·02 square degrees while the darkest clouds increase in number as the area decreases, to the limit of the survey. A number of very opaque clouds with areas under 0·009 square degrees are listed. It is pointed out that these objects resemble the Bok-Reilly globules in size and shape.

Divan has investigated the law of reddening for O stars, comparing a group of O stars that show great polarization with a group of weak polarization. No systematic difference is indicated.

A study by Rozis-Saulgeot (**137**) of the dependence of the reddening line in the $(U - B) - (B - V)$ diagram upon the spectral type of the reddened stars indicates that the lines are practically the same at O and A0, but that this is due to a compensation effect.

Wampler (**138**) has investigated the dependence of the law of interstellar reddening upon galactic longitude through photo-electric *UBV* photometry and photo-electric interference filter photometry at 3310 Å, 4500 Å and 5500 Å of O and B stars. He finds significant differences of the reddening law in regions around l^{II} equal to 0°, 17°, 78° and 133°, respectively.

Serkowski (**139**) has redetermined the slopes of the reddening trajectories and the intrinsic colors of early-type stars in the *UBV* system.

H. L. Johnson and Borgman have studied the law of reddening and its regional variation adding to previous bands an infra-red band centered at 2·2 micron. The interstellar extinction at this wavelength is presumably relatively quite small, and comparison with the V magnitude yields the total visual absorption $A(V)$ after a correction of about 10 per cent. For a number of early-type stars Johnson and Borgman have derived the ratio $R = A(V) / E(B-V)$. They find R to be essentially the same in Cygnus and Perseus ($R = 3{\cdot}1$), but in a number of young clusters, R is considerably larger. The largest value of R is found close to the center of the Orion Nebula, $R = 7{\cdot}4$, the value decreasing rapidly with increasing distance from the center. Values between 3 and 5 have been found for NGC6611, NGC6530, NGC2244 and II Per, while $R = 4$ in the obscured portion of the Sco–Cen association.

At the Royal Observatory, Edinburgh, an extensive program is in progress to investigate reddening as a function of distance and galactic longitude. Several hundred early-type stars

https://doi.org/10.1017/S0251107X00015078 Published online by Cambridge University Press

to a limiting magnitude $V = 11^m$, from Vulpecula to Orion, are being measured on objective prism spectra with a dispersion of 1000Å per mm taken with the Schmidt telescope. The wavelength range is about 3400Å to 8000Å.

Crawford (**140**) has published a catalogue of photo-electric *UBV* and Hβ photometry and color excess $E(U - B)$ for B8 and B9 stars brighter than $V = 6{\cdot}5^m$. On the basis of these color excesses and distances derived from the photometry Strömgren (**141**) has discussed the dust distribution within 200 pc. Crawford, Golson and Mander are carrying out a similar program of photo-electric photometry for B0-B5 stars brighter than $V = 6{\cdot}5^m$.

Friedemann (**142**) has carried out three-color photometry in a milky way field in Auriga and has found the two-color-index of W. Becker to be applicable for the determination of interstellar extinction.

Investigations of interstellar reddening as a function of distance have been carried out for selected regions in a number of investigations. Roslund (**143**) has determined magnitudes and colors for O and B stars in Scutum and found that A (V) in front of the Scutum cloud amounts to 1^m, and reaches 3^m in dark areas. Schalén (**144**) has investigated a region near β Cas through observations at 8000Å and in the photographic region, and Sandgren (**145**) has derived the wavelength dependence of the absorption for the same region. Pfau (**146**) has discussed the interstellar extinction in the region of the north galactic pole.

Zonn (**147**) has investigated the distribution of color excesses in interstellar dust clouds.

At the Abastumani Astrophysical Observatory two-dimensional spectral classification and magnitude determinations to 12^m have been carried out according to the Parenago Plan of Milky Way Investigation in two areas in Aquila and Scutum, covering four and eight square degrees, respectively. M stars to 18^m are also classified.

Absorption-distance curves have been determined for a number of smaller regions within these areas. The absorbing clouds appear to be situated from 150 pc – 500 pc, causing absorptions of $2^m - 8^m$ while the space between 3 and 9 kpc is relatively transparent. A dense absorbing cloud appears in Aquila at longitude 4° beyond 9 kpc.

The discussion is contained in a paper by Apriamashvili (**148**), and the catalogue of spectral types, magnitudes and colors for about 2500 stars in (**149**). A catalogue of spectra and magnitudes for about 100 stars in the Parenago Plan area in Cygnus has been published by Kharadze, Apriamashvili and Kotchlashvili (**150**). Kalandadze is carrying out investigations of the Parenago Plan area in Taurus, preparing a catalogue of spectra and magnitudes for about 4000 stars, for the purpose of interstellar absorption analysis.

Further work on interstellar extinction and the space distribution of the absorbing matter in different regions of the milky way is reported in the following publications: Brodskaya (**151**), Brodskaya and Grigorjeva (**152**), Dombrovski and Gagen-Torn (**153**), Voroshilov (**154**), Kolesnik (**155**), Fedorchenko, (**156**), Straizys (**157**), and Pronik (**158**). Pronik (**159**) has established the existence of a system of dark absorbing clouds forming the boundary of the Orion arm on its inner side.

The interstellar dust-gas ratio has been studied as a function of direction by Metik (**160**) Brodskaya (**161**), and by Pronik (**85**).

Wesselink has derived the *UBV* reddening line for B0I stars belonging to the Magellanic clouds and has found that Magellanic cloud stars and galactic stars are reddened according to the same law.

Investigations of the optical properties of interstellar dust particles have been carried out by Greenberg (**162**), and by Greenberg and Lichtenstein (**163**) and the results have been applied to theoretical analysis of the wavelength dependence of interstellar extinction.

It is concluded that the observed wavelength dependence cannot be accounted for on the

https://doi.org/10.1017/S0251107X00015078 Published online by Cambridge University Press

assumption of a medium consisting of purely dielectric grains. Through the choice of a suitable size distribution of the grains the observed wavelength dependence can be satisfactorily reproduced in the range up to and including the near infra-red, but not over the whole range of observation including the far infra-red. However, assuming dielectric grains containing cores with metallic properties, it is possible to reproduce the wavelength dependence in the entire wavelength range in question.

Lichtenstein and Greenberg (**164**) have applied the calculations of optical properties of interstellar grains just referred to in a study of interstellar grain temperatures for a variety of ambient physical conditions. Greenberg and Lichtenstein (**165**) have used these results in an investigation of the influence of the radiation from OB associations upon the size distribution and extinction properties of the interstellar dust.

Hoyle and Wickramasinghe (**166**) have investigated the possibility that the interstellar extinction is produced by graphite particles. They consider the optical properties of the particles and conclude that the observed reddening law can be satisfactorily accounted for in terms of extinction by graphite particles if the diameters are smaller than about 10^{-5} cm. Hoyle and Wickramasinghe suggest that the graphite particles originate through condensation at the surface of stars of spectral type N followed by expulsion into space by radiation pressure. They consider in turn the condensation process, the escape of the graphite particles, the question of the size of the interstellar particles produced by the mechanism in question and the rate of particle emission. They conclude that the mechanism may well produce an interstellar graphite particle medium with density and particle size distribution as required by the observations.

In a following investigation, Wickramasinghe (**167**) has carried out a more detailed investigation of the optical properties of graphite particles on the basis of the Mie theory. The earlier conclusions are confirmed except that agreement with the observed reddening law is only obtained if the upper limit to the particle size is chosen to be somewhat smaller, and this choice leads to certain difficulties in connection with particle albedo. It is suggested that agreement with observation may be obtained on the assumption that the medium consists of graphite cores surrounded by ice mantles. Condensation of interstellar atoms on graphite particles in interstellar space is to be expected. The thickness of the ice coating may depend upon the ambient radiation field, and corresponding variations of the law of reddening might be expected.

Kamijo has suggested that solid SiO_2 particles are formed in circumstellar envelopes of M type long period variables, and that these particles might act as seeding cores of ice particles in interstellar space.

The possible role of extinction by circumstellar particles in reducing the intensity in the rocket-ultra-violet spectrum of B stars has been considered by Pecker (**168**). Hoyle and Wickramasinghe (**169**) have suggested that interstellar extinction in the rocket-ultra-violet might explain the discrepancy between observed and theoretically computed B star intensities in this spectral region.

POLARIZATION AND THE INTERSTELLAR MAGNETIC FIELD

A number of investigations of the polarization of stellar radiation by interstellar matter have been carried out at the Observatory of the Warsaw University Observatory. Kruszewski (**170**) has investigated 24 highly polarized stars and determined the correlation between the ratio of the amounts of polarization in the blue and yellow spectral regions and the ratio of polarization to interstellar reddening. Kruszewski (**171**) and (**172**) has measured polarizations in the regions of the III Cep association and the α Per cluster, Krzemiński and Oskanjan (**173**) in the region of the I Lac association, and Krzemiński (**174**) in the galactic clusters NGC2169 and 7243. Paczyński (**175**) has analyzed the dependence of the ratio p/A (V) on the density of interstellar matter in the Cassiopeia region.

Lodén (**176, 177,** and **178**) has investigated interstellar polarization for 1300 stars in a number of small fields, generally Selected Areas, through photo-electric and photographic observations. In each field the correlation between distance and polarization is analysed. It is concluded that the correlation is fairly high in narrow fields and up to moderate distances. It is found that for 65 per cent of the stars with measured position angles of the planes of vibration the angle between this plane and the galactic equator is less than 20°. A program of future survey work is outlined. The intention is to observe about 100 stars in each of 19 selected $1^\circ \times 1^\circ$ fields.

Analysis of the distribution of stars, dark matter and interstellar polarization in a region in Cygnus has been carried out by Dombrovski (**179**). Similar analysis in the region of the galactic cluster NGC1502 has been carried out by Dombrovski and Gagen-Torn (**180**). From the polarizing properties of the absorbing interstellar matter, the structure of the galactic magnetic field in these regions has been derived.

Greenberg (**181**), Greenberg, Lind, Wang and Libelo (**182**), and Greenberg, Libelo, Lind and Wang (**183**) have shown that the amount and wavelength dependence of the polarization of starlight is reasonably well reproduced on the assumption of oriented non-spherical dielectric (dirty ice) grains whose size distribution is determined by the wavelength dependence of the extinction.

Wickramasinghe (**184**) has investigated polarization caused by interstellar aligned graphite flakes of sizes smaller than the wavelength of light, a problem first considered by Cayrel and Schatzman. It is found that the grains of this type need to be aligned only to a slight extent, about 2 per cent, in order to explain the observed polarization. The necessary alignment is shown to be accomplished by a galactic magnetic field of the order of 10^{-6} Gauss.

Piotrowski (**185**) has investigated the possible cause of the elongation of interstellar grains. Grzedzielski has considered the problem of magnetic fields in H I clouds.

In an investigation of extra-galactic objects, A. Elvius and Hall found that the light from M31 and other galaxies in the same region of the sky is slightly polarized. This polarization, $\Delta m(p) = 0\overset{m}{.}018 \pm 0\overset{m}{.}005$, is probably caused by absorption in our Galaxy and would indicate a total visual absorption $A(V) \sim 0\overset{m}{.}3$.

DYNAMICS OF INTERSTELLAR MATTER

Shklovski (**186**) has shown that a super-nova outburst in the interstellar medium can be considered as a strong adiabatic explosion in the medium with constant thermal capacity. New expressions have been obtained for the deceleration time of expanding nebulae-remnants of super-nova outbursts. It has been shown the super-nova II type outbursts occurring in the galactic plane result in a strong perturbation of all characteristics of the interstellar medium and generate 'bubbles' of the gas and relativistic particles and 'loops' of magnetic force lines with radii about 200–300 pc.

Pikelner (**187**) has considered the conditions required for the generation of cosmic magnetic fields, in particular, in radio sources—super-nova outburst remnants. The upper limit of the magnetic energy is determined by the energy of the gas or of the cosmic rays because its diffusion creates the magnetic field. The lower limit depends on the effectivity of the dissipative mechanisms which reduce inductive currents. In addition the damping of an inductive current can occur as the result of the beam instability or of the admixture of the neutral gas. In the Crab nebula the magnetic field can be accounted for only if there is an appreciable admixture of neutral atoms.

The general problem of the energy balance of the interstellar medium has been reviewed by Biermann (**188**), and problems of the small-scale dynamics of interstellar problems, particularly in H II regions by Kahn (**189**). Goldsworthy and his collaborators in Manchester have

https://doi.org/10.1017/S0251107X00015078 Published online by Cambridge University Press

been investigating the structures of interstellar ionization fronts and the question of the expansion of H II regions in their early stages. Vandervoort (**190**) has examined the stability of ionization fronts of the weak D-type that are believed to form the boundaries of H II regions in the late stages. Problems of strong shock fronts have been reviewed by von Hoerner (**191**). Pottasch (**192**) has investigated the dynamics of the bright-rim structures located within or near the edges of H II regions.

The characteristics of an ionization wave moving in the interstellar medium, in particular the dependence of the thickness of the neutral hydrogen layer upon pressure and temperature at the front of the wave have been analysed by Olijnyk (**193**).

Pacholczyk (**194, 195**) has studied the shapes of hydromagnetic wave fronts and the gravitational instability of magneto-hydrodynamical systems of astrophysical interest. The latter problem was also examined by Stodolkiewicz (**196**). Kossacki (**197**) has analysed the question of the magneto-gravitational instability of a homogeneous, viscous, rotating medium with finite electrical conductivity.

The general problem of thermal instabilities in the interstellar medium, and in particular the question of a mechanism that would generate interstellar clouds was investigated by Field (**198**).

Savedoff and Vila (**199**) have studied the growth of fluctuations in a uniformly contracting or expanding cloud.

Hatanake, Unno and Takebe (**200, 201**) examined the general question of the formation of condensations in the interstellar medium. The investigation was continued by Unno and Simoda (**202**), who examined the particular case that the heating of the interstellar cloud is mainly due to suprathermal particles.

Klimishin and Bazilevich (**203**) have investigated the correlation between the interstellar polarization of starlight and the angular distances of considered points in the sky. Kaplan and Klimishin (**204**) have considered the methods of investigation of interstellar turbulence, have investigated the correlation between the non-thermal radio emission and the angular distances of considered points and have evaluated the fundamental scale of the interstellar hydromagnetic turbulence as one-half the size of the galactic halo. Gershberg (**205**) has shown that it is difficult to obtain the information on inner motions of interstellar gas from observed fluctuations of diffuse nebula brightnesses because the correlations following from the local isotropic turbulence theory are very close to the ones that may be expected in the case of a random distribution of brightness; this conclusion is valid for correlations of any characteristics which are determined in a two-dimension space.

The problems of star formation and interstellar magnetic field are discussed by Spitzer (**206, 207**).

For a general review of the large-scale dynamics of interstellar matter, we refer to a volume mentioned in the introduction, L. Woltjer (ed.), *The Distribution and Motion of Interstellar Matter in Galaxies*, p. 215–303. Reference is also made to the Draft Reports of Commission 33 (The Structure and Dynamics of the Galactic System) and Commission 43 (Magnetohydrodynamics and the Physics of Ionized Gases).

The possibility of maintaining turbulent motions in the galactic halo, in interaction with the intergalactic medium, has been considered by Byakov (**208**).

Burbidge and Hoyle (**209**) have proposed a model for galaxies such as our own and M31, in which the halo that is emitting non-thermal radio emission is a transient phenomenon produced by a violent outburst in the nuclear region of the galaxy. It is suggested that the explosion in the nuclear region is also responsible for the outward-moving gas in the galactic disk. On this basis it is deduced that the outburst took place about 10 million years ago.

Considering the problem of a gravitational condensation of galaxies and globular clusters, Ozernoj (**210**) has found that large condensations are unstable to fragmentation into isolated protogalaxies and dwarf sub-systems. The next cooling stages are relatively very rapid, and this is seen as the cause of the absence of intermediate masses between dwarf galaxies and globular clusters and the observed increase of globular cluster sizes with distance from the galactic center.

BENGT STRÖMGREN
President of the Commission

REFERENCES

1. Henize, K. G. Catalogue of 202 emission-line objects in the southern sky, unpublished.
2. Apriamashvili, S. P. *Astr. Circ. U.S.S.R.* no. 202, 222, 231, 232.
3. Vorontsov-Velyaminov, B. A. *Astr. Zu.*, **38**, 75, 375, 1961.
4. Franzman, Yu. L. *Astr. Zu.*, **39**, no. 2, 1962.
5. Kohoutek, L. *Bull. astr. Inst. Csl.*, **13**, 120, 1962; **14**, 70, 1963.
6. Vorontsov-Velyaminov, B. A. *Soobšč. gos. astr. Inst. Sternberga.* no. 118, 1962.
7. Henize, K. G., Westerlund, B. E. *Astrophys. J.*, **137**, 747, 1963.
8. Gershberg, R. E. *Izv. Krym. astrofiz. Obs.*, **28**, 159, 1962.
9. Metik, L. P., Pronik, V. I. *Izv. Krym. astrofiz. Obs.*, **30** (in press).
10. Khromov, G. S. *Astr. Zu.*, **39**, 468, 1962.
11. O'Dell, C. R. *Astrophys. J.*, **135**, 371, 1962.
12. Collins, G. W., Daub, C. T., O'Dell, C. R. *Astrophys. J.*, **133**, 471, 1961.
13. Turchaninova, E. V. *Publ. Kievsk. Astr. Obs.* no. 9, 1961.
14. Turchaninova, E. V. *Astr. Zu.*, **39**, no. 5, 1962.
15. Gerschberg, R. E. *Izv. Krym. astrofiz. Obs.*, **28**, 159, 1962.
16. Khromov, G. S. *Astr. Zu.*, **39**, 468, 1962.
17. Metik, L. P., Gershberg, R. E. *Izv. Krym. astrofiz. Obs.*, **31** (in press).
18. Vorontsov-Velyaminov, B. A., Kostyakova, E. B., Dokuchaeva, O. D., Arkhipova, V. P. *Astr. Zu.* (in press).
19. Osterbrock, D. E., Capriotti, E. R., Bautz, L. P. *Astrophys. J.*, **138**, 62, 1963.
20. Capriotti, E. R., Daub, C. T. *Astrophys. J.*, **132**, 677, 1960.
21. O'Dell, C. R. *Astrophys. J.*, **138**, 293, 1963.
22. ,, *Astrophys. J.*, **138**, 1018, 1963.
23. Andrillat, Y., Andrillat, H. *Ann. Astrophys.*, **24**, 139, 1961.
24. Aller, L. H., Bowen, I. S., Wilson, O. C. *Astrophys. J.*, **138**, 1013, 1963.
25. Razmadze, N. A. *Astr. Zu.*, **37**, 1005, 1960, also *Abastumanskaja astrofiz. Obs. Bjull.*, **26**, 25, 1961.
26. Kuzmin, A. D., Salomonovich, A. E., Udaltsov, V. A. *Astr. Zu.*, **38**, 373, 1961.
27. Capriotti, E. R. *Astrophys. J.*, **139**, 225, 1964.
28. Osterbrock, D. E. *Astrophys. J.*, **135**, 195, 1962.
29. Pengelly, R. M. *Mon. Not. R. astr. Soc.*, **127**, 145, 1964.
30. Pengelly, R. M., Seaton, M. J. *Mon. Not. R. astr. Soc.*, **127**, 165, 1964.
31. Seaton, M. J. *Mon. Not. R. astr. Soc.*, **127**, 177, 1964.
32. Zanstra, H. *Quart. J. R. astr. Soc.*, **2**, 137, 1961.
33. Osterbrock, D. E. *Planet. and Space Sci.*, **11**, 621, 1963.
34. Saigusa, T. *Mem. Coll. Sc. Univ. Kyoto*, Ser. A., **30**, 137, 1962.
35. Sobolev, V. V. *Dokl. Ak. N. SSSR*, **136**, no. 3, 1960.
36. Ivanov, V. V. *Trudy. astr. Obs. Leningrad. gos. Univ.*, **19**, 52, 1962.
37. ,, *Astr. Zu.*, **39**, no. 6, 1962.
38. ,, *Astr. Zu.*, **40**, no. 2, 1963.
39. Khromov, G. S. *Astr. Zu.*, **40** (in press).
40. Pleshkova, T. F. *Astr. Zu.*, **39**, 235, 1962.
41. Hummer, D. G., Seaton, M. J. *Mon. Not. R. astr. Soc.* (in press).
42. ,, ,, *Mon. Not. R. astr. Soc.* (in press).
43. ,, ,, *Mon. Not. R. astr. Soc.* (in press).

44. Gurzadian, G. A. *Dokl. Ak. N. SSSR*, **141**, 1016, 1961.
45. Nikitin, A. A. *Vestnik Leningrad. Univ.*, no. 1, 1961; no. 13, 1962; no. 1, 1963.
46. Nikitin, A. A., Yakubovski, O. A. *Astr. Zu.*, **40**, no. 2, 1963.
47. Boyarchuk, A. A., Gerschberg, R. E., Pronik, V. I. *Izv. Krym. astrofiz. Obs.*, **29**, 291, 1963.
48. Seaton, M. J., Gebbie, K. B. *Nature* (in press).
49. O'Dell, C. R. *Astrophys. J.*, **138**, 67, 1963.
50. Turchaninova, E. V. *Cirk. Astr. Obs. Kiev.* no. 72 (in press).
51. Gurzadian, G. A., Hovhanesian, R. T. *Soobšč. Bjurakan. Obs.* (in press).
52. Chudovicheva, O. N. *Izv. glav. astr. Obs. Pulkove*, no. 174 (in press).
53. Wilson, O. C., O'Dell, C. R. *Publ. astr. Soc. Pacif.*, **74**, 511, 1962.
54. Pronik, V. I. *Izv. Krym. astrofiz. Obs.*, **26**, 342, 1961.
55. Khromov, G. S. *Astr. Zu.*, **38**, 809, 1961.
56. Osaki, T. *Publ. astr. Soc. Japan.*, **13**, 1, 1961.
57. Daub, C. T. *Astrophys. J.*, **137**, 184, 1963.
58. Gurzadian, G. A. *Dokl. Ak. N. SSSR*, **133**, 1053, 1960; **144**, 1011, 1962.
59. Klimishin, I. A. *Lvovsk. gos. Univ. astr. Obs. Cirk.*, no. 35-36, 31, 1960.
60. Chvojková, E., Kohoutek, L. *Bull. astr. Inst. Csl.*, **13**, 75, 1962.
61. Kohoutek, L. *Bull. astr. Inst. Csl.*, **15**, 1964 (in press).
62. Yessipov, V. F., Shcheglov, P. V. *Astr. Zu.*, **38**, 554, 1961.
63. Yessipov, V. F. *Astr. Zu.*, **39**, 365, 1962.
64. Gagen-Torn, V. A. *Trudy astr. Obs. Leningrad. gos. Univ.*, **19**, 166, 1962.
65. Parijski, Y. N. *Astr. Zu.*, **38**, 798, 1961.
66. Kuzmin, A. D., Noskova, R. I. *Astr. Zu.*, **39**, 241, 1962.
67. Zin Jun Khao *Astr. Zu.* **38**, 1069, 1961.
68. Mathis, J. S. *Astrophys. J.*, **136**, 294, 1962.
69. Vandervoort, P. O. *Astrophys. J.*, **137**, 381, 1963.
70. ,, *Astrophys. J.*, **138**, 426, 1963.
71. ,, *Astrophys. J.* (in press).
72. ,, *Astrophys. J.*, **138**, 294, 1963.
73. Yada, B. *Publ. astr. Soc. Japan*, **12**, 449, 1960.
74. Field, G. B., Partridge, R. B. *Astrophys. J.*, **134**, 959, 1961.
75. Moroz, V. I. *Astr. Zu.* (in press).
76. Lazarevski, V. S., Stankevich, K. S., Troitski, V. S. *Astr. Zu.*, **40**, no. 1, 1963.
77. Soboleva, N. S., Prozorov, V. A., Parijski, Yu. N. *Astr. Zu.*, **40**, 3, 1963.
78. Pronik, V. I. *Izv. Krym. astrofiz. Obs.* (in press).
79. Sholomnitski, G. B. *Astr. Zu.*, **40**, 223, 1933.
80. Gershberg, R. E., Pronik, V. I. *Izv. Krym. astrofiz. Obs.*, **26**, 303, 1961.
81. Gershberg, R. E., Yessipov, V. F., Pronik, V. I., Shcheglov, P. V. *Izv. Krym. astrofiz. Obs.*, **26**, 313, 1961.
82. Rozhkovski, D. A., Glushkov, Yu. I., Jakusheva, K. G. *Izv. astrofis. Inst. Akad. N. Kazakh. SSR*, **14**, 1962.
83. Rozhkovski, D. A., Jakusheva, K. G. *Izv. astrofis. Inst. Akad. N. Kazakh. SSR*, **14**, 1962.
84. Parijski, Yu. N. *Astr. Zu.*, **38**, 483, 1961.
85. Pronik, I. I. *Izv. Krym. astrofiz. Obs.*, **30** (in press).
86. Gershberg, R. E. *Izv. Krym. astrofiz. Obs.*, **30** (in press).
87. Moriyama, F. *Publ. astr. Soc. Japan.*, **12**, 203, 1960.
88. Gershberg, R. E. *Astr. Zu.*, **39**, 1033, 1962.
89. Wesselink, A. J. *Mon. Not. R. astr. Soc.*, **124**, 501, 1962.
90. Parker, R. A. R. *Astrophys. J.* (in press).
91. Dorschner, J., Gürtler, J. *Mitt. Univ. Sternw. Jena* no. 56, 1964.
92. Elvius, A., Hall, J. S. *Astr. J.*, **67**, 271, 1962.
93. Parsamyan, E. S. *Soobšč. Bjurakan. Obs.*, **30**, 51, 1962; **32**, 3, 17, 1963.
94. Rozhkovski, D. A. *Izv. astrofis. Inst. Akad. N. Kazakh. SSR*, **13**, 1962.
95. ,, *Izv. astrofis. Inst. Akad. N. Kazakh. SSR* (in press).

96. Minin, I. N. *Astr. Zu.*, **38**, 641, 1961.
97. Dibye, E. A. *Astr. Zu.* (in press).
98. Gershberg, R. E. *Astr. Zu.*, **38**, 819, 1961.
99. Khatchikyan, E. E., Kalloglyan, N. L. *Soobšč. Bjurakan. Obs.*, **30**, 45, 1962.
100. Johnson, H. M. *Publ. nat. Radio. Astr. Obs. Green Bank* no. 17, 1963.
101. Münch, G., Unsöld, A. *Astrophys. J.*, **135**, 711, 1962.
102. Walker, G. A. H. *Mon. Not. R. astr. Soc.*, **125**, 141, 1963.
103. Unsöld, A. *Z. Astrophys.*, **56**, 221, 1963.
104. Wilkens, H. *Asoc. Argentina Astr. Bol.* no. 4, 69, 1962.
105. Weinreb, S., Barrett, A. H., Meeks, M. L., Henry, J. C. *Nature*, Lond., **200**, 829, 1963.
106. Gould, R. J., Salpeter, E. E. *Astrophys. J.*, **138**, 393, 1963.
107. Gould, R. J., Gold, T., Salpeter, E. E. *Astrophys. J.*, **138**, 408, 1963.
108. Lambrecht, H., Schmidt, K.-H. *Mitt. Univ. Sternw. Jena* no. 57, 1964.
109. Gould, R. J., Harwit, M. *Astrophys. J.*, **137**, 694, 1963.
110. Takakubo, K. *Publ. astr. Soc. Japan* (in press).
111. Howard, W. E., Wentzel, D. G., McGee, R. X. *Astrophys. J.*, **138**, 988, 1963.
112. Rohlfs, K., Girnstein, H. G. *Z. Astrophys.* **59**, 83, 1964.
113. Sorotchenko, R. L. *Trudy fiz. Inst. Akad. Nauk SSSR* (Lebedev Phys. Inst.), **17**, 128, 1962.
114. Moroz, V. I. *Astr. Zu.*, **38**, 487, 1961.
115. Shcheglov, P. V. *Astr. Circ. U.S.S.R.* no. 240.
116. Oort, J. H. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 71.
117. Van Woerden, H., Takakubo, K., Braes, L. *Bull. astr. Inst. Netherlds*, **16**, 321, 1962.
118. Blaauw, A. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 48.
119. Blaauw, A. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 23.
120. Van Woerden, A. *Thesis*, Groningen Univ., 1962.
121. Blaauw, A. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 63.
122. Lozinskaya, T. A., Kardashov, N. S. *Astr. Zu.*, **39**, 840, 1962.
123. ,, ,, *Astr. Zu.*, **40**, 209, 1963.
124. Ryzhkova, N. F., Yegorova, T. M., Gosachinski, I. V., Bystrova, N. V. *Astr. Zu.*, **40**, 17, 1963.
125. Yegorova, T. M. *Astr. Zu.*, **40**, 382, 1963.
126. Parijski, Yu. N. *Astr. Zu.*, **38**, 242, 377, 1961.
127. Zin Jun Khao *Astr. Zu.*, **39**, no. 1, 1962.
128. Clark, B. G., Radakrishnan, V., Wilson, R. W. *Astrophys. J.*, **135**, 151, 1962.
129. Getmanzev, G. G. *Astr. Zu.*, **39**, 856, 1962.
130. Hayakawa, S., Nishimura, S., Takayanagi, T. *Publ. astr. Soc. Japan*, **13**, 184, 1961.
131. Gershberg, R. E. *Izv. Krym. astrofiz. Obs.*, **26**, 324, 1961.
132. Razin, V. A. *Radiofiz.*, **3**, 921, 1960.
133. Kardashov, N. S. *Astr. Zu.*, **39**, 393, 1962.
134. Demidov, V. P. *Astr. Zu.*, **38**, 1065, 1961.
135. Schoenberg, E. *Bayr. Akad. Wiss.* (in press).
136. Lynds, B. T. *Astrophys. J. Suppl.* **7**, 1, 1962.
137. Rozis-Saulgeot, A-M. *Ann. Astrophys.*, **23**, 504, 1960.
138. Wampler, E. J. *Astrophys. J.*, **134**, 861, 1961; **136**, 100, 1962.
139. Serkowski, K. *Astrophys. J.*, **138**, 1035, 1963.
140. Crawford, D. L. *Astrophys. J.*, **137**, 530, 1963.
141. Strömgren B. in *The Distribution and Motion of Insterstellar Matter in Galaxies*. ed. L. Woltjer, Benjamin, New York, 1962, p. 38.
142. Friedemann, Chr. *Astr. Nachr.*, **287**, 85, 1963.
143. Roslund, C. *Medd. Lunds astr. Obs.*, I, no. 201, 1962.
144. Schalén, C. *Medd. Lunds astr. Obs.*, I, no. 203, 1963.

145. Sandgren, B. *Medd. Lunds astr. Obs.*, I, no. 204, 1963.
146. Pfau, W. *Astr. Nachr.*, **287**, 97, 1963.
147. Zonn, W. *Acta astr.*, **12**, 141, 1962.
148. Apriamashvili, S. *Abastumanskaja astrofiz. Obs. Bjull.*, **30**, 1963.
149. Cf. *Abastumanskaja astrofiz. Obs. Bjull.*, **31**, 1964.
150. Kharadze, E. K., Apriamashvili, S., Kotchlashvili, T. *Abastumanskaja astrofiz. Obs. Bjull*, **31**, 1964.
151. Brodskaya, E. S. *Izv. Krym. astrofiz. Obs.*, **24**, 160, 1960; **26**, 375, 1961.
152. Brodskaya, E. S., Grigorjeva, N. B. *Astr. Zu.*, **39**, 754, 1962.
153. Dombrovski, V. A., Gagen-Torn, V. A. *Trudy astr. Obs. Leningrad. gos. Univ.* (in press).
154. Voroshilov, V. I. *Izv. glav. astr. Obs. Akad. N. USSR* (Kiev), **5**, 117, 1963.
155. Kolesnik, L. N. *Izv. glav. astr. Obs. Akad. N. USSR* (Kiev), **4**, 55, 1961.
156. Fedorchenko, G. L. *Izv. glav. astr. Obs. Akad. N. USSR* (Kiev), **5**, 128, 1963.
157. Straizys, V. *Lithuanian Physical Review*, **3**, no. 3, 1963.
158. Pronik, I. I. *Izv. Krym. astrofiz. Obs.*, **25**, 37, 1961.
159. Pronik, I. I. *Astr. Zu.*, **39**, 362, 1962.
160. Metik, L. P. *Izv. Krym. astrofiz. Obs.*, **30** (in press).
161. Brodskaya, E. S. *Izv. Krym. astrofiz. Obs.*, **31** (in press).
162. Greenberg, J. M. *Proc. Int. School of Physics 'Enrico Fermi', Cosmic Rays, Solar Particles and Space Research*, 235, Academic Press, New York, 1963.
163. Greenberg, J. M., Lichtenstein, P. R. *Astr. J.*, **68**, 279, 1963.
164. Lichtenstein, P. R., Greenberg, J. M. *Astr. J.*, **67**, 275, 1962.
165. Greenberg, J. M., Lichtenstein, P. R. *Astr. J.*, **68**, 74, 1963.
166. Hoyle, F., Wickramasinghe, N. C. *Mon. Not. R. astr. Soc.*, **124**, 147, 1962.
167. Wickramasinghe, N. C. *Mon. Not. R. astr. Soc.*, **126**, 99, 1963.
168. Pecker, J.-C. *Space Science Reviews*, ed. C. de Jager, D. Reidel Publ. Co., Dordrecht-Holland, **1**, 729. 1962–63,
169. Hoyle, F., Wickramasinghe, N. C. *Mon. Not. R. astr. Soc.*, **126**, 401, 1963.
170. Kruszewski, A. *Acta astr.*, **12**, 234, 1962.
171. Kruszewski, A. *Acta astr.*, **13**, 92, 1963.
172. Kruszewski, A. *Acta astr.*, **13**, 100, 1963.
173, Krzeminski, A., Oskanjan, V. *Acta astr.*, **11**, 1, 1961.
174. Krzeminski, A. *Acta astr.*, **11**, 7, 1961.
175. Paczynski, B. *Acta astr.* **12**, 206, 1962.
176. Lodén, L. O. *Stockh. Obs. Medd.*, no. 130, 1961.
177. Lodén, L. O. *Stockh. Obs. Ann.*, **21**, no. 7, 1961.
178. Lodén, L. O. *Stockh. Obs. Ann.*, **22**, no. 1, 1961.
179. Dombrovski, V. A. *Vestnik. Leningrad Univ.* no. 7, 142, 1961; *Dokl. Ak. N. SSR*, **137**, 814, 1961.
180. Dombrovski, V. A., Gagen-Torn, V. A. *Trudy. astr. Obs. Leningrad. gos. Univ.* (in press)
181. Greenberg, J. M. *Proc. Int. School of Physics 'Enrico Fermi' Cosmic Rays, Solar Particles and Space Research*, 227, Academic Press, New York, 1963.
182. Greenberg, J. M., Lind, A. C., Wang, R. T., Libelo, L. F. *Proc. Interdisciplinary Conf. Electromagnetic Scattering*, 123, Pergamon Press, 1963.
183. Greenberg, J. M., Libelo, L., Lind, A. C., Wang, R. T. *Symp. Electromagnetic Theory and Antennas*, 81, Pergamon Press, 1963.
184. Wickramasinghe, N. C. *Mon. Not. R. astr. Soc.*, **125**, 87, 1962.
185. Piotrowski, S. L. *Acta astr.*, **12**, 221, 1962.
186. Shklovski, I. S. *Astr. Zu.*, **39**, 209, 1962.
187. Pikelner, S. B. *Astr. Zu.*, **40**, 601, 1963.
188. Biermann, L. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 153.
189. Kahn, F. D. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 164.
190. Vandervoort, P. O. *Astrophys. J.*, **135**, 212, 1962; **138**, 599, 1963.

191. Von Hoerner, S. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 193.
192. Pottasch, S. R. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 205.
193. Olijnyk, P. A. *L'vovsk. gos. Univ. astr. Obs. Cirk.* no. 35–36, 51, 1960.
194. Pacholczyk, A. G. *Acta astr.*, **13,** 55, 1963.
195. Pacholczyk, A. G. *Acta astr.*, **13,** 1, 1963.
196. Stodolkiewicz, J. *Acta astr.*, **13,** 30, 1963.
197. Kossacki, K. *Acta. astr.*, **11,** 83, 1961.
198. Field, G. B. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 183.
199. Savedoff, M. P., Vila, S. *Astrophys. J.*, **136,** 609, 1962.
200. Hatanake, T., Unno, W., Takebe, H. *Publ. astr. Soc. Japan*, **13,** 173, 1961.
201. Takebe, H., Unno, W., Hatanake, T. *Publ. astr. Soc. Japan*, **14,** 340, 1962.
202. Unno, W., Simoda, M. *Publ. astr. Soc. Japan*, **15,** 78, 1963.
203. Klimishin, I. A., Bazilevich, V. M. *L'vovsk. gos. Univ. astr. Obs. Cirk.* no. 39–40, 3, 1963.
204. Kaplan, S. A., Klimishin, I. A. *Astr Zu.* (in press).
205. Gershberg, R. E. *Izv. Krym. astrofiz. Obs.*, **31** (in press).
206. Spitzer, L. in *The Distribution and Motion of Interstellar Matter in Galaxies*, ed. L. Woltjer, Benjamin, New York, 1962, p. 98.
207. Spitzer, L. in *Origin of the Solar System*, ed. R. Jastrow and A. G. W. Cameron Academic Press, New York and London, 1963, p. 39.
208. Byakov, V. M. *Astr. Zu*, **40,** 384, 1963.
209. Burbidge, G. R., Hoyle, F. *Astrophys. J.*, **138,** 57, 1963.
210. Ozernoj, L. M. Collected scientific student papers of Moscow Univ. 1962, P. 33.