34. COMMISSION DE LA MATIERE INTERSTELLAIRE ET DES NEBULEUSES PLANETAIRES

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INTRODUCTION

New fields of astrophysics, which arised recently, resulted in the enlargement of topics included into the list of problems of Commission 34. As far as the problems connected with quasars, structure of galaxies and their nuclei are concerned the review deals with questions relating to the diffuse medium. The review is partly based on the reports of Commission members, especially on those of Professor Osterbrock and Dr Aller. I am greatly obliged to Professor Greenberg, who kindly wrote a separate review on interstellar grains.

Since 1964 several new books and reviews have appeared:

Structure and Evolution of Galaxies, 1964, *Suppl. Prog. theor. Phys.*, Osaka, no. 31.

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Schalén, C., 1965, *Publ. astr. Soc. Pacif.*, **77**, 409.

Kaplan, S. A., Pikelner, S. B., 1965, *Izv. Akad. Nauk SSSR*, fiz. ser., **29**, 1830.

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Dieter, N. H., Goss, W. M., 1966, *Rev. mod. Phys.*, **38**, 256.

Kaplan, S. A., Pikelner, S. B., *Interstellar medium*, Harvard, in press.

Symposium on *Radio and Optical Studies of the Galaxy*, 1966, Mount Stromlo Observatory.

IAU Symposium no. 31, 1966, *Radio Astronomy and the Galactic System*, Noordwijk, Sept. (in press).

PLANETARY NEBULAE

During these years spectrophotometric observations of planetary nebulae were continued: absolute intensities of spectral lines and of continuum, in particular in peculiar and stellar-like objects, infrared and radio-observations. The classical theory of nebulae emission was improved. Transition probabilities and collision cross-sections for a number of ions were calculated. Theoretical investigations of the recombination spectra of H, He and of other elements were performed, especially for different l-values and for higher levels, where some anomalies were revealed. The chemical composition, in particular for nebulae of different sub-systems was defined more precisely. However the main progress now takes place in the investigation of the dynamics and evolution of nebulae, of their stratification, expansion, with simultaneous evolution of their central stars. This problem is particularly important, because planetary nebulae are advanced stages of the evolution of some types of stars, and a comparison of the central stars of different-age nebulae allows to find an evolutionary modification in blue dwarfs.

Eighty-six planetaries were identified on Palomar Sky Survey by Abell (**1**). A catalogue of 202 new planetaries on the South Sky was published (**2**), and two nebulae were found (**3**). Perek and Kohoutek have prepared for publication an extensive catalogue with charts, containing more than 1000 planetaries with positions 1950·0, galactic coordinates, sizes, surface brightness, magnitude, classification and information on the central star (**4**). Westerlund and Smith revealed 42 planetaries in LMC (**5**), measured their colours and magnitudes. Spectra of 20 planetaries in other galaxies are being investigated.

The determination of absolute proper motions in the system of FK4 for 16 planetary nebulae, with a mean error of $\pm$ 0″·008/year, is reported by Dr Chr. de Vegt.

Phtoelectric and photographic spectrophotometry was carried out for a large number of planetaries by Aller, Bowen, Czyzak, Faulkner, Liller, Kaler, O'Dell, Walker, Kohoutek (**7, 8, 9, 10, 11, 12, 13, 13a**). Application of the Lallemand image converter made it possible to study in detail a visual part of spectra (**14**). Absolute intensities of main lines were measured by photographic method in 65 northern and 90 southern nebulae (in the direction of the Galactic centre) by Vorontsov-Velyaminov, Kostyakova, Dokuchaeva, Arkhipova (**15, 16**).

Infrared line 12·8 μ Ne II was observed in IC 418 by Low (**17**). The flux is 10^{-16} w cm^{-2} in agreement with theoretical estimation $0{\cdot}6 \times 10^{-16}$ w cm^{-2} (**18, 19**). Radio observations of planetary nebulae were carried out by Golnev and Parijsky (**20**), Khromov and others (**21**), Menon and Terzian (**22**).

Models of nebulae based on these observations were constructed (**23, 24**), which are in agreement with optical data.

Transition probabilities for a number of permitted optical and ultraviolet lines of astrophysical interest were calculated by Czyzak, Aller and their associates (**25, 26**). Collision cross-sections for a fine-structure N III, O IV, Ne II were calculated by Osterbrock (**27**), and in (**28**) a general formula for the calculation of critical electron concentration is given. Dalgarno estimated A_{2s1s} for two-photon transition of He I and the distribution of the energy in two-photon emission (**28a**).

Capriotti (**29**) confirmed the conclusion by Osterbrock that $2s$ state is more important for optical depths of Balmer lines than $2p$ state, but the majority of planetaries are optically thin. Pengelly showed that the recombination spectrum of H and He II is not in agreement with observations for upper levels (**30**). It was necessary to take into account collisions transitions $n,l \rightarrow n,l+1$. Such calculations (**31**) including the radiation gave smooth transitions from the lines to the continuum (**32**). Similarly Kaler (**33, 34**) showed that in many planetaries higher members of H, He I, He II series are relatively brighter than in recombination theory. Discrepancies are not connected with parameters of nebulae and their origin is not clear. Clarke made more extensive calculations of stationary populations of sublevels, taking into account all effects. He obtained better agreement with observations than for the pure radiative decrement (**35**).

The temperature of nebulae calculated inclusive the fine structure of ion levels is in agreement with observations (**27**). From the uniform material (**15, 16**), physical parameters of nebulae were calculated (**36**). The importance of interstellar absorption was evaluated in

(37). The temperature and density of IC 4997 were calculated by Gurzadian (38). He also showed that the inner part of ring-shape planetary nebulae is relatively hotter due to high ionization (39). Chemical composition of a number of nebulae (40) and an average composition (41) was calculated by Aller.

The nebula in globular cluster M 15 contains few heavy elements but a normal abundance of He. Apparently He was in primordial matter. It makes the age of globular clusters shorter (42).

The transfer theory for nebulae is developed in (43). In (44) the probability of escape $L\alpha$ quanta is calculated numerically with frequency re-distribution and geometry. Accumulation of $L\alpha$ in many cases greatly exceeds the theoretical value apparently due to H I shell around the nebulae (45). It is supported by the presence of [O I] line which is an indicator of the nebulae optically thick in Lc (46). Mass, T_* and other parameters for such nebulae are calculated in (47, 48). Stratification of nebulae, ionization of He in different layers and for stars of different temperature were evaluated in (49). The space structure of a nebula can be determined from its picture and spectrum (50).

Expansion of nebulae was investigated on radial velocities (51). In several cases it was determined directly from proper motions (52, 53). In many nebulae there is no expansion, apparently due to a dense surrounding medium. Expansion was discussed theoretically in (54). The model of an expanding nebula, i.e. the distribution of the density, temperature and velocity with radial distance and with time was calculated by Mathews (55). He took into account the heating and cooling of the expanding gas and obtained the variation of $H\beta$ profiles and emission measure with time. To receive an agreement with the observations an additional stream of the gas from the central star is needed. This confirms that its activity is continued.

A central star of WN type was first revealed by Bertola (56). Spectrophotometry of nuclei is given in (57). Determination of nebulae distances as well as temperatures and luminosity of their nuclei allows to draw evolutionary tracks from the left end of the horizontal branch to the white dwarfs (58, 59). The evolution of central stars was discussed also in (60). In (61) a convection in cold variable supergiants-embryons of planetaries and the transfer of angular momentum into outer zone were discussed. The importance of rotation for detachment of the envelopes was stressed in (62). Temperatures of the central stars were determined in (63, 64), the theoretical model and the spectrum of the central stars were calculated in (65, 66).

Calculations on the theory of transfer of radiation in resonance lines (67, 68, 69, 70, 71, 72) can be applied to planetary nebulae.

DIFFUSE NEBULAE AND H II REGIONS

Investigations of diffuse nebulae and H II clouds developed mainly in traditional directions. More precise evaluations of the spectrophotometry in optical and infrared lines and in continuous spectrum were carried out, a thermal continuous radio-emission was determined. An investigation of emission radio-lines of highly excited hydrogen is a new step in this field. This allowed to identify distant heavily obscured H II regions and to determine their radial velocities. This also permitted the calculation of temperatures. Some contradictions with the theory stimulated the development of the latter. Questions were elaborated on: dynamics of the nebulae expansion, their interaction with the surrounding gas, the influence of the dust on the structure of ionization and shock fronts, formation of globulae and of elephant trunks, internal motions in nebulae. The structure and origin of cometary nebulae and the fine filamentary structure of reflecting nebulae are also connected with the dynamics of the gas and with magnetic fields. Searches and investigations of emission regions in Magellanic Clouds and in other galaxies were continued.

A catalogue of bright nebulae that appear on the Palomar Sky Survey was prepared by Lynds (**73**). The careful spectrophotometry of Orion Nebula in spectral region 3187–5016 Å was made by Kaler, Aller and Bowen (**74**). Relative intensities and identifications of lines up to $1{\cdot}5 \times 10^{-4}$ H β are given, O'Dell and Hubbard (**75**) made a photoelectric scanning of lines and continuum of the Orion Nebula. The continuum moving from the Trapezium becomes bluer and brighter relatively to H β. This is due to the light scattered by dust. Reitmeyer (**76**) made the photometry of the Orion Nebula images taken in selected wavelengths. Electron temperature determined from the ratio H β to the Balmer continuum is changed inside the nebula, it is higher where abundance O III is less. Some other results of the paper are not reliable as the influence of interstellar absorption was not taken into account (**76a**). The influence of the density fluctuations on the mass evaluation was discussed by Peimbert (**77**). He obtained a uniform temperature from the comparison O II and O III lines if the abundance of oxygen is constant. Wurm and Perinotto compared the structure of the Orion Nebula in lines and in the continuum (**78**).

Profiles of 10 830 Å He I in Orion were obtained by Voughan (**79**). Infrared observations by Moroz showed that, in 0,85–$1{\cdot}7\ \mu$, the main emission of this nebula is produced primarily by the gas, not by the dust (**80**).

The intensity of [O II] and the electron concentration were determined in several bright nebulae (**81**) and the spectrophotometry of the nebulae around η Carinae and 30 Doradus was made (**82**). In the central part of the Lagoon Nebula $T = 9000°$, $N_e = 250$ cm^{-3}, and in two bright condensations – 10 000° and $1{\cdot}6 \times 10^4$ cm^{-3} respectively. The mass of the condensations is about $0{\cdot}7\ M_{\odot}$ (**83**). Khachikian (**84**) determined the strong polarization of the Omega Nebula (18%) with a constant direction and came to the conclusion that the emission of the Nebula is not connected with the reflection. But the photoelectrical measurements do not give values exceeding 4% (**84a**), and the polarization is undoubtedly of interstellar origin.

Continuous radio-emission of the Rosetta Nebula gave (**85**) its emission measure, and observations of four nebulae on different frequencies showed the thermal origin of their emission (**86**). The thermal character of the spectrum is confirmed for a weak nebula near γ Cyg (**87**). The structure of nebulae in radio-emission and the connection of the structure with stars in Orion are studied in (**88**). It was confirmed that the thermal source Cyg X is a large Strömgren sphere around the association VI Cyg (**89**) which is situated at the distance of $1{\cdot}5$ kps along the arm (**90**). Twenty separate sources on the general phone Cyg X are revealed in (**91**). All of them, except one, have the thermal spectrum. Thirteen galactic radio-sources were investigated at the $\lambda = 6$ cm (**92**), their structure and brightness were determined.

In the central region of the Galaxy there are several sources with thermal spectra (**93, 94**). Their thermal nature is confirmed by the lines of highly excited hydrogen. These lines were predicted theoretically long ago and were revealed recently (**95, 96, 97**). They are an important source of information as they allow to measure the radial velocity of the source and to separate thermal and non-thermal radio-emission. The intensity of these lines as well as the continuum are proportional to the emission measure but their dependence on temperature differs. Therefore their ratio permits to determine T, if the Doppler width is known (**97**). Such measurements for 20 sources gave T from 4000 to 9000°. Earlier, Burbidge and others (**98**) obtained theoretically such low temperatures, taking into account the excitation of the fine-structure of ground states of abundant ions. But they overestimated the collision cross-sections. Osterbrock estimated once again the collision strengths for important transitions and showed that the expected temperatures are between 5000° and 10 000°. Temperatures of low-density nebulae are significantly lower than those of high-density nebulae, such as classical bright planetaries and the centre of the Orion Nebula (**99**). Observations of radio-lines deal with rather dense nebulae. O'Dell (**100**) measured the temperature from [O III] lines in NGC 6618 and NGC 6523 and in three rarefied planetaries and showed that they are in fact significantly lower than in the centre of the dense Orion Nebula. His measurements also gave a higher temperature than the theoretical one (**98**) and that from radio-lines. They agree better with Hjellming's calculations (**101**), who used new models of high temperature stars and obtained T from 5700° to more than 8000° depending on the star temperature.

An explanation of the temperature determined from radio-lines gave Goldberg (**102**). Populations of upper levels are practically the same as the equilibrium ones, especially if collisions are taken into account. However the lower the level, the more is the deviation from the equilibrium due to an increasing role of spontaneous transitions. The ratio of the population of two neighbouring levels deviates from the equilibrium one less than by 10^{-3}, but even such little relative overpopulation of upper levels gives a maser-effect and lines get brighter relative to continuum. It gives an anomalous low calculated temperature.

The widths of the lines of highly excited hydrogen were also in disagreement with theoretical expectations. The accepted theory by Griem, Kolb and Shen (**103**), which takes into account electron impacts besides the statistical stark-effect, suggested a width considerably exceeding the observed value (**104**). Some laboratory experiments with hydrogen plasma also show widths less than the theoretical ones (**105**). These discrepancies were apparently a result of a wrong dependence of broadening by electrons $\lambda_e \sim (n^5 + n'^5)$ in (**103**) and also of an incorrect extrapolation of the results found for the disturbance of one level for the general case of the disturbance of both initial and final levels (see (**106**)). Besides the hydrogen lines, higher transitions of helium were also observed (**107**). Palmer (**107a**) calculated the catalogue of radio-lines of hydrogen and helium.

Temperature of the gas is connected with its movements. High temperature of H II regions in galactic nuclei, determined from [N II]: Hα ratio, is explained in (**98**) by the influence of stellar winds, which is important in the regions with high star density. In (**101**), there was calculated the structure of H II regions which are limited by an ionization front. The absorption of the radiation in the nebula, scattered radiation and cooling due to the excitation of levels and sublevels of iones were taken into account.

The dynamics of the expansion of H II regions was discussed by Axford who took into account the absorption of stellar radiation at the early stage of expansion (**108**) and showed that the stability of weak ionization fronts of D-type increases due to this absorption (**109**). Vandervoort (**110**) calculated the age of the Orion Nebula (14–23 thousand years) from the comparison with the theoretical model. He calculated the early stage of the expansion of H II region (before the radius has reached the Strömgren radius), the propagation of the ionization and shock fronts, and investigated the non-stationary ionization front formed by a star with a varying flux of radiation (**111**). Lasker (**112**) discussed the later stage of expansion of H II regions with the age of about 2 million years. Goldsworthy (**113**) investigated the influence of gravitation on the central part of H II region and found a more precise age of the Orion and Rosetta.

Mathews (**114**) discussed the expansion of the nebula with the massive central star which has a considerable evolution during the expansion of the nebula. He evaluated all main processes of heating and cooling and found a model of physical conditions, velocity field in H II and parameters of a shock wave in H I with time. The maximum temperature is expected immediately behind the ionization front. He believes that the formation of a central hole in Rosetta and in similar objects can be explained by the pressure of 'winds' from the stars which are situated inside or by a condensation of a part of the gas in stars (**115**).

According to radio-observations the low-latitude regions H II are surrounded by H I, the main part of which does not expand. High-latitude regions are not associated with a considerable amount of H I (**116**). Apparently H II regions are immersed into large complexes of neutral hydrogen.

An estimation of the ratio of dust to neutral hydrogen density in Cas and Sge was done in (**116a**).

The presence of dust in the ionization and in shock fronts has an influence on their properties, since the grains absorb radiation and cool the gas. This makes the ionization front slower, especially if the density is low (**117**). The dust increases the compression in shocks (**118**) and has an influence on the dynamics of clouds collisions. The conditions in shocks, on the contrary, are important for the growth and evaporation of grains (**119, 120**). The relative velocity of the dust and gas was also determined. Calculations of the gas resistance under different conditions and with different velocities of grains are given in (**121**).

Gershberg and Sheglov (**122**) revealed with a Fabry-Pérot interferometer fast internal motions $V \approx \pm 50$ km s^{-1} in NGC 6618, $V \approx \pm 25$ km s^{-1} in NGC 6523 and $V \approx \pm 10$ km s^{-1} in NGC 7000 (see also (**123**)). Sheglov revealed weak components with V up to ± 100 km s^{-1} in Omega and Orion (**124**). The origin of these movements is not clear yet, they may be connected with outbursts of supernovae in nebulae (**122**), but the necessary outburst frequency is too high. A similar method was developed by Flynn and Ring (**125**) for the Orion Nebula. The general character of internal motions was evaluated here (**126**).

The presence of dust in diffuse nebulae was examined on the basis of H β and continuum ratio (**127**). The light reflected by dust is present in all three nebulae studied, so that the disintegration of dust in H II regions and its repelling by radiation pressure are rather slow.

The statistics of reflecting nebulae on Palomar Sky Survey was carried out by Dörschner and Gürtler (**128, 129**). They compared the dimensions of the nebulae with stellar spectra and with dimensions of H II regions around B–stars. Previous calculations of Strömgren's radii were overestimated, new ones were calculated. Cometary-like nebulae adjoin to the reflective ones. Hall showed that the polarizations of the variable nebula R Mon is chiefly radial, it increased with distance from the star and reaches as much as 34%. The colour along the axis first turns blue and then red (**130**). The spectra of cometary nebulae were investigated by Dibai and Esipov (**131, 132**). Usually it resembles the spectrum of the star but S 129 turned out to be a common gas nebula. The morphological features of this nebula may be explained by the focusing of the converged shock (**133**). Khachikjan and Parsamian showed that the polarization of NGC 2261 does not change for six years (**134**). They carried out the colourimetry of an anonimous nebula and came to the conclusion that its emission is not reflected light (**135**). There was compiled a list of 23 nebulae on Palomar Sky Survey (**136**). Vardanian (**137**) showed that the tails of cometary nebulae are parallel to the mean direction of the stellar polarization, i.e. their directions may be connected with the magnetic fields of the spiral arms. The fine filamentary structure of reflecting nebulae is apparently a sequence of the interchange instability, when the cloud without the field penetrates into the magnetic field of spiral arms (**138**). After the cloud disintegrates into the filaments, the field penetrates into them and fixes ions and especially charged grains.

H II zone around the Sun was calculated on the basis of the emission spectrum of the Sun in the ultraviolet and X-region (**139**). Due to a weak absorption for the quanta of high energy the ionization decreases continuously. The size of the zone is several hundred of astronomical units. A similar value is found in (**140**) where the electron concentration is inferred from $L\alpha$ observations. The cut-off of the spectrum of cosmic radio noise near 4–5 MHz confirmed the presence of the absorbing zone H II with the emission measure from 8 to 165 in different l (**141, 142**).

If it is not a cloud surrounding the Sun, then $< N_e >$ in the galactic disk should be about 0·1 cm^{-3}. However, the uniform distribution is quite improbable in this case. They are not common H II clouds, but more probable quasi-regular small-scale fluctuations of the gas between clouds.

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H II regions in the Magellanic Clouds were studied by Feast (**143**), Dickel (**144**), Mathis (**145**). Temperatures and densities, non-homogeneities, and masses were determined. The decrement of 30 Doradus gave the extinction. The abundance of He is the same as in galactic nebulaę (**145**). Baade and Arp (**146**) measured the positions of emission nebulae in M 31 which were used for drawing the pieces of arms (**147**). The catalogue of nebulae in M 33 (**148**) and in three other galaxies (**149**) is based on pictures in Hα. Sěrsic compiled a catalogue of 85 H II regions in NGC 300 (**150**).

DISTRIBUTION AND PHYSICAL CONDITIONS IN INTERSTELLAR GAS. MOLECULES

The general distribution of gas in the galactic disk had been investigated before. Therefore now only separate features and details were investigated, more attention was paid to deviations from the average picture. Relations of hydrogen and associations were studied, statistical parameters of clouds were determined (on hydrogen and Ca II lines). A great progress was achieved in the investigation of clouds on intermediate and high latitudes. Some peculiarities found here have not been definitely explained yet.

The temperature of the interstellar medium evaluated from radio observations depends on the kind of lines (emission or absorption) observed and on the distribution of the temperature in dense and rarefied clouds. The temperature itself largely depends on the presence of H_2 molecules. There are many papers with calculations of the abundance of these molecules, but there are no definite results yet. It may be concluded that the abundance of H_2 is relatively low in common clouds and high in dense globulae, but the total abundance in the disk hardly exceeds the abundance of atomic hydrogen. Methods of direct observations of H_2 ultraviolet lines are discussed. Among other molecules, especially interesting is OH, whose lines show extraordinary properties, which are qualitatively explained now as the result of stimulated emission (maser-effect) and sometimes as that of the presence of the magnetic field.

The rotation curve of the Galaxy was redetermined from new observations by Shane and Bieger-Smith (**151**). They showed that this curve is systematically different for the Milky Way in the Northern and Southern Hemispheres. The analysis also indicates the presence of systematic streaming motions with velocities about 10 km s^{-1} and breadths of the order of 100 pcs. This gives difficulties in the determination of the distribution of gas. Pronik analysed the published data of radio observations and showed that the rotation curves are not the same in regions with positive and negative latitudes (**152**). Streams along the Sagittarius arm were found by Burton (**153**). Lindblad has observed and analysed profiles 21 cm in the anticentral region, represented there in terms of gaussian components (**154**) and studied the structure and motions of the gas in this region (**155**). Asymmetry of the velocity field on both sides of the galactic centre was confirmed by Kerr and Hindman (**156**).

Using data on the cross-sections of the Galaxy in (r, z)-planes through the Sun, published earlier by Westerhout, van Woerden re-determined the general distribution of neutral hydrogen in the Galaxy (**157**). The thickness of the hydrogen layer increases markedly with increasing distance from the galactic centre, the amount of the neutral hydrogen in the Galaxy may be 5 to 7×10^9 solar masses.

From the analysis of optical and radio data Pskovsky (**158**), and Pavlovskaya and Sharov (**159**) came to the conclusion that our Galaxy is probably a multi-arm rather than usual spiral.

Gosachinsky (**160**) showed that far away from the centre in $l = 10$ to $40°$ hydrogen has the structure of sheets inclined to the Galactic plane. The cause of deviation of the disk from the plane was discussed by Elwert and Hablick (**161**). They think that the gravitational attraction of the Magellanic Clouds may have a resonance effect on the gas layer, which later on leads to the observed deviation.

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Smith (**162**) and Prata (**163**) found hydrogen concentrations with peculiarly high velocities. The nature of these objects is unclear, they may be similar to the gas complexes discussed in (**164**) which possibly are connected with the associations in Perseus. The distribution of H I in the region of the galactic anticentre and in the vicinity of super-nova remnant IC 443 (**165**), in the region of Taurus (**166**) was studied. A reverse correlation of absorption and of H I concentration was revealed in the latter paper so that in heavy clouds H_2 consists of 85% of the whole mass. Habing (**167**) revealed at the intermediate latitudes gas with velocities corresponding to those of the outer parts of the Galaxy. This gas may extend several kiloparsecs from the galactic plane; it may be a distorted part of a far arm.

A connection of gas with stellar associations was studied for the associations Mon I and especially for Mon II. Raimond (**168**) found there condensations of H I with total mass of about 20 000 $M_{\odot}$. Such condensations had been mentioned before, for instance gas was found in the cluster NGC 2244 which is a part of Mon II (**169**). An expanding shell was also revealed around this association (**170**). But Bystrova, Gosachinsky and Ryzhkov (**171**) believe that there is neither a concentration of gas towards the association nor an expanding shell. They interpret the maximum of hydrogen emission as a bridge between two arms. Investigations of H I in other associations are carried out mainly in the Netherlands (**172**). Goldstein (**173**) showed that the total mass of H I in the globular cluster M 13 is less than 140 $M_{\odot}$.

The distribution of H II is determined from thermal radio emission (cf. Draft Report of Commission 40), as well as from the absorption of low-frequency cosmic radio noise (**142**). The ring of H II in the inner part of the Galaxy (3·5–4·5 kpcs) may also be revealed on the deficiency of H I (**174**). The motion of a star with Strömgren sphere through the gas forms a shock (**175**).

Cloud structure and kinematics of the gas observed on intermediate latitudes, i.e. near the limits of the disk, were investigated by Takakubo (**176**) with the decomposition of the profiles into gaussian components (**177**). There was revealed a high correlation of the low-velocity peak of H I and the main components of Ca II line, in spite of the difference in directions. The correlation of the secondary peak of H I profile and the high-velocity Ca II component is poor, indicating that high-velocity clouds are small in size. Clark (**178**) determined densities, masses and other parameters of the clouds from the absorption components in spectra of five bright radio sources. He found on the average 4·1 clouds per kpc in the galactic plane. There is no systematic deviation from pure rotation—the line in the spectrum of Sgr A is symmetrical about standard frequency. The layer of the clouds is very thin and dense, H I clouds were not observed in absorption on high latitudes. The different width of absorption and emission lines is due to the fact that absorption components are formed in cool clouds, while emission components—also in the hot rarefied gas between clouds; this gas is transparent due to its high temperature.

A preliminary report on observations of optical lines for the comparison with radio observations is performed by van Woerden (**179**). The velocity dispersion of Ca II interstellar lines (6·9 km s^{-1}) is less than that of young stars (**180**). The dependence of the intensities of Ca II lines on the distance from the stars was studied by Wilkens (**181**). Buscombe and Kennedy (**182**) summarized all published radial velocities of Ca II lines on the southern Sky, together with new observations and compared them with new distances of OB stars. Na I lines were also studied.

Livingston and Lynds (**183**), and Hobbs (**184**) measured interstellar lines in the spectra of bright stars in particular α Cyg, with very high wavelength resolution, and showed that there are much more components than usually are observed with lower resolution. A superfine structure was also observed in some clouds. It means that internal turbulent velocities are less than 0,64 km s^{-1} (**184**). Smith (**185**) showed that when analysing profiles one should

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take into account the expansion of the clouds along the interstellar magnetic fields. The profile may be in such case with two peaks and will be interpreted as two clouds.

Resonance interstellar absorption lines of O I, S II, Al III, C II in the region 1260–1720 Å were observed with rockets by Morton and Spitzer (**186**) in the spectra of δ and π Sco.

A comprehensive investigation of H I at high latitudes ($b > +40°$) was carried out mainly by Dutch radioastronomers. A systematic survey resulted in the discovery of several new clouds approaching with high velocity (**187**). Blaauw and Tolbert (**188**) discussed the intermediate-velocity features up to ± 70 km s^{-1}. They suggested that an inflow of matter from $l \approx 120°$, $b \approx +15°$ penetrates close to the Sun. The total mass involved in disturbances is evaluated about 2600 $M_{\odot}$. The phenomenon is much more pronounced at the high negative velocities and is restricted to a smaller area on the sky. The high-velocity clouds were studied by Hulsbosch and Raimond (**189**). They determined for two clouds sizes of $-3°.5$ and $1°.3$ and masses of $-2500\ r^2\ M_{\odot}$ and $150\ r^2\ M_{\odot}$, where r is the distance to the clouds in kpcs. An investigation of high-velocity clouds near N and S galactic poles was carried out by Dieter (**190**). Two peaks with velocities -20 and -50 km s^{-1} are observed near the North pole. Masses and densities of the clouds are less than common ones. The picture in the southern hemisphere is similar, but there are no such definite streams as in the northern one. Some separate clouds with velocities up to -90 km s^{-1} were observed. The width of the lines corresponds to $T \geqslant 150°$, the velocity dispersion is about 2·5 km s^{-1}.

Oort considered several possible interpretations of these phenomena (**191**): motions in the galactic corona, connected with explosions in the disk or with giant associations, the inflow of metagalactic gas into the Galaxy, and so on. However, the flux of the flowing matter should be too high in this case, and we expect a considerable influence of it on the dynamics of the gas in the galactic disk. Moreover, too high density of metagalatic matter is necessary for this explanation. A possible exchange of the gas between different parts of the disk and outbursts of the gas from the galactic layer were discussed. It is difficult to explain the formation of condensed clouds with a high density and fast internal motions. The possibility cannot be excluded that the clouds are near-by and are supernova remnants. But a comparison with the data on Ca II lines speaks in favour of larger distances. Shklovsky supposed that there is a maser-effect in clouds, which increases the black-body radiation on the line frequency.

The inversion of H I atoms population may be created under some conditions with $L\alpha$ line from H II regions near the limits of the disk (**192**). The possibility of such inversion was studied by Varshalovich (**193**).

The distribution of the mass of clouds $\rho(M) \sim M^{-\beta}$ was calculated by Sheffler (**194**) from the distribution of the extinction. He found $\beta \approx 2$ for $M < 5 \times 10^3\ M_{\odot}$ and 1 to 1·5 for $M > 5 \times 10^3\ M_{\odot}$. The mass of a common cloud is 20–30 $M_{\odot}$ and the diameter is about 3 pcs. A general statistical model of clouds and of their transformation on the basis of former ideas by Oort and Spitzer was constructed by Field and Saslaw (**195**). They considered collisions of clouds, their confluence due to dissipative processes, gradual growth of the mass, formation of massive complexes. The appearance of young stars gives H II regions and the expanding shell of H I divided into little clouds run away from the complex. The calculations of the kinetics of this processes gave the spectrum of mass of clouds as $M^{-3/2}$ in agreement with (**194**). Inelastic collisions of clouds were considered also in (**196**) and (**197**). The propagation of the shock wave, heating and cooling of the gas up to the standard external pressure, a possibility of gravitational instability in the compressed region were discussed in the latter paper. Shock waves with emission, were discussed by Kaplan and Klimishin (**198**). They take into account the non-stationary scattering of light and heating of the gas before the front. Numerical calculations of the structure of the waves with the emission in a partly ionized gas were done by Kaplan and Podstrigach (**199**). The structural function of the turbulence was inferred from the analysis of interstellar lines by Kaplan and Klimishin (**200**).

Pikelner discussed general dynamics of clouds in the magnetic field of spiral arms (**201**). Common clouds are supported by the field. They have oscillations across the magnetic lines and the collisions in these directions are elastic. They move rather freely along the lines and the collisions are inelastic. The complexes grow, come down to the galactic plane and collect gas until the beginning of stars formation and flying away of the gas.

The temperature in H I regions used to be determined from saturated emission lines which give the harmonic mean $T \approx 125°$. Shuter and Verschuur (**202**) separated absorption lines 21 cm in the spectrum of radio sources into gaussian components, which they treat as thermal ones. The width of the components gives temperatures of clouds from 25 to 120° and N_H. The calculated harmonic mean temperature for all clouds and for 20% invisible clouds appears to be less than 70°. This value differs from the emission radio temperature, because the main contribution to the absorption gives cold clouds and the contribution to the emission gives, besides cold clouds, also hot clouds and the gas between clouds.

Different harmonic temperatures for emission and absorption lines with some given distribution of H I are obtained also by Marx (**203**). An influence of the cloud structure on the measurements of the temperature and density with 21 cm line was discussed by Rohlfs (**204**). The heating of the rarefied gas between the clouds in the absence of ultraviolet radiation may be performed by superthermal particles from 10 to 100 MeV (**205**).

The radiation field in different parts of the Galaxy was calculated by Zimmermann (**206**) and Kaplan (**207**). The density of the energy is higher in the halo where interstellar absorption is ineffective (**207**). Cooling of interstellar gas was reconsidered by Dalgarno and Rudge (**208**). They take into account excitations of C^+ and Si^+ in collisions with hydrogen atoms followed by spin exchange. The process appears from 3 to 5 times more effective than electronic collisions.

The temperature depends markedly on the presence of H_2 molecules, which cool the gas effectively if $T > 60°$. Cooling is a result of shock collisions 0–2 and spontaneous transition 2–0. Transitions 2–1 and 1–0 have insignificant probability (**209**). Transitions 2–0 give the line 28 μ, which can be principally observed. Its intensity in the galactic plane should be comparable with $B_\nu(50°)$. The possibility of observations of ultraviolet Lyman line H_2 have been discussed by Spitzer, Dressler and Upson (**210**). The curve of growth oscillator strength and equivalent width were calculated when different concentrations of H_2 were present.

Direct observations of H_2 have not been performed yet. The relative deficiency of H I in heavy absorbing clouds speaks in favour of the presence of molecules. For instance, there is relatively few H I in the cloud obscuring 'Omega' (**211**). The other method of evaluation is from the gravitational potential in the disk. Such estimates were done, for instance in (**212**), on the base of the comparison of velocities and Z-distribution of H I clouds and cepheids. The estimates gave for H_2 abundance of 0·8 to H. However. the evolutional effect for cepheids (their age is comparable with the time of motions from the galactic plane) and magnetic forces for clouds were not taken into account.

The origin of H_2 is usually connected with recombinations on the surface of an interstellar dust grain. Atoms are bound with the grain surface by van der Waals forces, i.e. by physical absorption. However in (**212a**) it was shown that due to zero-point energy, physical absorption of H atoms by grains with $T > 8°K$ is negligible. The possibility of chemical absorption is not studied yet.

In this connection the considerably less effective mechanism by Stecher and Williams (**213**) should be discussed. This mechanism is an outflow of H_2 from the atmospheres of cold giants and supergiants with stellar winds.

Very strong interstellar CN lines were revealed in the group of stars situated in the emission nebula (**214**). Propagation of the ionization front in the cloud with a high concentration of dust resulted in the evaporation of grains and dissociation of molecules of the stream. In general, CN lines are observed in complexes abundant with dust. One of the levels of molecule CN is very close to the ground state (the difference of the energy corresponds to 0·254 cm). Shklovsky (215), and Field and Hitchcock (216) pointed out independently that the population of this level is very sensitive to the density of cosmic radiation. The fine structure of CN absorption-line shows that the population of the second level corresponds to the temperature of exciting radiation about 3° (215, 217). This confirms the presence of black-body radiation in the Universe, as all other sources of radiation in interstellar space are much weaker.

OH molecule radio lines of which $\lambda = 18$ cm were revealed in 1963 is especially interesting. Observations of these absorption lines in spectrum of Sag A showed some peculiarities (218, 219). The lines are very strong, wide and displaced relatively to the position, expected from the velocities of hydrogen features. Relative intensities of quadruplets do not correspond to the theoretical values. First, there were attempts to explain this by the effect of saturation (220), but they were not a success. The distribution of OH in the vicinity of the galactic centrum is irregular, there are many clouds with different velocities, which are not in accordance with the velocities from 21 cm line (221).

It was an unexpected discovery that OH is observed in the emission (222) near large H II regions. The lines were very bright, the excitation temperature was more than 9°, i.e. much higher than that far from H II. One component of the quadruplet consisted of several very strong peaks with the width of about 0·4 km s^{-1} that corresponds to an unexpectedly low temperature. Some other components of quadruplet were not observed at all. Similar peculiarities were observed in the Orion Nebula and in others. It was revealed further that the emission in some components is strongly lineary polarized and the value and direction are different for the clouds with different velocities (223). All these properties were confirmed and investigated in detail in many papers (see Draft Report of Commission 40). More than 50% of all investigated H II regions show anomal OH emission. The size of the sources is usually less than 20″ (Burke), several details show almost 100% circular polarization (Barrett).

The interpretation of anormal intensity and of narrows of some components is connected with maser-effect. The excitation of upper levels may be due to ultraviolet emission of the surrounding H II regions (224), with their $L\alpha$ radiation (225a). According to (225) the maser-effect is connected with the infrared radiation of the hot pre-stellar bodies which contain OH molecules inside. Effects of polarization are connected with magnetic field. In different components maser-effect can be different and probably it is effective mainly along the magnetic field, giving circular, but not elliptic polarization (Ginzburg). The details of this process are not clear yet.

There were some attempts to observe the ultraviolet absorption line of OH 3080 Å in the spectrum of O6 star (226). The line was absent and the upper limit of abundence of OH was 9 times less than may be expected from the radio data. Apparently OH is concentrated in small regions which are not projected on the star. Abundance of OH in the interstellar gas is determined mainly by exchange reactions with H_2 and other molecules at temperature of about 1000° connected with shock waves (227).

SUPERNOVAE REMNANTS, MAGNETIC FIELD OF THE GALAXY, DYNAMICS AND ORIGIN OF SPIRAL ARMS

Hogg (237) showed that the radio source IC 443 has a shell-like structure, coinciding with a region of optic brightness. He measured also radio radiation from a great number of other possible remnants of supernovae. Davies (238) investigated a part of a spur, visible from England, and showed that its outer edge is sharp and the spur itself is similar to Cygnus loop by its structure and brightness. Brosche (239) investigated the expanding of a shell of Crab Nebula by proper motions. He confirmed that the motion is accelerated. Heiles (240)

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investigated a shell expanding in interstellar gas. He showed that Shklovskii's automodel solution is true only as long as the temperature behind the front does not fall below 10^7 °K. After this stage the emission of ions O VIII and others becomes essential. However in (**240**) the isothermicity of plasma behind the front is proved incorrectly. In the layers, near to the front, Coulomb interactions cannot establish the equi-partition. The electron temperature should be determined rather by different instabilities. Sheglov (**241**), discovered in NGC 6990 radiation of Fe X with intensity of 3–5 relays, proved experimentally the high electron temperature behind the front in Cygnus Loop.

The influence of the magnetic field of the Galaxy on the expanding shells of supernovae was considered by scientists of the Princeton group (**242, 243**). They considered a case of a strong and weak field – the last one is closer to reality. The field is compressed strongly only near a shell-piston, and in the main part of interstellar gas, compressed by a wave, it is strengthened slightly. The instability of Rayleigh-Taylor takes place near the boundary, it explains the filamentary structure. The Crab Nebula is the most interesting supernova remnant. Here, radio emission is concentrated on the centre and it has not a shell structure. Shklovsky showed that, on the whole, relativistic electrons, but not protons, are generated in it, so such a nebulae cannot be a source of usual cosmic rays (**244**). Both the origin of relativistic particles in remnants and the formation of the magnetic field in it are left to be a problem, because a magnetic flux, for example that of the Crab Nebula, could not be taken from a star or interstellar medium. Kardashov (**245**) supposed that in the period of a stellar collapse a rotating instability occurs, a shell, connected with a star by a magnetic field, is separated, and the fast rotation of the central nucleus winds the lines of force. The rotation is maintained by compression and takes place till now. Observations show that for 10 years the optical polarization of Crab Nebula has half decreased and that the nebula radiation has a component with an elliptic polarization (**247**). A checking of these wonderful results is very desirable.

Westerlund and Mathewson (**248**) discovered in LMC three nebulae – remnants of supernovae of type II. Two of them and many associations are situated in the ring H I by a diameter of about 1 kpc – apparently it is a remnant of an explosion of a massive supernova of the first generation. The third remnant is in the other ring, containing associations and strong non-thermal source. The mass of a large shell is about $3 \times 10^7 M_\odot$, therefore, the original mass is about $10^5 M_\odot$, the age is about 3 million years with medium density of 1 cm^{-3}. Apparently, a series of superexplosions results in conditions for the formation of associations and individual stars.

The interstellar polarization gives one of the methods of the investigation of the magnetic field. Martel (**249**) investigated a dependence of the polarization on a wavelength. Studying a correlation with the galactic longitude, Lodén (**250**) investigated in great detail the polarization of accidentally selected stars in 19 regions of the sky. Serkowski (**251, 252**) determined a dependence of the polarization on longitude and investigated in detail a region including a cluster and association of Cyg VI. Dombrovski (**253**) found a region of homogeneous polarization in a district of the cluster NGC 1502. Pronik (**254**) compared the polarization with both the velocities of Ca II and the shape of dark nebulae. The field turned to be very irregular, often directed differently above and under the galactic plane, and in some parts it was not parallel to the galactic plane and not directed along the arms. Visvanathan (**255**) investigated 30 stars in LMC. The maximal polarization is $0\overset{m}{.}068$; $(p/A_v)_{max} = 0.07$ on the average all over a cloud. The polarization plane does not change in large regions. On the average, lines of force are parallel to the plane and to the structure of the nebula, forming a very flat disk. Zwicky (**256**) found in M 82 three types of polarization – common, along a plane, radial around some luminous spots and directed along filaments and light band, thrown out by an explosion.

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The polarization of non-thermal radiation gives information on a magnetic field of the Galaxy. Mathewson and Milne (**257**) found that regions of high polarization of radiophone coincide with that of weak Faraday rotation for distant radio sources, it is naturally explained by low depolarization on these places. They found that the direction of polarization, as a rule, lies in a band with width of 60° relative to a big circle, passing through galactic poles and the equator point with $l = 160°$. It has been confirmed in (**258**) and indicates the presence of a sufficiently homogeneous field in the arm.

The rotation of a polarization plane of extragalactic sources takes place, as it has been shown before, in the Galaxy, and the field is parallel to the galactic plane (**259**). However, the field structure is compound and does not correspond to a simple picture of a tube of parallel lines of force. However, the authors did not divide north and south latitudes, where a rotation has a different sign. Indeed, Morris and Berge (**260**) showed that the rotation is carried out by lines of force, which are parallel in a middle of the arm, but have an opposite direction in the northern and southern hemispheres. Moreover, RM is 1·5 to 2 times as much in the S hemisphere than in the N. Gardner and Davies (**261**) made these results more precise and found that there is a third narrow region along the equator where the rotation is especially strong and has one sign.

Bologna and others (**262**) investigated the depolarization of extragalactic sources. The polarization increases towards the equator and, therefore, it is determined by the Galaxy. The depolarization grows with the increase of an angular dimension of the source. These phenomena can be in principle explained if fluctuations which are less than 0·3 pcs and with $N_e\tilde{H} \approx 3 \times 10^6$ are superimposed on the general field. Maltby arrives at smaller dimensions (0·1 pcs) and expresses his doubt that the depolarization is in the Galaxy (**263**). Such a doubt is expressed in (**259**), too.

Measurements of Zeeman's effect in 21 cm line (**264, 265, 266**) gave $B \leqslant (5\text{–}7 \times 10^{-6}$ G in the cloud, but this result depended on the adopted direction of the complete vector $\boldsymbol{B}$.

The obtained data of observations do not yet allow to construct a picture of the field, but they exclude some simple models proposed before. Stępień (**267**) and Hornby (**268**) consider that observations are presented best by lines of force which form (inside the arm) a spiral, stretched by the differential rotation, thus the plane of spires form with an axis of the arm an acute angle. Woltjer (**269**) considered the field as consisting of weak quasi-homogeneous (B later 5×10^{-6} G) (Symposium no. 31), on which the strong chaotic field are superimposed. The lines of force of this field are parallel to the axis of the arm, but changing the sign at a distance of about 0·1 pcs. This little scale is necessary for the explanation of a regular distribution of the rotation measure with the position on the sky. It is supposed that the field has no dynamic meaning on the gas. Using this picture, Wentzel (**270**) applied Petchek's mechanism to the interstellar gas—the compression of gas between the regions of the opposite fields and ejection of compact clouds from there. However Pikelner (**201**) points out a number of dynamic difficulties in the picture of the strong irregular field. Besides that, the explanation of the rotation of the polarization plane in the presence of small irregularities needs improbably high electronic concentration, if gas is neutral in the main. As a whole, the problem should be additionally investigated—both by observation and theoretically.

The problem of the origin and existence of spiral arms is of great interest. The gravitation theory is widely used. Small disturbances in the gas of gravitating stars are considered (**271**). The density fluctuations propagate as a heavy sound. The field of these fluctuations attracts stars with low velocity dispersion and the gas fluctuations can have a spiral form under certain conditions.

By the gas compression the field in it takes a prolonged orientation. The arms are not wound, because perturbations move relative to stars. The investigation of perturbations in a rotating disk, its stability, axis-symmetric oscillations was carried out in many papers (**272,**

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273, 274, 275, 276). The gas flows into the arm on the one side, on the back one it flows out. True, it is not proved yet whether this process could take place in the non-linear approximation, when the gas density is comparable to or exceeds the stellar density of the background. The decay and formation of arms and indirect influence of the field on the relaxation of star velocities in linear approximation are considered in (277, 278). Pikelner (138) considered another model, where the field has a definite dynamic role. It explains the thickness of arms in different galaxies and at different distances from the centres, allows to understand the opposite direction of lines of force and explain a number of other peculiarities. However, this theory, as others, which consider the arm as a conservative formation, cannot explain a persistence of the spiral shape. Probably, there should be a synthesis of both points of view, where the field plays an essential dynamic role, but the gas flows through the arm. Richter and Wallis (279) supposed that, in the Galaxy, the gas forms rings, not spread out by the differential rotation, and arms are formed by crossing these rings with fronts of shock waves, originated from explosions in the centre.

Now the formation of the field of arms is usually connected with a condensation of metagalactic field together with the gas when forming of the Galaxy. Piddington (280) showed that the strength of the magnetic field in the disk depends considerably on the relative orientation of the primary field and rotation axis.

Barred spirals are also considered within the limits of the gravitating theory (281, 282, 283), the angular momentum of individual stars is not constant in this scheme because of the attraction of a bar, and streams in the outer directions appear. However, the stability of the system is not proved and, in general, the whole scheme needs artificial suppositions and special initial conditions. Pikelner (284) supposed that in SB, especially in SBc, there is an almost homogeneous sphere of old stars, in the field of which the rotation is rigid body. Such a sphere is formed as the result of the explosion which has taken place in the Galaxy at the very early stage of its formation. Streams along the bar, condensations on its ends, the transition of the bar into spiral arms, etc. are explained within the limits of this scheme.

The accretion of intergalactic gas, flowing into the Galaxy and winding can form in principle a spiral arm (285). However, this hardly explains the symmetry and regular structure of the arms.

The formation of bridges between interacting galaxies and tails is discussed in (284, 286, 287). Zasov (288) supposed that intergalactic gas flows to bridges, penetrates into them and then falls to galaxies. The statistics of distortions of gaseous layers of galaxies (it is often in small close groups) are given in (288).

THE INTERACTION OF THE GAS WITH COSMIC RAYS. INTERGALACTIC GAS, GAS IN QUASI-STELLAR SOURCES

The interaction of cosmic rays with interstellar medium becomes apparent not only in nuclear collisions and in collisions with moving magnetizing clouds, but also in the interaction with plasma waves which should always be present in the gas with microscopic motions. It was investigated in detail for different conditions by Tsitovitch (see a review (289)), a possibility of the acceleration of relativistic particles was determined. Ginzburg (289a) showed that the interaction with plasma waves explained the isotropy of cosmic rays. Parker (290) supposed that the formation of the galactic corona can be connected with the instability of the gas with the field, retaining cosmic rays.

The existence of the metagalactic gas is inferred sometimes from cosmological considerations, according to the value of critical density, necessary for the noticeable slow-down of the metagalaxy expansion. However, such a slow-down has only been proved indefinitely so far, that is why direct observations of the gas is very important. Kowal (291) has discovered dark spots on the background of three galaxies, but they are smaller than galaxies and in two cases they are connected with the galactic structure, that is why they cannot be considered as metagalactic. Gunn and Peterson (**292**) investigated a weak depression in the spectrum of the distant quasars 3C 9 beginning from $L\alpha$. It corresponds to $n_{\mathrm{H}} \approx 6 \times 10^{-11}\,\mathrm{cm}^{-3}$ at this distance, it is considerably smaller than the critical density even taking into consideration the ionization when $T = 2 \times 10^{6}$. However, such an estimate depends strongly on the extrapolation of the continuous spectrum, and the latest data indicate that absorption is somewhat smaller. Bahcall and Salpeter (**293**) indicated that if gas is concentrated in clusters, lines but not depressions should be in the spectrum of quasars. The absence of H_2 1108 Å line means that the abundance of molecular hydrogen is small and, apparently, the intergalactic gas is ionized completely. The absence of H_2 is shown in (**294**), too. The low concentration of atomic hydrogen follows also from measurements of 21 cm line from Cyg A and Vir A—$\tau < 0{\cdot}001$ and $0{\cdot}02$ correspondingly. In the second case it means that hydrogen does not absorb also in this galaxy itself—the spin temperature is high because of the strong radiation and the gas is transparent (**295**).

The ionization of hydrogen can be connected only with high kinetic temperature. The temperature conditions of metagalactic hydrogen was discussed by Ginzburg and Ozernoy (**296**). They took into account the emission of hydrogen and cooling due to the general expanding of gas, not being a part of clusters of galaxies. Heating is produced by cosmic and sub-cosmic rays, the existence of which is probable in the rarefied gas. Explosions of radiogalaxies give the directed streams of relativistic particles, which generate plasma waves, heating the gas. This mechanism is especially effective in clusters. In the result of it the temperature in a cluster depends on the history of the given gas, and between the clusters the temperature, apparently, is about 10^{5} or somewhat higher. A similar calculation, taking into account helium, but without the general expanding, was carried out by Gould and Ramsay (**297**). The upper limit of the temperature of the intergalactic gas when $n \approx 10^{-5}\,\mathrm{cm}^{-3}$ is determined by the absence of the noticeable background of X-rays. Different mechanisms of production of X- and γ rays in the Galaxy and Metagalaxy are discussed by Ginzburg and Syrovatski (**298**), Tucker and Gold (**299**) (see in detail Commission 44). Modern measurements of X-rays give the upper limit of $T < 3 \times 10^{6}$ (**300**). The absence of the background of X-radiation shows also that the quantity of relativistic electrons is considerably smaller in the Metagalaxy than in the Galaxy, otherwise there should be a strong inverse Compton-effect for photons of the relict black-body radiation (**301**). This fact and the existence of black-body radiation itself, exclude steady state cosmology.

Black-body radiation was discovered at centimeter waves in 1965 (**302, 303**). Its spectrum and the energy density correspond to $T = 3°\mathrm{K}$. It is a remnant of the black-body radiation of high temperature at the initial period of the Universe expansion (**304**). From the theory of the hot Universe it follows, that about 10% of He atoms should be in the primordial gas. The possibility of observations of He^{3} in metagalactic and interstellar gas is discussed by Sunyayev (**305**).

Emission lines of different ions are observed in quasars (**306, 307, 308, 309**). The analysis shows that it is a shell with a standard chemical composition and possible filamentary structure, surrounding the nucleus of quasars and expanding with the velocity of about $1000\,\mathrm{km\,s^{-1}}$. Both the conditions of ionization and excitation and the gas temperature are studied, but here there are yet many indefinite parameters (**310, 211, 312, 313**), in particular, conditions of excitation. The ultra-violet part of the spectrum of synchroton radiation is calculated on the basis of the optic part by Greenstein (**314**). The absorption lines of expanding shells are observed in some quasars (**315, 316**).

Dibai, Pronik, Esipov carried out the spectrophotometry of nuclei of Seyfert galaxies with strong emission lines, calculated physical conditions in gas, discussed the probable mechanisms

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of excitation (**317, 318, 319**). Besides that, they analysed spectra of quasi-stellar sources (**320, 321**), estimated the mass of the gas.

GRAVITATIONAL CONDENSATION, FORMATION OF STARS AND GALAXIES

The general theoretical consideration of the gravitational instability of the non-uniform medium was carried out by Ozernoy (**322**) and Simon (**323**). The influence of the magnetic field, when the compression occurs along lines of force or independently, is estimated in (**324**). In the first case the critical mass is two times less. The thermal condition during a protostar compression, escape of energy in H_2 lines, the role of H_2 dissociation are considered by Gould (**325**). When $n < 100\ \text{cm}^{-3}$ and $T \approx 100°$ compression turns into free fall, in spite of the possible heating by fast particles and turbulence (**325**). When $n > 100\ \text{cm}^{-3}$ superelastic collisions decrease cooling and compression becomes slower, turning into oscillations (**326**). McNally (**327**) took into consideration that the centre of a cloud (from which a cluster forms) is more dense. It cools quicker, that is why a compression occurs there also quicker and a dense nucleus forms. In protoclusters with $M < 10^4 M_\odot$ the central temperature is only about 100°, cooling occurs slower, and no nucleus forms.

The thermal instability is possible on scales smaller than the critical Jeans' length. Field (**328**) takes into account the sound velocity, heat conductivity, magnetic field, rotation, external gravitational field; and Hunter, the gravitation of fluctuations themselves (**329**). Such an instability can give condensations in nebulae, the solar corona and partly facilitate the formation of galaxies. But it is effective only in special conditions, that is why its role in the formation of stars and galaxies is hardly considerable. Condensations in nebulae are also formes not due to thermal instability (**330**).

The compression of a cloud, when there is an external pressure, can be not quasistatic, but with the formation of a cumulative shock wave, forming a region of high pressure in the centre of a cloud (**331**). It facilitates the stellar formation in the centres of globules, submerged into nebulae. The formation of pre-stellar bodies in a cloud, compressed by a shock wave, is calculated also by Kossatsky (**332**).

Massive clouds fragments during compression. This process was considered on a simple model when $p = 0$ for different types of disturbances (**333**). The statistics of fragments according to masses allow to explain the function of stellar masses (besides massive stars) in clusters (**334**). The integration of fragments is taken into consideration in (**335**).

Grzedzielski (**336**) examined the fragmentation of protogalaxy with large dispersion of internal velocities. Besides the condensation of globules, the appearance of young stars in old clusters can be connected with the accretion of gas by stars (**337**). Earlier, this idea was expressed by Lebedinsky. As the result of condensation of globules or accretion non-stationary red dwarfs and Herbig-Haro objects are formed with small mass. Schatzman and Magnan (**338**) supposed that the excitation of these objects is produced by protons of high energy and Lortet-Zuckermann estimated the emission of the interstellar matter in the neighbourhood of flare stars (**339**).

The dense stellar nuclei of galaxies lose stars and compress until the collisions of stars would be essential (**340, 341**). The gas appears, it compresses in a thin disk, and stars form again (**342**). This may result in a marked luminosity increase.

A number of review papers, covering the investigations of Japanese scientists in this field (carried out in the main till 1964) is included in the collection 'The structure and evolution of galaxies'. The evolution of galaxies, radiogalaxy, the formation of spiral arms and dynamic model of barred galaxies, explosions of galactic nuclei, the stability of spiral arms are included in this review.

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Lynden-Bell (**343**) considered the large-scale instabilities, appearing during the collapse of the rotating self-gravitating spheroid without internal pressure. The formation of the bar distributed along the diameter is possible in this process. From the other point of view the formation of bar and spiral arms can also be connected with the fact that the gravitating condensation compresses the field at first in the central, more dense, nucleus, and magnetic forces give the initial disturbance and stimulate the condensation of the gas situated along the tube of lines of force (**138, 284**).

The discovery of the black-body relict radiation allows to make a considerable progress in the understanding of the early stage of the formation of galactic clusters.

The conception of Jeans' instability raises a question on the initial equilibrium state, which could not be the state one. Peebles showed that in the hot expanding Universe the gas was connected at first with the radiation by way of a friction. Condensations could not compress because the radiation pressure prevented it (**344**). Osernoy (**345**) considered in detail the development of these instabilities, their temperature condition, the radiation output in the period of gas-recombination, the influence of different mechanisms of heating and cooling of the gas at different stages of the compression and fragmentation. Zeldovich, Novikov and Doroshkevich (**346, 347**) investigating the same problem, have shown that during the gas-recombinations the density is still so large that fragments with $M \approx 10^5 M_{\odot}$ are formed, i.e. still not clusters of galaxies. The energy resulting from the condensation of the first fragments, which may be quasars, heats the gas and prevents the condensation of other fragments. This energy creates conditions when the large masses of the galactic clusters type can be condensed.

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INTERSTELLAR GRAINS AND RELATED TOPICS

(prepared by J. Mayo Greenberg)

Diffuse Nebulae

A. Elvius and J. S. Hall have made observation of the color and polarization of the reflection nebulae NGC 2068, NGC 7023 and the Merope nebula in three spectral regions (**1, 2**). The polarization was found always to increase with wavelength and its direction was usually radial with respect to the illuminating star except in the region south of Merope where the polarization tended to follow the filamentary structure. The colors of the nebulae NGC 2068 and NGC 7023 were bluer than the (reddened) light of the illuminating stars. For Merope the color of the nebula was found to increase with distance from Merope. O'Dell (**3**) and Roark and Greenberg (**4, 5**) have reported on observations on Merope and have confirmed that the nebula is bluer than the star and that it becomes redder with increasing distance from the star. A preliminary analysis by O'Dell (**3**) indicated that the nebular particles are not small metallic or dielectric ones. Greenberg and Roark (**4, 5**) using a more detailed analysis found that the nebular particles are probably intermediate sized dielectric grain, perhaps slightly larger than the average of those which give rise to interstellar extinction. Greenberg and Roark found that the density of grains in Merope is at least ten times greater than in a standard interstellar cloud and one thousand times greater than in the average interstellar medium.

Dorschner and Gürtler (**6**) have made a statistical analysis of 196 reflection nebulae on the charts of the Palomar Sky Survey. They consider a possible cosmogonic relation between stars and dust clouds.

Minin (**7**) considered spherically symmetric cloud models and by comparing theoretical with observational results on polarization and brightness for several nebula concluded that if the scattering particles are dielectric they are smaller than $a = 0{\cdot}07$ micron.

Vanysek (9) made photoelectric measurements of NGC 7023 including the ultraviolet region. By comparing his observations and those of others with a theoretical spherical cloud model he found that the scattering particles are slightly larger than those commonly used to account for the interstellar extinction. The observations show the blue color of the nebula returning to the star color (becoming redder) at increasing distances from the star.

R. C. Hall (10) has also found this color variation in Hubble's Variable Nebula NGC 2261 and has shown from polarization measurements of the wavelength dependence that the light of NGC 2261 is due to a reflection process rather than to synchrotron emission.

A number of investigations of dust in H II region have been made. O'Dell and Hubbard (11) have observed the strength and energy distribution of the continuous radiation of the Orion nebula and corrected for the expected atomic component. The effective gas-to-dust ratio appeared to decrease sharply in the outer regions. Possible interpretation based on effects of radiation pressure on and evaporation of grains have been discussed. Further analyses of the physical interactions of the dust in H II regions have been made (12, 13, 14). The possibility of accounting for the anomalous reddening law in the Trapezium have been examined. It has been shown by Greenberg (15) that no minor modification of normal size distribution of dielectric grain can account for this anomaly. It has been shown that the grains must be about ten times larger than the average in interstellar space.

Gürtler (16) has estimated the value of the albedo and its wavelength dependence for the contribution to the nebular continuum in the Orion nebula by the scattering off dust particles.

Dorschner (17) has compared sizes of reflection nebulae around B stars with the expected radii of H II regions and finds a discrepancy with the radii of the Strömgren spheres.

Ahmed, Lawrence and Reddish (18) examined the nebulosity in the Pleiades and found evidence for wavelength independent absorbing matter.

Boyce (19) showed that ignoring effect of interstellar reddening in the Orion nebula can lead to anomalous results.

Extinction and the Distribution of Interstellar Grains

Some very interesting results have been obtained on extinction in the infrared (20, 21, 22, 23, 24). The review articles by Johnson (20, 21) cover a wide range of observations. The most peculiar extinction curves appear to be for φ Persei and for α Leonis the latter showing gray extinction from the far infrared out to the near ultraviolet. For many stars there is a sharp rise in the extinction up to the M color and what may be referred to as a knee in the extinction curve in the infrared. Comparison of extinction made by variable-extinction methods, cluster diameters methods and the color-differences method was made. Johnson (22) and Johnson and Mendoza (23) found essential agreement between the color-difference method determination of $R = A_V/E_{B-V} > 3$ for M type supergiants and the cluster diameter value of $R = 5{\cdot}6$ in Perseus. Similar agreement has been found in Cepheus. In any case a wide variety of values of R have been obtained with a value of $R = 3$ appearing to be an approximate lower bound. Further discussion of this question of the variability of extinction laws in the giving rise to values of R from 3 (in most regions) to 7 (in the Orion nebula region) has been given by Borgman (24).

Observations of interstellar reddening in Cygnus and Perseus have been made by Nandy (25, 26, 27). The results are based on spectrophotometric measurements of O and early B type stars using spectra taken with the Schmidt telescope of the Royal Observatory in conjunction with an objective prism. In both regions the mean reddening curve can be represented by two straight lines which intersect near λ 4300 Å but the ratio of the slope of the ultraviolet part is smaller by 30% in Perseus than that in Cygnus. Schalén (28) discussed the method of using spectrophotometric measurements of objective prism plates for making detailed studies of the wavelength dependence of interstellar absorption.

Underhill and Walker (**29**) compared the measured spectral intensity distribution for O stars with those from model atmosphere calculations and found that the mean extinction curve showed a slope discontinuity at $\lambda\, 4445$ Å.

Whiteoak (**30**) used a photoelectric spectrum scanner to find wavelength dependence of extinction at 30 wavelengths in the spectral region $3448\,\text{Å} \leqslant \lambda \leqq 10\,500\,\text{Å}$. Stars in Perseus, Monoceros, Cygnus and Cepheus were investigated. Perseus and Cepheus are similar. Stars inside and outside the Orion nebula give the usual difference in reddening. Monoceros lies between Orion and the others. No correlation of variation with galactic structure was found.

Guthrie and Nandy (**31**) combine their extinction results with those of Mendoza (**32**) to arrive at a mean extinction law in the Pleiades, similar to that in Cygnus. They found a value of $R = 3{\cdot}3$ as against the value $R = 4{\cdot}2$ given by Mendoza. In any case the value of R is greater than the average as might be expected in the regions of hot stars.

Wampler (**33**) discussed the curvature (or lack of curvature) of the reddening line in the *UBV* color-color plot.

Becker (**34**) showed that in studying the color magnitude diagrams of clusters and associations the value of $R = A/E_{(B-V)}$ is increased by including nonphysical members. Becker showed that this spuriously large value of R is produced by the distance effect in the reddening of field stars and that statistical methods may be used to distinguish nonphysical members which affect the scatter in R.

Krzeminski and Serkowski (**35**) applied the variable extinction method to members of the cluster Stock 2 and obtained the ratio of total to selective extinction $R = A_V/E_{(B-V)} = 3{\cdot}4 \pm 0{\cdot}1$.

Lodén (**36**) has estimated the value of $R = 3{\cdot}9 = A_V/E_{(B-V)}$ in the region of the association Pup I.

Neckel (**37, 38**) using the galaxy count method found a value of $R = A_V/E_{(B-V)} = 4$ and indicated the possibility that there may be an appreciable amount of neutral absorbing material at high galactic latitudes whose relative abundance perhaps increases with increasing distance from the galactic plane.

Glushneva (**39**) showed by spectrophotometry of the pair ϵ Per and ρ Per out to $\lambda = 3000$ Å that the absorption follows a λ^{-1} law and does not begin to bend over as indicated by Stebbins and Whitford.

Boggess and Borgman (**40**) extended the extinction measurements to the wavelength bands centered at 2600 and 2200 Å. The extinction continues to rise more or less linearly out to the farthest measurement.

Stecher (**41, 42**) observed extinction in the far ultraviolet out to $\lambda = 1200$ Å and found not only the generally tendency to increasing extinction with decreasing wavelength but also a possible detailed hump-like feature at $\lambda^{-1} = 4{\cdot}4\,\mu^{-1}$.

Oja (**43, 44**) has made spectrophotometric studies of over 2500 stars in the area $80° < l^{\rm I} < 100° \,|\, b^{\rm I} \,| < 3°$. The absorbing clouds appear to concentrate in the spiral arms ('0' and '+ I') i.e., concentrated within distances less than 1 kpc and some near 3 kpc respectively. Diameters of some clouds near the Sun have been estimated to have 40 pc diameter. Stars brighter than $m_{\rm pg} = 14$ in a one-degree field in Cassiopeia are under investigation (**44**).

Ekedahl (**45**) found a dust cloud with a fairly sharp border in Kapteyn Selected Area 4. Absorption is 0·4 magnitude in V at 400 pc with no significant absorption outside the cloud. T. Elvius has studied the distribution of stars and interstellar dust clouds in a Milky Way field around the cluster NGC 7654.

Ljunggren (**46, 47**) found no continuous absorbing layer toward the North Galactic Pole. The photoelectric and spectrophotometric investigation showed interstellar reddening to set in at a distance of about 200–250 pc with average absorption in the layer of about 0·4 magnitude in *V*. Sjögren (**48**) has investigated absorption in Sel. Area 8 ($l^{II} = 125°$, $b^{II} = -2°$) and has discussed available polarization data in this area. Absorbing matter near the South Galactic Pole is being investigated by P. I. Erikson.

Scheffler (**49**) derived frequency distributions for color excesses of stars with $|z| < 75$ pc and six distance intervals from data on 4700 stars. For distance less than 1·3 kpc, he obtained statistically = 5 clouds/kpc. From 1·3 to 4 kpc the average absorption (in $l^{II} = 160° \ldots 360° \ldots 20°$) was only about one fifth that for $r < 1{\cdot}3$ kpc.

From data of about 4700 stars and galactic clusters Neckel (**50**) has derived a spatial distribution of absorbing matter. It was shown that for $150° \leqslant l^{II} \leqslant 330°$ the absorption is generally smaller than in the remaining Milky Way. Within the galactic plane the dust is concentrated in clouds ranging from 100 to 1000 pc in diameter. Neckel derives an absorption layer of about $\beta = 40$ pc. Elsässer, Neckel and Scheffler (**51**) have reinvestigated insterstellar reddening and its relationship to spiral structure and disagree with conclusions of Isserstedt and Schmidt-Kaler (**52**).

Straizys (**53**) has found that narrow band magnitudes at 4000 Å and 4500 Å are indispensable in two-index diagrams for a single valued determination of interstellar absorption for the whole range of spectral types.

Grigor'eva (**54**) showed that absorption in the brighter portion of the region $117° \leqslant l^{II} < 124°$ varies between $1^m\!.7$ for 1700 pc to $2^m\!.4$ for 4500 pc and in the darker portion from $2^m\!.6$ to $3^m\!.2$. The study was based on 2816 O–B stars investigated by Brodskoya and Grigor'eva.

Herzog (**55**) has found in the Palomar Sky Survey plates three cases for direct measurement of absorption in intergalactic bridges.

Gosachinskii (**56**) showed that the dense cloud obscuring much of the Omega Nebula (HGC 6618) is associated with a reduced density of neutral hydrogen atoms as inferred from observations of the 21 cm line in absorption. Schmidt (**57**) has studied the correlation between dust and gas in Andromeda.

The problem of correlation of gas and dust is complicated by the possible existence of undetectable molecules which may form on interstellar grains. The H_2 molecule and its formation on grains has therefore come under investigation. K. H. Schmidt (**58**) has found the probability of formation of H_2 molecules on dielectric grains to be sufficiently large that the indicated percentage of interstellar molecular hydrogen is as much as 80%. On the other hand Knaap, van den Meijdenberg, Beenakker and van de Hulst (**59, 60**) showed that at grain temperatures above 8°K the chance of simultaneous presence of two adsorbed H atoms on the grain is too small for efficient recombination. Stecher and Williams (**61**) have applied the theory of chemical reaction between gas atoms and dust atoms. Rates of formation and destruction of molecules on graphite flake grains are discussed for varying conditions in the interstellar medium.

Polarization and Galactic Magnetic Field Structure

Behr (**62**) found that the color dependence of polarization is not uniform in all parts of the sky. A weak dependence upon galactic longitude may be indicated however a better correlation can be found if the angle between the line of sight and the lines of the magnetic field (assuming Davis-Greenstein mechanism) is regarded.

Serkowski (**63**) found that the ratio of polarization in the yellow to that in the blue is generally greater than one. The smallest ratio of yellow to blue polarization was observed for the association VI Cygni and for the Star 55 Cygni both situated in the region of anomalous reddening in Cygnus. An attempt to associate both of these effects with grain size or character is natural. Correlation between polarization and reddening was found for cluster M 25 and

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for the association VI Cygni. For the stars observed the degree of polarization ellipticity was less than 0·05%. Serkowski, Chojnacki and Rucinski (**64**) found a correlation between the ratio of yellow to blue polarization with the ratio of total of selective extinction. Higher values of P_V/P_B are associated with increasing values of $A_V/E_{(B-V)}$. Krzeminski and Serkowski (**35**) find no correlation of polarization with reddening in the cluster Stock 2. The microscale 0·3 pc was found for the fluctuations in the polarizing medium.

Gehrels and Meltzer (**65**) made measures of the wavelength dependence of polarization of eight stars. Coyne and Gehrels (**66**) observed the wavelength dependence of polarization of 18 stars for seven wavelengths between $1{\cdot}05\mu \leqslant \lambda^{-1} \leqslant 3{\cdot}04\ \mu^{-1}$. The results conclusively indicate a lack of uniformity in the wavelength dependence of polarization, and a correlation with variability of the reddening curve. An overall average of this data has been made by Greenberg (**15**) and shown to be almost identical with that of Visvanathan (**67**) and furthermore both give a maximum at $\lambda^{-1} \simeq 2\ \mu^{-1}$. Coyne and Gehrels noted that variability of polarization position angle with wavelength. Visvanathan found no general distinction between polarization in H I and H II regions.

Gehrels and Silvester (**68**) found ten stars showing an appreciable wavelength dependence of position angles. These stars are mostly at distances greater than 0·6 kpc.

Lodén (**69**), by means of the polarization parameters of the stars of highest polarization in 19 sample fields, has studied correlation between polarization parameters and galactic coordinates. A first impression was that the degree of polarization statistically depends more upon the distance to the stars than upon any other parameter. The polarization has a flat maximum within the visual region.

Visvanathan (**70**) has observed polarization for 30 stars in the large Magellanic Cloud. The maximum value of P/A_V was found to be 0·07 and the average of P/A_V was 0·05 indicating a high degree of ordering and also that the cloud is seen nearly face on. Polarization alignment was uniform over distances of the order of kiloparsecs and seemed to be related to the cloud structure.

Pronik (**71**) analyzed polarization of starlight, the motions of interstellar Ca II clouds and Milky Way photographs and showed that these all indicate an irregular galactic magnetic field in the solar neighborhood.

Appenzeller (**72**) has made polarization measures for 320 stars in Cygnus and Orion. A system of 20 polarimetric standard stars was established. Using polarization measures Appenzeller (**73**) found the magnetic field in Cygnus to be rather uniform and parallel to the galactic plane and to $l = 45°$. In Orion aggregate about 140 pc below the plane the magnetic field is almost perpendicular to the plane.

Serkowski (**74**) found that the Mira variables have intrinsic polarization whose values are always greater in ultraviolet than in the blue and yellow spectral regions. For several stars the position angle is different in each spectral region, changing gradually from yellow to ultraviolet.

Theories of Interstellar Grains and Interpretations of Extinction and Polarization

The physical, chemical and optical properties of interstellar grains have received active attention and a wide range of detailed calculations have been made.

The problem of the source of nuclei upon which grains may grow has been considered by Kamijo (**75**) who calculated the rate of growth and ejection of small icy (mainly SiO_2) particles formed in the circumstellar space of M giant stars.

Friedemann and Schmidt (**76**) have reinvestigated the work of Hoyle and Wickramasinghe on the evolution of graphite particles in the atmospheres of carbon stars. They estimate that particles of some 10^{-6} cm are or are not able to escape in a time equal to the mean period of variation depending on whether the accommodation coefficient for carbon atoms is greater or less than 10^{-3}. Donn, Wickramasinghe, Hudson, and Stecher (**77**) have re-examined the Hoyle-Wickramasinghe mechanism for condensation of graphite in N stars. The formation of graphite in amorphous polycrystalline, needle, and plate shapes was considered. It is of interest to note in this connection that Mendoza and Johnson (**78**) assume that carbon stars are not affected by interstellar extinction because of their position in the galaxy with respect to the B and A stars observed by Eggen.

The growth and destruction of ice mantles on interstellar graphite grains has been calculated by Wickramasinghe (**79, 80**) who showed that the process of sputtering by the gas atoms in a heated cloud is to be considered as the principal destruction mechanism.

Light scattering and extinction by graphite spheres using Mie theory has been calculated for a wide variety of sizes and for various postulated optical properties of graphite (**80, 81, 82, 83, 84, 15, 85**). Nandy and Wickramasinghe (**86**) have shown that calculated extinction by graphite spheres (**84**) with radii $0{\cdot}05 - 0{\cdot}07\mu$ yield good fits with the observed reddening in Cygnus and Perseus. Lenham and Treherne (**87**) have experimentally obtained somewhat different optical constants for graphite than have been used in most of the scattering calculations.

In view of the unlikelihood that pure graphite grains could exist indefinitely in space, model calculations of grain consisting of graphite cores with dielectric mantles have been made. Various observed extinction curves have been matched in varying degrees of precision using spherical graphite core-ice mantle grains by Greenberg (**8**), Wickramasinghe, Dharmawardhana and Wyld (**88**). Wickramasinghe (**79**), Schalén (**89, 90**). Schalén (**90**) and Greenberg (**15**) have also considered metallic iron cores. Stecher and Donn (**91**) have indicated a possible connection between detailed structure of the extinction in the ultraviolet at $\lambda^{-1} = 4{\cdot}4\mu^{-1}$ with graphite optical properties.

The polarization of small graphite flakes has been shown by Greenberg (**92**) to follow a λ^{-1} law rather than have a flat maximum in the visual. Subsequent approximate calculations on larger oblate spheroidal graphite grains by Wickramasinghe, Donn, Stecher and Williams (**93**), by Wickramasinghe (**94**) and by Wickramasinghe and Krishna Swamy (**95**) on dielectric coated graphite platelets indicate a decrease of polarization toward shorter wavelengths. In the former paper (**93**), it is assumed that the small graphite interstellar particles tend to be spherical and that mainly the larger ones are formed as platelets. Consequently the extinction is due mainly to the small particles and the polarization to the larger ones which now require a high degree of orientation and a field of 10^{-5} gauss. The coated graphite grains (**94, 95**) have been shown by Greenberg (**96**) to require fields considerably in excess of $B = 10^{-5}$ gauss assuming that the approximate extinction values in (**95**) are correct.

The estimates of magnetic field strengths required to orient the interstellar grains have been improved on in an interesting extension of the Davis-Greenstein theory by Spitzer and Jones (**97**).

Wickramasinghe, Ray and Wyld (**98**) considered the effects of radius independent destruction mechanism on ice grains and showed that dielectric spherical grains could not account for the observed high ultraviolet extinction.

Danielson, Woolf and Gaustad (**99**) in looking for a strong ice absorption band in the infrared at $3{\cdot}1\mu$ have suggested an upper limit of $1/4$ of the interstellar extinction being due to H_2O ice.

Field, Partridge and Sobel (**100**) have considered the effects of absorption spectra of solid methane, ammonia and water ice on the ultraviolet extinction by various sized spherical ice grains.

Aivazyan (**101**) has developed an approximation for computing extinction by spherical interstellar particles having a small absorptivity and real values of m in the range $1{\cdot}15 < m < 1{\cdot}50$.

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Pronik (102) has considered a range of causes of variation in the reddening law and has found that the more dense dust clouds consist, on the average, of larger particles.

The development by Lind and Greenberg (103) of a procedure for calculating the scattering by arbitrarily oriented long cylindrical particles of any given sizes and optical properties has been applied to calculation of the polarization and extinction by elongated dielectric grains. The microwave analog method has been shown by Lind, Wang and Greenberg (104) and by Greenberg, Lind, Wang and Libelo (105) to be capable of producing almost complete and very accurate information on extinction by arbitrarily oriented particles. A wide range of microwave experimental data has been accumulated for both elongated and for flat particles (15). Greenberg and Shah (106, 107) have used perfect Davis-Greenstein orientation of cylindrical dielectric particles to calculate simultaneous reddening and wavelength dependence of polarization. More realistically oriented cylindrical particles have been considered by Greenberg (96) to determine both the wavelength dependence of polarization and extinction as a function of the strength of the orienting magnetic field. It was shown that a field of 10^{-5} gauss is required to produce a reasonable ratio of polarization to extinction. Effects of magnetic field tangling (partial disordering of field lines) were also considered. Extensive computation of polarization and extinction by varying size distribution, optical properties, and degrees of orientation of cylindrical particles have been performed (15) and good agreement has been simultaneously found for the extinction as observed out to the ultraviolet and for the average of the wavelength dependence of polarization observed by Gehrel and Visvanathan. Earlier calculations (8, 108) on two and three parameter size distribution of spherical dielectric particles produced too small extinction in the ultraviolet.

Stein (109) has examined the possibility of detecting infrared radiation at wavelengths greater than 10 microns and from a study of its spectral distribution obtain information about the grain composition and temperature.

Irvine (110) has calculated radiation pressures, and symmetry factors for spherical particles. Radiation pressure calculation have been applied by O'Dell (12) and Greenberg and Lind (111) to dust in H II regions. The motion of small bodies in tenuous gases has been carefully studied by Baines, Williams and Asebiomo (112) and approximate expressions for drag resistance over a range of translation speeds were found which should be suitable for application to astronomical problems. Resistance tables have been obtained by Dorschner (113).

Thompson (114) has performed experiments on the chemical effects of far ultraviolet radiation on molecules containing the cosmically abundant atoms H, O, C and N.

Gidalevich (115) has examined the dust-gas interaction and the radiation pressure effects on dust in the propagation of shock and ionization front in a H I medium.

Gehrels (116) has postulated scattering by loose molecules on grain surfaces to account for the wavelength dependence of polarization.

Cernuschi, Marsicano and Kimel (117) have proposed the condensation of interstellar metallic grains in expanding supernova clouds. Magnetic fields are assumed to saturate these small spherical particles which then combine to form elongated grains which are shown to account for the accepted values of interstellar polarization.

Ireland, Nandy, Reddish and Wickramasinghe (118) attribute the wavelength variation of polarization position angle to a time variation in the orienting magnetic field and to the fact that smaller particles have shorter orientation times than the larger particles. The plane of polarization is observed to rotate with wavelength with the opposite sense on opposite sides of $l^{II} = 145°$.

Donn, Stecher, Wickramasinghe and Williams (119) attribute the variable intrinsic polarization in Mira variables to small graphite flakes.

Diffuse Interstellar Lines

The observational data on diffuse lines has continued to accumulate and the information has become somewhat better defined. Although several new and interesting proposals as to their origin have been suggested the theoretical situation remains a mystery.

Stoeckly and Dressler (**120**) made photoelectric intensity measurements of λ 4430 for 59 stars and suggested that a correlation between weakened λ 4430 absorption relative to extinction and high negative velocity Ca II velocities implied that λ 4430 originates in very small grain which are evaporated near hot stars.

Wilson (**121**) has made some remarks on the interstellar absorption bands.

Treanor (**122**) pointed out the complementarity in the use of low and high dispersion methods of studying λ 4430.

A fairly symmetric λ 4430 profile has been reconfirmed by Wampler (**123, 124**) who noted possible differences from star to star. Wampler found no evidence for the extended wings and also no correlation with polarization. A possible detection of λ 4430 where there is apparently negligible color excess indicated that the agency responsible for λ 4430 may not be bound physically to the extinction producing grains.

On the other hand a high correlation—almost 1:1—between λ 4430 strength and color excess was found for 147 intermediate and late type B stars in Cygnus, Cepheus and Cassiopeia by Kristenson and Rudkjöbing (**125**). This work has been extended (**126**) to 506 O, B, and A stars.

Walker (**127**) has suggested that the apparent extended wings of the λ 4430 diffuse line are due to the slope discontinuity in the extinction curve at approximately this wavelength.

Herbig (**128**) found no evidence for wings or fine structure in the profile of λ 4430 in the star HD 183 143. The wavelength of the band minimum was found to be near 4428·0 Å. Herbig (**129**) pointed out the strong correlation of a variety of 26 diffuse lines or bands including λ 4430 and suggested these are all attributable to the same origin. He also noted that they all fall in the narrow energy range 1·9 to 2·8 eV with 2·8 eV corresponding to the slope discontinuity in the extinction curve.

Unsöld (**130**) proposed that very small metallic particles within grains would act like plasmas and that they would give rise to λ 4430. A further discussion of this suggestion was made by van de Hulst (**131**).

A novel proposal for the source of the diffuse bands has been made by F. M. Johnson (**132**) who suggested either electron-vibrational absorption spectra of free radicals or inverse Raman absorption spectra, the latter leading to consideration of such molecules as cyclopentane, cyclopropane and others.

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NOTE

Addenda to this Report of Commission 34 will appear in Volume XIII B of the *Transactions of the IAU*.