34. COMMISSION DE LA MATIERE INTERSTELLAIRE ET DES NEBULEUSES PLANETAIRES

PRÉSIDENT: Dr L. Spitzer, Director of the Princeton University Observatory, Princeton, New Jersey, U.S.A.

MEMBRES: L. H. Aller, Behr, Bok, Courtès, Mlle Divan, Gum†, Gurzadian, J. S. Hall, Haro, Hatanaka, Hiltner, Kahn, S. A. Kaplan, Kerr, Kharadze, Kipper, Lambrecht, Mayall, McCrea, Minkowski, G. Münch, Pikelner, Rozhkovski, Safronov, Savedoff, Schalén, Schatzman, Schlüter, Seaton, Sharpless, Shklovsky, Sobolev, Strömgren, Thackeray, van de Hulst, Velghe, Vorontsov-Velyaminov, Whitford, Zanstra.

INTRODUCTION

During the last few years the study of diffuse matter between the stars has been profoundly influenced by the development of new techniques. Some of the most important observations in this field are now obtained by radio astronomy, including virtually all the observations at 21 cm. Measures at more conventional wave-lengths have been much extended in precision by use of photo-electric techniques and, especially in the infra-red, by image tubes. While measures with more classical techniques can still be very useful, especially in the southern hemisphere, there is every indication that rapid changes in observational techniques will continue. In time the acquisition of data at additional frequencies from telescopes above the atmosphere will open up still additional areas of research in the field of interstellar matter.

During the last three years substantial new information has accumulated on the density distribution and velocity of the interstellar material. Also, our understanding of the processes involved in the conversion of stellar ultra-violet into the light observed from nebulae has increased. However, our understanding of the basic dynamical processes occurring is still rather limited; in particular, the effect of magnetic fields is very uncertain, although interstellar theoretical research has at least served to point out the unsolved problems.

The present report is essentially an annotated bibliography based on the reports submitted by members of the Commission, and by several non-members; this material is gratefully acknowledged. Some other research work has been included, but the coverage is necessarily incomplete, particularly in the important field of radio astronomy. Incomplete research work has not been included; references are made only to papers which are either published or in press.

PLANETARY NEBULAE

Books and survey paper: Aller (**1**) and Seaton (**2**).

Twenty-one new planetary nebulae have been found by Perek (**3**) on Tonantzintla plates, mostly marked by Haro as emission objects. Westerlund and Rodgers (**4**) have identified 34 planetaries in the Large Magellanic Cloud. The distances of the planetaries have recently been discussed by Kohoutek (**5**), Pskovsky (**6**) and Razmadze (**7**).

New observational material on planetary spectra has been obtained by several authors. Bowen (**8**) has published new data on lines observed with wave-lengths as short as 3109 Å, and has reviewed the accuracy of wave-length determinations. Intensities of spectral lines have been measured by Razmadze (**9**), with some estimates by Evans (**10**). Gurzadian and Razmadze (**11**) report a five per cent polarization for the continuous radiation from the planetary nebula

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NGC 7026; this observation, if confirmed, would have important consequences for the physical nature of these systems. B. Vorontsov-Velyaminov (**11a**) discovered slow but strong variations of line intensities in the spectra of planetary nebulae NGC 6905 and IC 4997. Apparently they are caused by the variation of emission of their nuclei.

Considerable advances have been made in the theory required to interpret such observations in terms of physical conditions within planetaries. The theory of electron-proton recombination has been extended by Burgess (**12**), and Searle (**13**), who have taken properly into account the difference in transition probabilities between the different angular momentum states of a level with given n. Only a finite number of states was considered. The theory for an infinite number of levels has been developed by Seaton (**14, 15**), without, as yet, considering separately the states of different angular momenta. Calculations on the recombination spectrum of N III have been carried out by Nikitin (**16**), while Garstang (**17, 18**) has computed transition probabilities for lines of interest in Ni II, Ni III and Fe IV. Pottasch (**19**) has analyzed the factors determining the number of hydrogen atoms in the $n=2$ level.

Electron densities in planetary nebulae have been considered further by Osterbrock (**20, 21**), based on the intensity ratio of O II lines; the correlation observed between electron density and surface brightness for 22 planetaries is consistent with the same mass and temperature for all planetaries. The electron density and structure of NGC 7293 and of NGC 6164-65 have been considered by Efimov (**22**) and Westerlund (**23**), respectively. The structure of NGC 2818 has been considered by Johnson (**23a**).

The temperatures of the exciting stars of planetary nebulae have been considered by Zanstra and Aller (**24**), who find the same temperature from helium lines as from hydrogen lines, indicating that all stellar radiation is absorbed by the nebulae in the far ultra-violet. Pronik (**25**) computes this stellar temperature from the ratio of forbidden lines of O^+ to those of O^{++}, and from the corresponding ratio of S^+ to S^{++}. Analysis by Pronik (**26**) of the electron temperature in IC 418, as determined from the ratio of O^+ lines with different excitation potentials, indicates values of about 2×10^4 °K in the inner part and half this value further out; he suggests that the heating is caused by corpuscular emission from the central star.

Additional papers on abundance of elements in planetaries have been published by Burgess and Seaton (**27**) and by Seaton (**28**), dealing respectively with oxygen and helium.

Physical processes in planetary and cometary nebulae have been analyzed by Gurzadian (**29, 30, 31**). He finds that the continuous spectrum of the cometary nebulae is due to synchrotron emission by relativistic electrons. His analysis (**32**) of the electron temperature in a medium subject to synchrotron radiation indicates that the thermal electrons have a temperature of 10^5 °. He concludes that cometary nebulae differ greatly from the usual diffuse and planetary nebulae.

DIFFUSE NEBULAE

A number of catalogues of diffuse nebulae have appeared, containing photometric and other data. Ikhsanov (**33**) has published such a catalogue of 28 diffuse nebulae in the γ Cyg region, while Gershberg and Metik (**34**) have prepared a catalogue of 159 such nebulae, giving the absolute brightness in Hα, together with estimated densities and masses. Sharpless (**35**) lists 313 H II regions north of $-27°$, with estimated diameters and brightness. The catalogue of Rodgers, Campbell and Whitlock (**36**) lists 182 Hα regions in the southern Milky Way, with estimated brightness. Courtes (**37**) has made precise interferometric measures of Hα regions, measuring the ratio of the forbidden N II line at 6548 Å to Hα, as well as the Doppler shift of Hα. Vorontsov-Velyaminov (**38**) has found three filamentary nebulae in the Palomar Atlas, and suggests that these may be supernova remnants.

Research continues on the photometry and analysis of reflection nebulae, with detailed discussions by Rozhkovski (39), Johnson (40), Gershberg (41), and Dombrovsky (42). The last three authors discuss the observed polarization in filamentary nebulae such as the Pleiades, and the possible influence of magnetic fields. Dombrovsky (42) suggests that the non-radial polarization observed in NGC 6618 is not consistent with reflection of starlight. Similar polarimetric observations on ten reflection nebulae have been reported by Miss Martel (42a).

A theoretical analysis of light diffusing through a reflection nebula has been carried out by Sobolev (43, 44) and Ivanov (45). The related problem of $L\alpha$ radiation diffusing through a layer with a velocity gradient has been considered by Kaplan, Klimishin and Sivers (46), by Kaplan and Sivers (47) and by Sobolev (48).

Of the individual emission nebulae considered the Orion nebula has received the greatest attention. The Andrillats (49) find that the continuous spectrum from 5800 to 9000 Å agrees with theoretical predictions based on two-photon emission by metastable H atoms. A similar conclusion was reached by Pottasch (50) for ten diffuse nebulae as well as for Orion. Flather and Osterbrock (51) have measured and identified many emission lines in the Orion nebula, from 3587 to 7330 Å. Aller and Liller (52) have carried out a program of photo-electric photometry of many of these lines and have analyzed the composition. Osterbrock and Flather (53) have determined the electron densities in this nebula, from ratios of the two forbidden O II lines. The local density obtained in this way is thirty times the root mean square density determined from the surface brightness, indicating the presence of small condensations in the gas; the total mass of the Orion nebula also follows from their analysis. This mass is also considered by Dokutchaeva (54) who measured photographically the absolute brightness in $H\alpha$. The temperature of the gas, as determined from the radio emission, is closer to 10^4 than to 2×10^{4} ° according to Rishbeth (55). Internal motions in the Orion nebula have been measured in great detail by Wilson, Münch, Flather and Coffeen (56), who find the H II region expanding into the cold gas at about 10 km/sec; the supersonic turbulence does not show the Kolmogroff spectrum. The spectrum of turbulence in the Orion nebula has also been considered by Courtès (37), whose interpretation differs from that of Wilson and his collaborators. The distribution and velocity of the surrounding gas have been studied by Menon (57).

Other emission nebulae have also been studied. Gershberg and Pronik (58) have made absolute measurements for both the line and the continuous spectrum in the North America nebula, NGC 7000. They find that the electron temperature is constant throughout the nebula (in contrast with measures in the planetary IC 418 (25)); the continuum is attributed to unresolved faint stars rather than to two-photon emission. Similar investigations of the nebulae, NGC 6523 and 6618 have been carried out by Pronik (59), Gershberg, Pronik and Shcheglov (60) and by Jessipov (61), this last with the aid of an image converter in the infra-red. Osterbrock and Stockshausen (62) have made photo-electric measures of $H\beta$ in NGC 281 and 2175 and Osterbrock (63) has used O II line ratios to determine electron densities at various points in the Cygnus loop. Additional measures on emission nebulae have been made by Ikhsanov (64), Herbig (65) and Osterbrock (66). The association of $H\alpha$ emission stars with some gaseous nebulae has been studied by Dolidze (67). Osterbrock (68) has discussed the appearance of narrow filaments in diffuse nebulae; these filaments tend to appear whenever a dark cloud is ionized by a star outside the cloud. $H\alpha$ emission in the Magellanic Clouds and a number of emission lines from 30 Doradus have been measured by Johnson (68a).

The radio emission of several individual nebulae has been analyzed in connection with studies of interstellar extinction. Parijsky (69) computes the visual extinction from comparisons of $H\alpha$ measures with the radio emission; for NGC 6618 the optical extinction so computed amounts (70) to 10 magnitudes. Helfer (71) and Helfer and Tatel (72) have made a detailed survey of the 21-cm radiation from the Pleiades, finding essentially no correlation between the radiating gas and the reflecting dust clouds.

Among the theoretical studies relevant to diffuse nebulae are various papers on the magnitude of s_0, the radius of the Strömgren sphere comprising an H II region. Gershberg and Pronik (**73**) have computed values of s_0, taking into account the ultra-violet flux obtained from various model-star calculations. Pottasch (**74**) finds that s_0 is increased by a factor from 1·5 to 1·9 because of the wave-length variation of the continuous absorption coefficient, and the relatively large probability of radiative capture in the ground state, followed by re-emission. The effect on s_0 produced by a gradient in electron density has been treated by Grubissich (**75**). Ikhsanov (**76**) has discussed the information on s_0 provided by the radio emission observed from H II regions.

The continuous emission from ten diffuse nebulae has been attributed by Pottasch (**50**) to two-photon transitions in hydrogen; he also finds that the optical depth in Hα exceeds unity for these nebulae. However, Gershberg (**77**) concludes that this optical depth is generally small in diffuse nebulae. Aller and Chapman (**78**) have investigated the effect of thermal diffusion in gaseous nebulae, and concluded that this effect is generally negligible. Evidence for genetic association between clouds and O stars has been investigated by Ikhsanov (**79**).

Preliminary observations of radiation in the far ultra-violet have been made from a rocket by Kupperian, Boggess and Milligan (**80**). In the wave-length region from 1225 to 1350 Å they find diffuse sources around a number of stars. In particular, from α Vir they find no evidence of a point source at these wave-lengths, but instead report a nebula about 23° in diameter. Shklovsky (**81**) has suggested that this radiation might be produced by Doppler-shifted Lα radiation emitted by rapidly moving hydrogen atoms ejected from the star. As yet, however, there is no generally accepted explanation of these observations, nor have they been confirmed. Johnson (**81a**) failed to observe any evidence of Hα emission from the region around α Vir.

DISTRIBUTION AND PHYSICAL STATE OF INTERSTELLAR GAS

Books and Survey Papers: Mills (**82**), Pikelner (**83**), Oort, Kerr and Westerhout (**84**), and Vorontsov-Velyaminov (**85**); *Symp. IAU* no. 9 (**86**).

According to a re-determination by Oort (**87**), the gravitational limit on the local density of matter, less the density of known stars, yields an upper limit of 3 H atoms per cm^3 on the local density of interstellar material, about three times the accepted mean value.

Relatively few studies of interstellar absorption lines have been carried out since 1957. Douglas and Morton (**88**) have identified the line at 3579 Å as due to CH^+. Burgess, Field and Michie (**89**) have computed the equivalent width to be anticipated for the line of interstellar A I at 3944·0 Å. Rogerson, Spitzer and Bahng (**90**) have developed a high-dispersion photo-electric spectrophotometer, suitable for measuring such absorption lines with an equivalent width of several milli-angstroms. The distribution of interstellar Ca^+ ions has been analyzed by Takakubo (**91**), who finds that both small clouds and large clouds must be assumed. Smak (**92**) finds that the concentration of interstellar Ca^+ to the galactic plane is substantially less than that of dust and early-type stars. Lambrecht and Schmidt (**93**) find a correlation between the densities of neutral Na and H, as well as between gas and dust. Measures of the λ4430 band are reported both by Code (**94**) and by Wilson (**95**), who also measures broad absorption features at 4760 and 6180 Å. Spitzer and Zabriskie (**96**) discuss some of the many problems that could be investigated if interstellar absorption lines between 912 and 3000 Å could be measured from a satellite telescope.

Information on the Hα emission from the southern Milky Way is being presented in an

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atlas compiled by Rodgers, Campbell, Whiteoak, Bailey and Hunt (**97**). The Atlas, accompanied by identification charts, covers the galactic longitude interval between Monoceros and Aquila and is 30° wide in galactic latitude. Identification of the nebulae is according to the catalogue of the Hα regions of the first three authors (**36**). Similar photometric information has been obtained in a survey by Johnson (**98**). The general density of ionized hydrogen in the Galaxy has been studied by Westerhout (**99**) on the basis of radio measures at 22 cm; he finds that the ratio of ionized to neutral hydrogen in the solar neighborhood is between 0·03 and 0·06.

Among the theoretical papers on physical processes in the interstellar gas is the work by Krassovsky (**100**), who finds that neutral molecules form clusters around ions in a cold interstellar gas, and that such clusters may account for the interstellar extinction. Donn (**101**), however, concludes that such clustering is negligible. The processes determining the kinetic temperature of the gas have been considered by Takayanagi and Nishimura (**102**) and by Hayakawa (**103**), who suggests that energetic particles may be important for heating interstellar clouds. The rate at which H atoms form H_2 molecules by combining on the surface of grains has been considered by McCrea and McNally (**104**), who find that the increasing rate of molecular formation at higher densities sets an upper limit of about $10^2/cm^2$ on the density of neutral H.

Fundamental information on the galactic distribution of hydrogen continues to be obtained from studies of the 21-cm line. The possibility of measuring the radio line of CH in absorption has been considered by Brenhaus (**105**), but as yet no lines other than the H line have been detected astronomically in the radio range. Among the surveys of 21-cm radiation may be mentioned papers by Bolton, Stanley and Harris (**106**), Davis (**107**), Dieter (**108**), Gum, Kerr and Westerhout (**109**), Hack and van Woerden (**110**), Kerr (**111**), Kerr, Hindman and Gum (**112**), and McGee and Murray (**113**), with related studies by Pronik (**114, 115**). Kinetic temperatures less than 60 °K at the centers of H I clouds are reported by Radhakrishnan (**116**). Detailed studies of the Cyg X radio source at 21 cm as well as other wave-lengths have been reported by Sorotchenko (**117**), Ikhsanov (**118**) and Large, Haslam and Mathewson (**119**).

The gas near the center of the galactic center has been the subject of special study. Courtès and Cruvellier (**120**) have detected Hα emission from the 'galactic bulge'. The radio emission at 3·2 and 9·4 cm has been measured by Parijsky (**121**), while measures by Davis and Jennison (**122**) at 22 cm have been used to deduce a mass of $6 \times 10^5\ M_\odot$. Shklovsky (**123**) attributes the absence of non-thermal emission from the galactic center to absorption of cosmic rays by this relatively dense gas. The galactic corona has been analyzed by Razin (**124**), who concludes that the electron density is about $10^{-3}/cm^3$, and by Getmanzov (**125**), who finds a cloud size of less than 75 pc from the spatial fluctuations of the observed radio intensity. A general survey of the nature of the galactic corona has been given by Pikelner and Shklovsky (**126**).

On the important question of how much matter is present between the galaxies Kahn and Woltjer (**127**) present theoretical arguments that this density amounts to 10^{-4} H atoms per cm^3 within the Local Group. However, Field (**128, 129**) has shown that the density of neutral H in the line of sight out to the Cyg A radio source is less than 6×10^{-6} H atoms per cm^3 provided that the gas is less than 50% ionized.

Studies of interstellar material in other galaxies have mostly been carried out by optical methods. Feast (**130**) has determined electron densities and temperatures in the 30 Doradus regions of the Large Cloud, with turbulent velocities of 11 km/sec. Rodgers (**130a**) has shown that the ionized gas in the Small Magellanic Cloud is distributed in the form of a distorted one-arm spiral. Münch (**131**) measures expansion velocities of some 60 km/sec for the Ca^+ gas in the nucleus of M 31. In elliptical galaxies Minkowski and Osterbrock (**132**) show that gas is sometimes present, with maximum electron densities less than about $10^2/cm^3$. In NGC 4278

Osterbrock (**133**) finds a total mass of $10^5 M_\odot$ in ionized H. Wentzel and Van Woerden (**134**) fail to find any 21-cm radiation from M 32. In a theoretical study of emission nuclei with wide emission lines, corresponding to velocities of 1000 km/sec. Woltjer (**135**) concludes that these objects are probably in a steady state, rather than in rapid expansion. Vorontsov-Velyaminov (**136**) has analyzed the connection between such galaxies and radio sources.

EXTINCTION AND THE DISTRIBUTION OF INTERSTELLAR DUST

Information on selective extinction of starlight becomes progressively more detailed. Kron (**137**) has published color excesses of 139 super giants, based on six-color photometry. Lambrecht and Schmidt (**138**) give color excesses of 19 stellar associations, and conclude that the ratio of electron density in H II regions to the density of dust is widely variable. Color excesses of Cepheid variables have been measured by Kron and Svolopoulos (**139**), Torondzhadze and Khatissov (**140**), and Alania (**141**). Divan (**142**), Rodgers (**142a**) and Schalén (**143**) conclude that the variation of extinction with wave-length is about the same for all stars, with the first two authors attributing observed anomalies to peculiarities in the stellar spectra.

The total interstellar extinction has been determined by various authors, including Alksnis (**144**), Ikhsanov (**145**), Parijsky (**69, 70**), Pronik (**146**), Toronzhadze (**147**), and Westerlund (**148, 149**). Individual dark clouds have been analyzed by Khavtasi (**150**), who has prepared a general atlas (**151**) of such objects between +20° and −20° in galactic latitude.

The correlation between dust and neutral hydrogen continues to be studied. Correlation between these two constituents of the interstellar medium is confirmed by Davis (**107**), Kurochin (**152**), Lambrecht and Schmidt (**93**) and Schmidt (**153**). However, in the relatively small reflecting clouds surrounding the Pleiades, Helfer and Tatel (**72**) find no correlation.

Dark obscuring clouds in the globular cluster M 4 are reported by Idlis and Nikolsky (**154**); similar conclusions have been reached by Roberts (**155**) for 12 of the 32 clusters examined. Confirmation of this remarkable result would be very important.

POLARIZATION AND THE INTERSTELLAR MAGNETIC FIELD

Review papers and summaries: Hall (**156**) and Serkowski (**157, 158**).

Methods for measuring polarization of starlight have been discussed by Bartl (**159**), Behr (**156**), and Serkowski (**156, 160**).

Polarization measurements have been published by a number of authors. Behr (**161**) has measured the polarization, p, of 550 stars, mostly within 250 pc of the Sun, and finds the plane of vibration mostly parallel to the local spiral arm. Hall (**162**) gives p for 2592 stars; he finds that the plane of polarization is correlated with the direction of filamentary structure, but finds no effect by H II regions on the polarization of more distant stars. Krzeminski (**163**) has measured p photo-electrically in 23 stars in which the λ 4430 line has a known intensity, finding a correlation coefficient of 0·7 between these two quantities; he has also (**164**) measured p in the open clusters NGC 2169 and 7243. Krzeminski and Oskanjan (**165**) have measured polarization in the I Lac association. Serkowski (**166**) has measured polarization and reddening of stars in the double cluster in Perseus; the spatial autocorrelation gives a distance scale of 1·8 pc for the regions of uniform magnetic field. Polarization of 30 Cepheids has been measured by Schmidt (**167**). Hoag and Smith (**168**) have measured polarization in the galactic cluster NGC 2244, while Larsson-Leander and Serkowski (**169**) have measured p in Stock's cluster in Perseus, finding the same polarization as in the double cluster, 2°·4 to the south and eight times further away. Polarization of the light from galactic nebulae has been measured and discussed by Gurzadian and Rasmadze (**11**) for the planetary nebula NGC 7026 and by Dombrovsky (**42**) for NGC 6618. As emphasized by Dombrovsky (**42**) and Gershberg (**41**) the non-radial polarization observed in the reflection nebula may also require a magnetic field for its explanation. A similar conclusion has been reached by Elvius (**169a**), based on the observations by Miss Martel (**42a**), which indicated that the plane of vibration in reflection nebulae is generally perpendicular to the direction of planetary structure.

The variation of polarization with wave-length has been investigated by Behr (**170**) and Gehrels (**156**, **171**) who finds a flat maximum in the green. Application of scattering theory to the extinction and polarization by simple forms of particles has been the subject of renewed interest. Wilson (**180a**) has considered infinite cylinders, while Greenberg (**180b**) has analyzed spheroids and other simple geometrical shapes. Using also microwave results on scattering by dielectric spheroids, obtained by Greenberg, Pedersen and Pedersen (**180c**), Greenberg and Meltzer (**180d**) have predicted that wave-length dependence of extinction should depend systematically on the orientation of the grains, with different values observed across a spiral arm than those found in a direction along the arm. For the very small scattering particles proposed by Platt, Greenberg (**180e**) has shown that this effect is much less, thus providing a possible method of distinguishing between the proposed types of scattering particles.

The correlation between polarization, p, and extinction, A, has been studied by many authors, especially by Bielicka and Serkowski (**172**), Dombrovsky (**173**), Grzedzielski (**174**), Kaplan and Klimishin (**175**), Pacholczyk (**176**) and Schmidt (**177**); the ratio p/A depends appreciably on galactic longitude, but much less on latitude. As pointed out by Lodén (**178**) in many areas there is a correlation between p and the direction of the plane of vibration. Pacholczyk (**179**) finds only an indirect correlation between p and the intensity of the λ 4430 line. The spatial auto-correlation of p has been examined by Kaplan and Klimishin (**180**) yielding an indication of the scale of the irregularities in the interstellar magnetic field.

The basic problem of the magnitude of B, the interstellar magnetic field, is still unsolved. Attempts by Davies, Slater, Shuter and Wild (**181**) to measure circular polarization in the 21-cm line yield an upper limit of 5×10^{-6} gauss for B in the Orion arm. This value is rather low for consistency either with the Davis-Greenstein alignment theory or with the Chandrasekhar-Fermi hypothesis that B is predominantly in one direction, along the spiral arm. Henry (**182**) has shown that the Davis-Greenstein theory for paramagnetic particles can be extended to alignment of ferromagnetic particles, with the magnetic fields required reduced to 10^{-6} or even 10^{-7} gauss. Spitzer (**183**) points out that condensation of clouds is difficult to understand unless B is substantially less than 10^{-5} gauss, and concludes that the lines of force are probably quite tangled. Burbidge (**184**, **185**) computes the value of B required to explain synchrotron emission on the assumption of minimum total energy. He obtains values ranging from 10^{-6} gauss in the galactic plane up to 10^{-3} gauss in the Crab nebula; if the primary particles are protons, which produce energetic electrons in collisions, the magnetic fields are half an order of magnitude greater. Grzedzielski (**186**) points out that on the basis of the Davis-Greenstein theory an important amount of polarization should be produced in the rarefied H II region between clouds. Biermann and Davis (**186a**) conclude that the magnetic field exceeds 2×10^{-5} gauss in the galactic disc.

The hypothesis that the interstellar magnetic field is probably force-free has been assailed by Kaplan (**187**) and Rozis-Saulgeot (**188**). The former concludes that no change of velocity is possible in a forcefree field, while the latter points out that the material pressure exceeds $B^2/8\pi$ in H II regions, and that magnetic forces can therefore be envisaged. The nature of a magnetic field around a contracting protostar has been analyzed by Mestel (**189**).

The magnetic field outside the galactic plane and in other galaxies is even more uncertain than the field in spiral arms. A small polarization of radio waves from the galactic corona has been reported by Razin (**190**) and Thompson (**191**), but Pawsey and Hartig (**192**) conclude that any polarization at 1·4 meter wave-length is less than one per cent. In their general

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discussion of the galactic corona Pikelner and Shklovsky (**126**) deduce a field strength of about 5×10^{-6} gauss. Burbidge (**193**) infers a value of B of about 10^{-7} gauss in inter-galactic clouds within clusters of galaxies.

DYNAMICS OF INTERSTELLAR MATTER

Books, Review papers: Burbidge (**194**), Ebert, v. Hörner and Temesváry (**195**), Kahn (**196**), Kaplan (**197**), Spitzer (**183**).

Interstellar motions have been determined from the measured Doppler shifts of lines both in the optical and radio region. Courtès (**37**) has shown that H II regions partake of the general galactic rotation. In a detailed study of the 21-cm data from both the northern and southern sky Kerr (**111**) has found that the neutral hydrogen is moving radially outwards in the galactic plane, with a velocity decreasing from the 50 km/sec previously observed near the galactic center to about 6 km/sec in the solar neighborhood. Comparable expansion velocities near the nucleus of M 31 have been observed by Münch (**131**). In the direction of the galactic poles McGee and Murray (**113**) find neutral hydrogen falling toward the galactic plane at about 5 km/sec. Random and internal motions of individual nebulae have been observed by Courtès (**37**), Courtès and Cruvellier (**198**), Menon (**57**), and Wilson, Münch, Flather and Coffeen (**56**), while random motions within the Large Magellanic Cloud are reported by Feast (**130**). Pottasch and Courtès (**199**) have measured the motions of the gas in bright rims of dark nebulae. The kinematics of the hydrogen gas within about 1000 pc. have been analyzed by Helfer (**199a**).

From the extensive literature on interstellar dynamics may be distinguished a series of papers on the motions of individual clouds, especially on the interaction between clouds and stars moving with respect to each other. Hruška (**200**) has analyzed the dynamical interaction between a star and a moving cloud, taking into account the radiative force on the grains, interactions between grains and gas, and the magnetic field; he finds (**201**) that near a hot star the radiative pressure on grains is somewhat decreased by the transformation of ultra-violet light into $L\alpha$. Rozhkovski (**202**) has also investigated the dynamics of such encounters, and has discussed the influence of radiation pressure on the structure of reflection nebulae. Lambrecht (**203**) and Lambrecht, Schmidt and Weigert (**204**) have analyzed the accretion of stellar mass resulting from such encounters, and conclude that the effect is unimportant. Shimuzi (**205**) has considered the orbits of clouds in the gravitational field of the Galaxy, comparing his results with observed velocities.

Another series of papers deals with the thermal and dynamical effects arising when a hot star begins to shine in an initially cold, dense cloud of neutral hydrogen; the shock and ionization fronts considered here are also relevant to collisions of clouds. The general evolution of such a cloud surrounding an O or B star has been considered by Gershberg (**206**) and Goldsworthy (**207**). A related analysis has been presented by Chvojková (**208**), who suggests that planetaries may be created in this way by entrance of an existing hot star into a cloud. The detailed structure of the ionization front appearing at the boundary of the expanding H II region has been analyzed by Axford (**209**), while the effect of radiation in heating gas in front of the associated shock wave has been analyzed by Kaplan and Klimishin (**210**). The radiative cooling of material behind a shock has been considered by Zimmerman (**211**), with special reference to a high-speed shock moving at 100 km/sec. Relevant papers on radiative transfer in an expanding nebula have been published by Kaplan, Klimishin and Sivers (**46**), by Kaplan and Sivers (**47**), and by Sobolev (**48**).

Yet another group of papers deals with star formation, first by gravitational instability, followed by fragmentation into protostars. The idealized problem of gravitational instability in a uniform medium has been considered by Pacholczyk (**212**) and by Pacholczyk and

Stodólkiewicz (**213**), who considers the effect of such phenomena as rotation, viscosity and electrical resistivity. The instability of a flattened rotating disk has been considered in some detail by Safranov (**214, 215**); Bonnor (**216**) has considered the instability of a gaseous sphere subject to an external pressure, extending to a polytropic sphere his previous result for the isothermal case. Debye (**217**) points out that the initial cause of the instability may be the passage of a shock wave past a globule, compressing it beyond the instability point. The general problem of star formation by instability and subsequent contraction has been analyzed by Hatanaka, Unno and Takabe (**218**), by McCrea (**219, 220**), by Pacholczyk and Stodólkiewicz (**221**), and by Spitzer (**222**), see also the review papers cited above. In view of the many complications, no detailed theory can be regarded as established, but star formation by the processes considered seems plausible. Debye (**223**) has suggested that cometary nebulae are formed from the observed 'elephant trunk' dark nebulae after a star has formed in the head of the trunk.

The effect of a magnetic field on these problems of interstellar gas dynamics has been considered by various authors. Mestel (**189**) has analyzed the nature of the magnetic field around a protostar, and points out that such a field reduces the rate of accretion appreciably. Pikelner and Gershberg (**224**) have considered the formation of filamentary structures by twisting a tube of force; the radial magnetic forces produced in this way can compress substantially the gas near the axis. A related problem, distortion of a magnetic cloud by galactic rotation, has been considered by Wentzel (**225**). In an attempt to explain the outward flow of interstellar gas in the galactic plane Hoyle and Ireland (**226**) have analyzed the transfer of momentum by means of a magnetic field directed along a spiral arm; while magnetic forces of this type can produce outward velocities near the galactic center, they should also cause radially inward velocities further out, contrary to observation. Grzedzielski (**227**) attributes the slowing down of the radial motion, as the gas moves out from the galactic center to the effect of a magnetic field of order 10^{-5} gauss. Pikelner (**228**) has analyzed the interaction between cosmic-ray particles and the galactic magnetic field, investigating why the cosmic-ray energy density is about equal to the magnetic energy density. The circulation of the gas between the halo and the disc, driven by magnetic fields, has been considered by Wentzel (**229**). The dynamics of hypothetical galactic rings of gas which contain a magnetic field directed along the ring and which do not coincide with the observed spiral arms have been considered by Elvius and Lindblad (**230**) and by Elvius and Herlofson (**231**).

Investigations of gas dynamics on a galactic scale have been made by Pikelner and Shklovsky (**126**) and by Kahn and Woltjer (**127**). The former review the arguments for a quiescent galactic corona, in hydrostatic equilibrium, and for a dynamic corona, supported by motions of magnetized clouds; they conclude that the dynamic model seems more likely. The latter authors discuss the dynamical effects produced by motion of the Galaxy through inter-galactic matter, and conclude that the tilting of the galactic plane at large distances, as determined by 21-cm observations, can be explained by such an interaction.

LYMAN SPITZER JR.
President of the Commission

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