34. COMMISSION DE LA MATIERE INTERSTELLAIRE ET DES NEBULEUSES PLANETAIRES

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The contributions of about forty persons, members and non-members of this Commission are gratefully acknowledged. One look at the list of references and the range of subjects covered will show that it is not possible to transform within a limited time all of this material into a critical review. It seemed that the interests of the members would be best served by a report in the form of a bibliography with comments. This form is sufficiently flexible to include data about investigations in progress, wishes for future work, and an occasional critical note. Completeness has been aimed at but undoubtedly has not been reached. The report consists of five sections, of which only the first (Planetary Nebulae) and the last (Solid Particles) form clearly distinct subjects. Topics largely or completely omitted from this report are: nebulae and dark matter in other stellar systems, including the Magellanic Clouds; radio astronomy; origin of stars; cosmic rays; hydromagnetics and hydrodynamics.

PLANETARY NEBULAE

Books and survey papers: Aller [1], Gurzadian [2], Sobolev [3].

Planetary nebulae form fascinating examples of aerodynamic processes on a cosmic scale: they are more regular than diffuse nebulae and more accessible to detailed observation than nova shells. The understanding of their forms and internal motions as one of the prime research aims has been put forward in studies by Gurzadian [2,4,5], Wilson [6] and Zanstra [7]. Magnetic fields almost certainly play a role in some nebulae.

The need for more and better observations is still keenly felt. The extensive programme of Aller and associates [8,9] now includes photo-electric photometry in the 5007 line of 112 nebulae and photo-electric spectrum scans of twenty-six nebulae. Other photometric studies were made by Razmadze [10,11], Gulak [12], and Geake [13]. Mayall's programme to measure the radial velocities of 150 faint planetaries is near completion.

The classical problems of the radiative processes in a planetary nebula have had continued attention, namely, the temperature of the nucleus [14], the electron temperature [15,16,17], the Balmer decrement [14,18,19], the shells of successive ionizations [22,23]. New chemical compositions have been determined for ten nebulae [24] following a detailed investigation for NGC 7027 based on very fine material [25,26].

The new method for determining electron densities of the order of 10^3 cm^{-3} from the (O II) doublet ratio [27] is being applied by Osterbrock to planetaries with faint outer shells.

The complicated process of non-coherent scattering of the radiation in Lyman α and the corresponding He II line, which is important for the radiation pressure on the shell seems to be understood in principle but leads to a surprising variety of results [28-37].

Andrillat [15], Seaton [38], Kipper [39], and Gurzadian [40] have discussed the continuous spectrum arising from recombination and from 2-photon emission. They do not all agree that the accordance with the observations is good.

Shklovsky [20] made the important suggestion that the apparent diameters of planetary

nebulae, if properly interpreted, provide a better distance criterion than their magnitudes. Discussion on this point is being continued [41, 42, 21].

The problems of origin and evolution have been further studied [43-5] but no unanimous answer is seen yet.

DIFFUSE NEBULAE

Diffuse emission nebulae, H II regions and the general interstellar gas form one wide field of investigation. An attempt at drawing a sharp distinction somewhere would be premature, although it is clear that some objects are evolutionary units, whereas others are due to chance coincidences of hot stars and gas clouds.

Great observational activity is going on and the instrumental development is by no means at an end. Better dyes for isolating Hα and He 5876 are being sought [46, 47], photography at high speed (f/1) with big telescopes is now possible [48, 49]. J. Ring and L. D. Davies will also attempt to survey the He-emission regions. Courtès has steadily improved the interferometer technique [50], which is now suitable for measuring radial velocities [51], for isolating (N II) from Hα [52], and for detecting fainter regions than are now known.

Sensitive means for detecting H II regions also are by radio emission in the 20-cm range [53] and by absorption in the metre range [54]. Perhaps even the far ultra-violet radiation received by rockets may provide useful information; excess radiation from the general area of Vela-Puppis, where the nearest H II regions are located, has already been reported [55].

Selected regions of the northern and southern sky have been surveyed [56-65] for their emission regions, while Bok and Sharpless report work in progress. Sharpless and others [66, 67] have made a special search for the exciting stars. Full data on these stars are needed before reliable distances may be estimated [68]. A statement on the work needed for the preparation of a full catalogue of emission regions is given at the end of this report. A list of new reflexion nebulae was provided by Rozhkovski [69].

Among the individual nebulae the Crab nebula has received the greatest attention. Its polarization, which had just been discovered at the time of preparation of the previous report, has been fully confirmed [70-7] and has been mapped in greatest detail from plates taken by Baade with the 200-inch telescope [78, 79]. The continuous radiation is undoubtedly due to the synchrotron mechanism and a number of theoretical investigations have been made to establish the nature of the magnetic field and the energy spectrum of the electrons [75, 80, 81]. Osterbrock [82] has determined electron densities of the filaments; Mayall and Münch [83] have studied their radial velocities. Woltjer [84] combines all available data and proposes that the field in the nebula is force-free and surrounded by the surface currents formed by the filamentary shell.

Attempts to measure polarization of the Crab nebula in radio waves have failed at long wave-lengths [85] but have given positive results at 3 cm [86].

The results on the Crab nebula have inspired many further polarization studies on nebulae. They have led to the definite presence of synchrotron radiation in the extra-galactic nebula M 87 [87, 88], and its suspected presence in a T Tauri star [89] and in the cometary nebula NGC 2261 (Gurzadian). The polarization in IC 432 is not radial [90]. The polarization in η Carinae [91], which Wesselink photo-electrically found locally to exceed 40%, probably arises from electron scattering. Two reflexion nebulae studied by Khatschikian [92] have a radial polarization of 14%. Also Dombrovski [93, 94] continues his studies of the polarization of nebulae.

The filamentary nebulae remain of great interest. In spite of earlier conflicting evidence [95, 96], Minkowski [97] now finds that the spectrum of the Cygnus loop arises from collisional excitation. Miyamoto [98] gave a general survey of the problems of collisional excitation. Chamberlain [99] refined the excitation theory by including the effect of charge transfer in collisions between H and O^+. It seems probable that all of the objects of this class are remnants of super-nova shells [100, 97].

A very detailed investigation of the Orion nebula is in progress at Mount Palomar.

Electron densities are now available at twice as many points as published before [101]. The multi-slit survey of radial velocities by Wilson and Münch is near completion [83]. It has an angular resolution of 1″. Several spectrophotometric and polarimetric studies of the Orion nebula have been published [102–6].

Three new studies on the cometary variable nebulae have been reported [107, 108, 73]. Rozhkovski investigated the dust clouds in the Trifid nebula [109] and compared several nebulae in ultra-violet and red light [110].

DYNAMICS OF THE INTERSTELLAR MEDIUM

Books and survey papers: Idlis [111], I.A.U.-I.U.T.A.M. Symposium on Cosmical Gas Dynamics 1957 [112], Kaplan [113].

The Symposia on cosmical gas dynamics organized by I.A.U. and I.U.T.A.M. have not led to the explicit solution of many problems. However, they have been extremely useful in putting the problems (suggested by theory and observation) in their proper context. The hope of understanding a whole set of phenomena by one word, e.g. *turbulence*, or *collisions*, is gone and a new interest for details has emerged. The problems of gas dynamics form a link between the properties of individual emission nebulae and those of the interstellar gas at large and hence are given a place in this report between these two subjects.

The fundamental problem is that of the expanding H II regions. Their kinetic energy, derived from the nuclear reactions in the exciting O-stars, appears to be about sufficient for keeping up the state of motion of the interstellar gas at large [114, 115], but the quantitative estimates of gain and dissipation are not conclusive. Shajn [116, 117, 118], Savedoff [119] and others [120] have studied the relations of nebulae and stars and other data in support of theories of this kind. New theoretical studies of the expanding regions, including heating and cooling effects-have been made by Savedoff and Greene [121] and by Goldsworthy [122, 123]. Oort and Spitzer [124] have paid special attention to the acceleration of clouds. The presence of three stars shot out at high speeds from the Orion nebula is still unexplained.

Also the radio observations at 21 cm suggest expanding H I regions around some H II regions [125, 126].

The closely related question of the contraction of interstellar gas clouds into stars cannot be fully reviewed here; reference is made to papers by Ebert [127], Ruskol [128, 129], Mestel and Spitzer [130], and McCrea [131]. Further investigations of the accretion process may also be relevant [132–6].

Gurzadian [137] has discussed the radiation pressure on the gas around an F-star.

The peculiar trunk shapes and the bright rims of dark markings in emission nebulae have intrigued several authors. Observational data on these structures have been collected by Rozhkovski [138], Pottasch [139] and Osterbrock [140, 141]. The earlier suggestion that the trunk shapes are due to Rayleigh-Taylor instability [142] is criticized by Kahn [143] and Pottasch [144]. The bright rims are ionized regions of high density; their properties can be explained on a model of gas streaming through the ionization front [144, 145].

Many investigations of the basic hydrodynamic and hydromagnetic processes underlying interstellar gas dynamics have been made. Discussions at the Symposium have shown how difficult a rigorous treatment of these processes is. A full review will not be attempted. Attention has been given to the collisions of clouds [146–8], to shock waves [95, 149, 150, 151], and to turbulence [95, 152, 153, 154].

It may be emphasized that these few lines cannot do justice to two wide fields of growing importance, namely, hydromagnetics and primary cosmic rays. Most of the interest in *hydromagnetics* has recently centred on applications to the Sun, the Earth and to stellar interiors. Nevertheless it remains also of vital interest to interstellar matter and nebulae. The subject of *cosmic rays* traditionally belongs to physics but the origin, acceleration and dissipation of the primary cosmic rays is fully an astronomical problem. Both topics might well be given the standing of a separate commission of the I.A.U.

MATIERE INTERSTELLAIRE

DISTRIBUTION AND PHYSICAL STATE OF THE INTERSTELLAR GAS

It would be hard to over-emphasize the importance of the 21-cm observations for the study of the distribution of the interstellar gas on a truly galactic scale. A wealth of new material [155–7] is now available for study. Maps of the spiral arms within 3 kpc from the Sun, based on radio and optical data have been given by Gum [58] and van de Hulst [158]. As this subject comes more directly under Commissions 33 and 40, further details must be foregone.

A subject of renowned difficulty in the field of our Commission, namely, the cloudiness and velocity distribution of the interstellar gas [159, 160], also received welcome new clues from the radio astronomy of the 21-cm line. This is due both to the higher angular resolution of modern radio telescopes and to the possibility of observing the 21-cm line in absorption in at least four radio stars [161, 162]. The optical data on the radial velocities of the Ca^+ lines have been greatly extended by the work of Münch [163]. In the southern sky Thackeray [164] has embarked on a similar programme. An interferometer for this purpose was described by Ring and Woolf [165]. Upon reviewing the available data, van de Hulst [158] concludes that the radio and optical data on the velocity distribution are in fine agreement but that no definite conclusion on the sizes of the clouds can be reached. A model with clouds all of one size does not fit. Using Adams' data, Pikelner and Metik [166] find that the fast clouds move preferentially along the spiral arms.

Following the discussion in our Commission at the Dublin meeting, Pikelner and Shklovsky [95, 167, 168] and Spitzer [169] have made a deeper study of the properties of the gaseous halo of the Galactic System. Other authors have discussed its relation to radio astronomy [170] and to cosmic rays [171]. A lively discussion at the Symposium on Cosmical Gas Dynamics established the hope that further observational and theoretical investigations will help to settle this important problem in the near future.

Ever since Kahn [172] suggested that the heating of H I clouds might occur suddenly, so that the clouds might have widely varying temperatures, radio astronomers have simply ignored this warning. It now seems that the first evidence for such fluctuations from the 21-cm radiation is forthcoming. Davies estimates that in some regions the H I density is a hundred times normal and the temperature as low as 20° K. Further contributions to the theory have been given by Seaton [173], by Purcell and Field [174] and by Schatzman [175].

Important work is devoted to the more classical problems of the ionization and chemical composition of the interstellar gas. Lambrecht and associates have recomputed the interstellar radiation field [176–8] and the corresponding ionization equation [179]. Further work on the ionization cross-sections, like Seaton [180] has done for Ca and Mathis [181, 182] for He, is needed before these computations can be much improved.

Other studies have been devoted to the Na/Ca ratio [183], to Be [184], and to the (S II)/(O II) ratio [185]. Radio observations have so far failed to reveal Deuterium [186–8] and OH [189]. McKellar and Richardson [190] have identified the 3143 line with CH. The complete silence about the 4430 band and the diffuse interstellar lines in the red region should not make us forget that they still have to be identified.

INTERSTELLAR EXTINCTION AND POLARIZATION

Review paper: Pikelner [191].

The existence of interstellar extinction cannot be denied. Nor can the fact that it depends on wave-length (thus causing interstellar reddening) and on the state of polarization (thus causing interstellar polarization) be denied. However, the traditional assumption that all of these phenomena have to be explained by solid grains with diameters of 1000 Å and more has been challenged. Platt [192] suggests that particles of 10 Å grown from the light elements in the interstellar gas would be quasi-metallic and might explain all the phenomena. Earlier, other authors have tried to explain at least the polarization by very small particles, probably because no scattering theories for

larger ellipsoids were available. Zimmermann [193] is the first to go one step beyond the approximation for sizes much smaller than the wave-length. A monograph on scattering properties of particles of various sizes and forms is now available [194].

A problem in the traditional theory is that the constancy of the extinction law (curve of extinction versus $1/\lambda$) would require a very constant mean size of grains from one region to the other. Re-evaluation of the effective λ's of the 6-colour photometry by Whitford [195] has brought corrections to the extinction curve in the same direction as urged by Schalén [196]. The new curve resembles the one obtained in 1939 [197] and coincides with that of Mlle Divan [198] over the common range. The new ratio A_{vis}/E_{B-V} is 3·0. The suggestion that the extinction law is subject to regional variations [199, 200] has been debated again by other authors [201–6]. Further investigations on the extinction law have been made [207–9] or are in progress.

Meanwhile, investigations on galactic structure continue to use reddening and extinction data, both for correcting stellar distances and for finding the distribution of the dust itself [210–14]. Isolated dark clouds have been studied [215, 216] and catalogued [217]. The hopes that the photometric parallaxes may be so much improved that interstellar extinction studies become possible for much smaller distances than before still are high-strung. A first attempt to determine extinction at $r < 100$ pc by comparing photometric and geometric parallaxes has been made [218].

Incidentally, there are numerous papers with conflicting results on the statistics of the dark clouds and the brightness fluctuations of the Milky Way, e.g. [219–25].

Detailed studies of a number of reflexion nebulae have been made by Fessenkov [226] and by Mme Martel [77]. Cederblad's list of reflexion nebulae has been supplemented by Rozhkovski [69].

The radiation pressure exerted on the grains may certainly lead to a partial segregation of gas and dust [227, 228] and perhaps even to more peculiar phenomena like the dust being trapped at a certain distance from the star [229].

Steady progress is being made in the observations of interstellar polarization. Extensive lists with discussions have been published by Hiltner [230] and for the southern sky by Mrs Smith [231], while a full catalogue of 2400 stars by Hall is in preparation. In addition to these surveys several regional studies have been published [232–4].

It is well realized that, although the theoretical interpretation may not be fully clear, these data have an important bearing on the structure of the galactic magnetic field, both on a large scale and locally. Shajn [235–41] has devoted special attention to relations between the direction of the polarization and the elongated forms of luminous and dark nebulae. He finds that the magnetic field controls both the polarization and the forms of the nebulae, and that it is usually directed along a spiral arm, although noticeable local deviations occur. Similar problems have also been discussed by Takakubo [242, 243], by Serkowski [244] and in the discussions at the Gas Dynamics Symposium. The general impression was that it may be too early to draw definite conclusions.

Also in this field the instrumental possibilities are by no means exhausted. Behr [245] measured many of the nearest stars with a mean error of 0·03% polarization and showed the existence of an elongated polarizing cloud in the Bootes region. Finally, there is the exciting prospect that some time it may prove feasible to detect the interstellar magnetic field directly by the Zeeman effect on the 21-cm line [246].

STATEMENT ON A CATALOGUE OF DIFFUSE EMISSION NEBULAE

The report of the Sub-commission in the preceding *Transactions* may serve as a basis for discussion. The following points require consideration:

(1) A new catalogue is desirable but not quite urgent.

(2) The most satisfactory way to recognize individual nebulosities in a crowded region is by identifying their exciting stars.

(3) The catalogue should list all known objects and not only new ones.

(4) The catalogue should not be combined with a catalogue of extragalactic nebulae

or radio sources. The questions of including emission nebulae in the Magellanic Clouds, or reflexion nebulae, or large planetary nebulae and nova shells should be separately decided.

(5) The large sizes and strange shapes make a purely descriptive catalogue of limited use. However, a full photographic atlas cannot be undertaken for reasons of cost and duplication with the Mount Palomar Atlas of the Sky.

(6) A compromise would be a catalogue, combined with an atlas of the complete sky, in the form of drawn maps at a scale about $1° = 1$ cm in the galactic belt and much smaller scale away from the plane (about thirty quarto pages in total).

(7) The preparation of such a catalogue is both a work of compilation and of additional research.

H. C. VAN DE HULST
President of the Commission

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Note: *C.G.D.* stands for '*Cosmical Gas Dynamics*', ref. [112].

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COMMISSION 34

Report of Meeting. 14 August 1958

PRESIDENT: H. C. van de Hulst.

SECRETARY: Leverett Davis, Jr.

The *Draft Report*, which was based on material available up to October 1957, was accepted.

The agenda proposed by the President was accepted without modification.

The next item was the consideration of the recommendation of the Presidents of Commissions 29 and 35 that a new Commission on 'Magneto-hydrodynamics and the Physics of Ionized Gases' be established. Following some discussion Commission 34 expressed its support of the recommendation.

A communication on planetary nebulae was presented by Dr G. A. Gurzadian. Theoretical isophotes based on models having dipole-like magnetic fields were presented and compared with a number of observed isophotes. Spiral arms of planetary nebulae were explained as due to the combination of a uniform galactic field and a dipole nebular field. Following discussion of this paper, the Commission considered whether or not it was now appropriate to recommend that a symposium on Planetary Nebulae be held in the near future. A number of experts in the field supported this proposal, it being pointed out that the observational and theoretical results now available make such a symposium appear fruitful.

Two communications dealing with the hitherto largely unobserved interstellar region closer than 300 pc to the Sun were presented. Dr A. Behr described observations on interstellar polarization made at Göttingen by means of a differential photo-electric method for which the mean error was 0^m0006. For stars nearer than 50 pc the observed polarization was barely significant, 0^m0010; but beyond 100 pc it increased rapidly in the galactic plane. The polarization observed had the electric vector more or less parallel to the galactic plane but with strong local distortions. In Bootes an elongated cloud showed a mean polarization of 0^m005; if this is regarded as a manifestation of the local spiral arm, it is directed toward 45° galactic longitude in agreement with radio-astronomical results. Following discussion of this paper a communication describing measurements made at the Carnegie Institution on the 21-cm line at high galactic latitude was presented by Dr W. C. Erickson. A 54-channel receiver was used to determine antenna temperature as a function of radial velocity for gas that was mostly within 1/2 kpc of the Sun. The observations suggest that un-ionized gas is falling toward the galactic plane from both poles, that the Sun is north of the median plane of the gas, and that this plane is skew to the galactic equatorial plane (being to the north near galactic longitude 270°). This paper was then discussed.

The final topic considered by the Commission was faint diffuse nebulae. A communication by Dr B. J. Bok presented a progress report on work with the 8-in. Schmidt at Mt Stromlo Observatory. Photographs were made of the Milky Way from 200° to 340° galactic latitude and were searched for small nebulosities by a blinking technique. It is hoped that the results can be published as an atlas, a catalogue, and charts. A communication by Dr S. L. Sharpless described a punched-card list of H II regions made from the Palomar Sky Survey prints. Data given include the position, a code characterization, and the exciting star. Copies of the punched cards can be made available if it seems appropriate. These communications were discussed, as was the desirability of attempting a catalogue combining all available results. It was urged that publication be not postponed unduly for any individual catalogue because of the hope that a general catalogue would appear. It became clear that the general catalogue under consideration should not include extragalactic nebulae or large planetary nebulae. It seemed impossible to resolve at this meeting the question as to whether the time had come to initiate action on a general catalogue of faint diffuse nebulae or whether further discussion should be postponed until the next General Assembly. Accordingly the President of Commission 34 undertook to arrange further consideration of this problem by those most concerned.