34. COMMISSION DE LA MATIERE INTERSTELLAIRE ET DES NEBULEUSES GALACTIQUES

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MEMBRES: MM. Aller, Ambartsumian, Baade, Beals, C. Bertaud, Bok, Bowen, Cernuschi, Dufay, Dunham, Greenstein, Henyey, Mlle Hoffleit, MM. McKellar, Malmquist, Menzel, P. W. Merrill, F. D. Miller, Minkowski, Öhman, Oort, Schalén, V. M. Slipher, B. Strömgren, Struve, Swings, ter Haar, Trumpler, van de Hulst, Whitford, O. C. Wilson, W. H. Wright, Zanstra.

This Commission was organized at the Stockholm meeting of the Union in 1938, and now after ten years has the opportunity to make its first report. The rearrangement of the fields of the different Commissions at Copenhagen in 1946 gives Commission 34 some responsibility for the entire volume of space between the stars, if not between the galaxies. Since the presence of interstellar material in any region of space may be revealed by emission, reflection, scattering, or absorption of radiation, the study of this material falls under or overlaps the activities of half a dozen other Commissions of the Union. Because of this extent of the relations of the Commission we may consider again the directions in which international co-operation may function to advantage. As pointed out by Schlesinger when the Union was organized, such co-operation is valuable in matters of convention; in avoidance of duplication; and especially in investigations too large for one institution or even one country to undertake.

Because of the world situation and the difficult times through which we have been passing, it seems advantageous to bring together brief summaries of the recent work of different members of the Commission and their plans for the near future, which, though necessarily incomplete, may serve as a basis for discussion and for formulation of further plans both individual and collective. In the nature of the case much important work has been done outside the membership of the Commission, but even a partial survey of the present situation should be of some value. The theoretical investigators presumably need little organization and advance planning, but information on current and future observational programmes can be of value to all workers in the field.

About half of the members of the Commission have responded to the chairman's communication, and these reports are given herewith without an attempt to classify them according to subject matter. Following the reports are some of the proposals which might well be discussed in the meetings of the Commission at the next General Assembly of the Union.

The Commission is indebted to Dr Walter S. Adams for permission to include in this report an abstract of the second Henry Norris Russell Lecture delivered before the American Astronomical Society in December, 1947. The abstract follows.

THE GASEOUS CLOUDS OF INTERSTELLAR SPACE

The material upon which this lecture is based consists of spectral observations of 300 stars, nearly all of types O to B9, observed with the Coudé spectrograph and 100-inch telescope at the Mount Wilson Observatory. Four-fifths of the spectra were photographed on a linear scale of 2·9 A. to the millimeter, and one-fifth on the smaller scale of 10 A./mm. The range of wave-lengths covered, λ3500 to λ4700, includes a large proportion of the more important interstellar lines.

A brief summary outlines the discovery of numerous sharp interstellar lines in addition to H and K which has raised the number now known to a total of 26; the complete identification of the new lines, and the recognition that no less than 11 of them originate in molecules of the diatomic gases CH and CN; and the discovery by Beals of the double character of the H and K lines in the spectra of a few interstellar clouds.

The study of the observational material has included: (1) a search for interstellar lines other than H and K, with especial reference to the molecular lines; (2) an examination of the structure of H and K; and (3) estimates of the intensities and measurements of the radial velocities of all interstellar lines including the components of H and K.

About one-sixth of the spectra of the 300 stars show the molecular lines in the intervening gaseous clouds. The chief conclusions to be drawn are:

1. Relatively few stars show essentially all the atomic and molecular lines at the same time. Examples are ζ Ophiuchi, ζ Persei, ρ Ophiuchi, and some others. H and K are not exceptionally strong in these stars.

2. Lines of ionized CH are usually stronger than those of neutral CH, and appear in many clouds in which neutral CH is not observed. The ratio of the intensities of ionized to neutral CH shows a wide range.

3. Neutral CN is usually present with neutral CH.

4. Lines of neutral iron and $\lambda 4227$ of neutral calcium are always faint, and seem to appear when H and K are very strong.

5. Stars close together in position usually show the same interstellar lines.

Of the stars investigated 122 show double or multiple interstellar H and K lines. They are divided as follows: double, 100; triple, 17; quadruple, 4; five components, probably 1 (P Cygni). With few exceptions the most complex lines appear in stars of very low galactic latitude, and very frequently the same structure is repeated in stars which lie close together. In only one star, HD 193322, is the strongest molecular line, $\lambda 4232$, clearly double, but when H and K are complex the molecular lines appear wider than normal.

The radial velocities given by the single H and K lines, or by their strongest component if complex, are, after correction for the solar motion, very low, averaging 5 km./sec. The molecular lines give values accordant with H and K. In a few stars like χ Aurigae, which show double H and K with nearly equal components, the molecular lines give velocities corresponding to the mean of the two components. Since most of the stars are bright and relatively near, the effect of galactic rotation should be small, and such is found to be the case.

On the other hand, some of the fainter components of H and K, originating probably in smaller and thinner clouds, show very considerable radial velocities. In 21 cases these exceed 30 km./sec. and in five cases 50 km./sec. The highest velocity observed is +96 km./sec. for a well-marked component in the spectrum of a seventh magnitude star, HD 169454, in Sagittarius. HD 199478 in Cygnus shows two components which give velocities of +41 and +60 km./sec., respectively. These motions may be those of small thin interstellar clouds moving rapidly with reference to the much larger and deeper clouds of low velocity.

The question whether the clouds which give rise to the molecular lines may differ from those which produce H and K, and may be considered as circumstellar and related to the stars by means of which they are observed, is of considerable interest. The consistency of the radial velocities derived from the molecular lines as compared with H and K, together with the lack of any correlation between the velocities of the clouds and those of the stars, indicates that such a relationship, if it ever existed, has probably been lost. Even in the case of the Pleiades cluster, for which the argument for circumstellar origin of the molecular lines may be considered strongest because of their abnormal intensities relatively to H and K, the radial velocities derived from H and K and the molecular lines show a difference of +10 km./sec. from the velocities of the stars forming the cluster.

WALTER S. ADAMS

During 1943, 1944, and 1945, thanks to the kindness of Drs J. H. Moore and C. D. Shane, the present writer, then at the University of California, was able to secure at the Lick Observatory spectrophotometric observations of some 45 planetary nebulae for a study of emission-line intensities and particularly the brightness distribution in the monochromatic nebular images. Special emphasis was placed on those objects that showed interesting structural features, e.g. NGC 6720 and 6905 which show lines of the Bowen fluorescence mechanism, the high excitation objects NGC 4361 and 2022, and the binuclear nebulae NGC 6778 and 2440 which resemble NGC 7026. Crossley slitless spectrograms supplemented by plates taken with the Cassegrain spectrograph of the 82-inch McDonald Reflector provide material for a study of the brighter central stars of the planetary nebulae. An analysis of the spectra of the absorption-line nuclei of NGC 2392, 6891, II 4593, 6826, and 6210 suggest that these stars are dwarfs with masses comparable with that of the sun. Absorption lines of C III, C IV, He II, and emission lines of O VI characterize the spectrum of the central star of NGC 246. I have measured emission-line intensities in a number of objects, e.g. the carbon-oxygen type Wolf-Rayet nuclei of NGC 6751 and 6905.

In collaboration with R. Minkowski at the Mount Wilson Observatory I have undertaken an intensive spectrophotometric study of NGC 7027. Mount Wilson plates covering the region from $\lambda 9000$ to $\lambda 3700$ are supplemented by McDonald spectra in the interval $\lambda 5000$–$\lambda 3200$. Vega and Epsilon Persei are the comparison stars. We are measuring the intensity distribution in the continuous background as well as the emission lines in this rich, high-excitation spectrum.

LAWRENCE H. ALLER

Data on intensities of interstellar calcium and sodium lines have been collected at the Dominion Astrophysical Observatory for about 250 O to B0 stars, and it is proposed to prepare this material for publication as soon as possible. Parts of the work have already been published in *M.N.* **93**, 585, 1933; **94**, 663, 1934; **96**, 661, 1936; *Ap. J.* **87**, 568, 1938; *Pub. A.A.S.* **9**, 115, 1937. It is intended to collect all material on interstellar lines by the writer into a single publication giving intensity and radial velocity data for each line measured.

General reviews of the field of interstellar matter have been published in *M.N.* **102**, 96, 1942; and *Pop. Astr.* **52**, 47, 1944. A programme of observations of spectrophotometric gradients of early-type stars was begun at Victoria for the purpose of investigating the subject of space reddening and gradients were measured for about sixty stars. The transfer of the writer to Ottawa in November, 1946, has interrupted this programme, but it is hoped to carry it on with a different type of equipment.

The writer has felt the need for some means of unification for the numerous systems of indicating the colour of a star. A certain amount of confusion is inevitable in trying to correlate spectrophotometric gradients secured by photography, photoelectric gradients, photographic colour indices, and photoelectric colour indices of various kinds. If some means could be found of reducing all four to a common system, say that of photographic gradients, I believe that it would contribute to the advancement of the subject.

C. S. BEALS

The work by myself and my immediate associates at Harvard Observatory can be briefly summarized under the headings that follow:

1. *Colours of faint Henry Draper Extension Stars. Ap. J.* **101**, No. 3 of May 1945, contains two papers that deal largely with star colours. The first, written jointly with Mrs Rendall-Arons, deals with the section of the Milky Way in Monoceros, the second, written jointly with Miss Frances W. Wright, refers to two fields in the southern hemisphere. Miss Olmsted and I are now working on a similar investigation for eleven centres in Gemini and Orion. It is the primary purpose of these studies to obtain information about the stellar distribution for this section of the Milky Way. But, incidentally, we obtain colour excesses for many faint B and A stars, and star counts for the entire region under investigation, which together serve to fill in the detail about the distribution of interstellar dust as derived from the colour excesses of O and B stars.

2. *Faint Cepheids.* During the war Father Francis J. Heyden and I began to assemble plates for a study of the colour curves, blue and red, for seven faint Cepheids in Cygnus. The results of this work have been published by Father Heyden in the *Astrophysical Journal.* Dr Joseph Ashbrook has under way a similar investigation for a number of Cepheids in Cassiopeia, and I am now working with our Jewett Schmidt telescope on some faint Cepheids in Cygnus and in Ophiuchus. We are much impressed with the potentialities of this method, which promises to give accurate information about faint reddening at great distances.

3. *Theoretical Studies.* A full day of the Harvard Observatory Centennial Symposia was devoted to problems of interstellar matter. My own paper at this symposium dealt with condensations in interstellar material and their probable evolution, a subject on which I had done some preliminary work jointly with Miss Edith Reilly.

4. *Plans for the Southern Hemisphere.* The principal large-scale project for the future is one that Shapley and I are planning to undertake jointly with the new Baker-Schmidt telescope at Bloemfontein. We shall have one-third of the observing time on this telescope with the remaining two-thirds going to the Armagh and Dunsink Observatories. If all goes well, we expect to have a large objective prism for use with this telescope; the free aperture will be 32 inches and the focal length 120 inches. Our first plans call for exhaustive star counts, spectra and colour surveys for a limited number of centres. Preference will be given to fields at low galactic latitudes, especially in Carina, in and near the Southern Coalsack, and in the central region of Sagittarius. I am now doing at Oak Ridge preliminary work on the establishment of photometric standard sequences in blue and red in some of the Harvard Standard Regions at $+15°$ (C-regions).

5. *Photoelectric Work.* Since the end of the war, we have become very much impressed with the need of supplementing our photographic and spectral work on colours and colour excesses with photoelectric work. One of our students, Albert Linnell, is building a photometer for use on the 61-inch at Oak Ridge, and if this works out successfully, and if we can find some cash for further development, we plan to build one or more additional photometers, especially with the idea of using one in the southern hemisphere. Not only would this instrument come in handy for work on individual Cepheids, O and B stars and the like, but such a cell could probably be used also effectively in the establishment and checking of the scale of our faintest blue and red standard sequences.

BART J. BOK

Terminology. There has been some discussion of the advisability of agreeing on an unambiguous and theoretically correct set of terms in the field of interstellar material. (1) The words 'dust' and 'smoke' refer to different types of small aggregates. Dust is the result of pulverization of larger pieces of solid matter; smoke, in the United States, is usually the end product of a chemical process involving oxidation. Use of one term or the other should only be in the proper context of a theory of the origin of the small interstellar grains. (2) The term 'particles' has become, in modern physics, applicable mainly to elementary atomic or nuclear particles, including photons. A more specific word like grain or granule may be preferable. (3) The term 'extinction' covers both absorption (involving change of frequency) and scattering.

Outline of Work since 1938. The general problem of the ratio of interstellar extinction to reddening has been treated in a series of papers; the goal was a distinction between the metallic and dielectric types of granules, and a determination of the distribution function of sizes. My own older spectrophotometric results have been recently surpassed in accuracy by the six-colour photoelectric photometry of Stebbins and Whitford; analysis of these data leads to a probable minimum value of A_{pg}/E_1 of about nine. An investigation by a completely non-spectrophotometric method (with L. G. Henyey) showed that the non-selective extinction is small. It may be suggested that care be taken in conversion of colour excesses on one colour system to another because of the 'curvature' of the relative energy differences between reddened and unreddened stars. The best technique for calibration of the ratio of absorption to reddening at present seems to be a determination, on each colour system, of the colour-excess of stars whose reddening on a very wide base line is known. With L. G. Henyey a series of theoretical and observational investigations on the colour effects in reflection nebulae was made; unfortunately the multiple diffusion of light, if a nebula is optically thick, hides most of the differences between true absorbing and scattering grains. However, our investigations did indicate that the nebulae are slightly bluer than their illuminating stars, that the albedo of the material is high, and that most of the scattering is of a forward-throwing type, as is expected for dielectric granules. Observations which indicated the existence of diffuse 'galactic light' in the Milky Way also lead to the same conclusions.

A group of astrophysical problems is involved in the spectrophotometry of diffuse galactic nebulae. A steep Balmer gradient was found, probably due to interstellar reddening. The complex reflection, emission line and continuum spectrum of the Orion nebula has been accurately measured; the theoretical interpretation is not completely satisfactory. It may be noted that relatively high-resolution slit spectrograms with an $f/1$ camera can now be obtained of many galactic nebulae, and that this field is quite unexplored. Observations of nebulae at radio frequencies are to be desired. Recent work has been on stars deeply involved in bright and dark nebulosity; such as the T Tauri stars, and the variable nebulae, NGC2261 and 6729. The variable nebulae apparently produce absorption lines of hydrogen. Wide peculiar emission is observed near T Tauri stars in dense dark regions. In collaboration with Struve I found peculiar absorption lines in the variable stars in the Orion nebula. With Aller I found no peculiarities in giant stars in nebulae. Apparently the low radiation pressure in dwarfs permits both solid and gaseous components of the interstellar medium to approach more closely to the star. This field of the interaction of the interstellar medium with the stars may prove important also in the study of the interstellar grains.

JESSE L. GREENSTEIN

In three papers (*Stockholms Obs. Ann.*, Bd. **13**, No. 4, 1939; *Uppsala Astr. Obs. Ann.*, Bd. **1**, No. 7, 1943 and No. 8, 1945) I have treated the problem of determining the distance, radial extension and absorption of a dark nebula. E. Vanäs has published a spectrophotometric study of stars in Cygnus, embracing the well-known 'Northern Coalsack' (*Uppsala Ann.* Bd. **1**, No. 1, 1939), and G. Wernberg has made a spectrophotometric investigation on stars in bright and dark regions in Cepheus (ibid. No. 4, 1941). Works on dark nebulae in Auriga, Cygnus, and Taurus are in progress, embracing the determination of red, yellow, and blue magnitudes together with spectral classification.

K. G. MALMQUIST

In the series of papers 'Physical Processes in Gaseous Nebulae', published in the *Astrophysical Journal*, we have been attempting the solution of certain detailed problems of a rather general nature. In each case, we have adopted some idealized nebula and carried through a detailed solution, which I think is fairly accurate both physically and mathematically, to discover what effect the dilute high-temperature radiation from a star would have on a gaseous envelope.

In working out this series of papers, I have had the extremely valuable assistance of a number of scientists, physicists as well as astronomers. Without their aid, I should not have been able to carry the problem through as far as it is at present. We started out to study the luminosity of the hydrogen nebulae, since hydrogen appears by far to be the most abundant material. Later on we discussed the effect of other processes that arise from the presence of impurities, in particular the metastable ions of oxygen, nitrogen, neon, etc.

Our studies, therefore, are by no means limited in application to conditions in the planetary nebulae. In many cases they could be applied to determine the physical state of interstellar material.

It seems to me that the chief gap in our present knowledge, from the interpretation of both interstellar material and nebulae, lies in the field of atomic parameters needed to describe the phenomena. We need to know more specifically than we do at present the various excitation functions, collisional parameters, radiation transition probabilities, etc., for a number of atoms and molecules. Hebb and I made a start along this type of computation, but we limited our discussion to one of the simplest cases, namely O III. Certainly a great deal more work needs to be done here. I understand that Aller and Ufford have made some progress in the important case of O II, but I believe that their work relates more to transition probabilities in radiation than to those for collision. I have no work of this sort going on at the present time although I have been in correspondence with D. R. Hartree of Cambridge, England, with respect to some computations that he has been planning. I now have one student well trained in the method of wave mechanics, but he is working on problems more closely associated with stellar atmospheres and with interstellar space. However, some of his transition probabilities will be useful for calculating the densities of forbidden iron lines, like those that appear in Eta Carinae. Owing to the fact that so many of the physicists have rushed off to study the nucleus of the atom, we astronomers are left alone with respect to the exteriors of atoms and molecules. If we are to get the information, we shall either have to make the calculations ourselves or perhaps inspire some physicist to carry on the work. Shortley (of Ohio State University), Aller, and Herget have some long-range plans for the solution of atomic problems with the aid of the computing machinery at Cincinnati. I cannot now forcast what direction these calculations will take, but I am glad to note that Shortley has a continued interest in atomic exteriors.

I hope shortly to publish an investigation that I have carried out on the earth's ionosphere during the war. This treats the ionosphere in much the same way that we handled the nebular problem. Some of the new techniques that I have worked out for the ionospheric studies may be useful in further interpretation of nebulae and possibly even for matter in interstellar space.

With respect to the nebulae, I have one further improvement in mind. Our initial assumptions implied that the matter of the nebula was uniformly distributed in a shell around the central star. I now believe that the planetaries, like prominences, are distinctly filamentary. A recalculation will undoubtedly cause us to revise our estimates of densities and masses of the nebulae. The tendency will be to lower the masses and raise the densities.

From the standpoint of interstellar space, there is one factor that worries me. Lacking any direct information to the contrary, theorists have tended to calculate the ionization as if it were produced by dilute radiation from a large number of black bodies at the spectral temperatures of the stars. Now, the radiation of greatest interest to us is the radiation beyond the series limits—from 1500 A., let us say, to 200 A. or higher. I am not quarrelling with the black-body assumption as long as we remember that it is definitely an assumption. However, one may argue that the amount of available energy is far greater than that from a black body. For example, in the case of the sun, we know that the corona must send out large amounts of ultra-violet radiation at a temperature more nearly of a million degrees rather than a temperature of 6000°. I assume that other stars may do the same. In such a case, the ionization would be far greater than the simpler assumption would indicate. Or, perhaps, one might use inverse reasoning and say that the hydrogen layers of stars and the hydrogen immediately surrounding the star would tend to absorb a proportion of the ultra-violet radiation and convert it to the visible range, forming bright nebulae. In this case, we would have less radiation than our computations would indicate. I do not know the answer, and have thus tended to keep myself out of the interstellar field until I can get a better estimate of the spectral distribution in the far ultra-violet. Certainly, I see no real justification for the assumption that a star must radiate like a black-body over so long a range of its spectrum. In some cases, I might even expect that the radio waves from stars might exert some effect upon the ionization in interstellar space. Also, the increasing evidence for stratification and for cloud formation in interstellar space must be taken into account.

DONALD H. MENZEL

General. It is now clear that the chief interstellar lines are formed largely in relatively thin curtains stretched at irregular intervals between the stars. Calculations based on uniform distribution of interstellar gas may, therefore, be greatly in error and are probably no longer profitable. More detailed investigations should be preferred.

Abundance of Chemical Elements. Further study is needed of the probable distribution of interstellar atoms among various stages of ionization. Condensation or chemical combination also should be given consideration because they might play an important part in removing atoms from the states in which they can produce the observed atomic lines.

Broad Unidentified Lines. These lines are probably caused by dust particles. The correlation of their intensity with space reddening should be further studied. Laboratory materials (perhaps in thin films) at very low temperatures would seem a promising method of attack on the identifications.

PAUL W. MERRILL

In connection with the general spectrophotometric work at the Stockholm Observatory much attention is being paid to different problems relating to interstellar absorption. In 1941 Ramberg's investigation of the Hyades (*Stockholms Obs. Ann.* **13**, No. 9) gave as a by-product some valuable information about the obscurations in Taurus. Among investigations in progress which are expected to give interesting contributions to our knowledge of interstellar absorption Elvius's spectrophotometric work in Kapteyn's selected areas and Larsson-Leander's study of faint open clusters should be mentioned.

Photoelectric work made by me on selected reddened B stars (*Stockholms Obs. Medd.* No. 55, 1944) have given evidence in favour of the opinion that the $1/\lambda$ law is not governing the selective absorption. In fact the observations indicate a steeper gradient of the absorption curve on the red side of λ5000 A. than on the violet side of the same wave-length, a result which agrees well with determinations made by Baade and Minkowski, Strohmeier, and by Stebbins and Whitford. An improved photoelectric colorimeter is now being constructed which will allow measurements of two colour indices on each side of λ5000 A.

Though not strictly in the scope of Commission 34, Lindblad's investigations of the interstellar absorption in some extragalactic systems ought to be mentioned here (*Stockholms Obs. Ann.* **14**, No. 3, 1942; *Ap. J.* **104**, 211, 1946, together with R. Brahde). Also my polarigraphic studies of illuminated clouds in the great Andromeda Nebula may be of a certain interest (*Stockholms Obs. Ann.* **14**, No. 4, 1942).

YNGVE ÖHMAN

The possible existence of a rough equilibrium between the solid particles of the gas in interstellar space was studied by van de Hulst and myself in *B.A.N.* No. 376, as well as in my George Darwin Lecture (*M.N.* **106**, 159, 1946). It was suggested that for gases other than hydrogen and helium the equilibrium was maintained by the evaporation of particles at mutual collisions caused by the random motions of the interstellar clouds. The investigation led to a theoretical determination of the distribution function of the radii of the particles, of the 'absorption' coefficient in the galactic plane, and of the way this varies with the wave-length.

I have indicated that with this mechanism there would only be a relatively narrow range of gas density at which solid particles could develop sufficiently to give rise to absorption phenomena. This may possibly have a bearing on the occurrence of rings of absorbing matter, which are typical in early-type spirals (still unpublished).

I have also investigated the effects of the heating of the gaseous parts of the clouds upon encounter, and have shown that it may easily explain the luminescence of rim nebulae like that south of ζ Orionis. It is not unlikely that also some of the shells of old novae (Nova Persei 1901) and supernovae (Veil nebulae in Cygnus) derive their luminosity from such a process. This investigation has not yet been finished.

Some of the hydrodynamic problems connected with the motions and collisions of interstellar gas clouds have been studied by Prof. J. M. Burgers of Delft; these studies have appeared in *Proc. Amsterdam Acad. Sci.* **49**, 589 and 600, 1946; ibid. **50**, 262, 332, 442 and 573, 1947.

J. H. OORT

The distribution of particle sizes and the theoretical representation of observed absorption curves (Baade-Minkowski and Strohmeier) has been discussed in *Uppsala Ann.* **1**, No. 2, 1939. *Uppsala Medd.* **75** = *Zs. f. Ap.* **17**, 260, 1939, contains computations of the radiation pressure on small particles and the significance of radiation pressure for the formation of dark clouds. The structure of the dark cloud in Auriga is discussed in *Uppsala Medd.* **78**, 1940.

A study of reflection nebulae is in *Uppsala Ann.* **1**, No. 9, 1945. It is pointed out that a study of the variation of the colour of the nebula with the distance from the exciting star is of importance for the investigation of the constitution of the nebula. An attempt has later been made to measure the colour of the Merope nebula, but the results have not yet been published.

CARL SCHALÉN

1. *Galactic Nebulae*

My studies of planetaries and of their nuclei, during the period 1938–47, have mostly been published in *Ap. J.* and *Proc. Nat. Acad. Sci., Washington*. Here are some results:

(*a*) Certain nebulae which are very rich in nitrogen have a WC-nucleus which contains *no* nitrogen (Ex.: Campbell's envelope star; HD 167362).

(*b*) Certain nuclei of Wolf-Rayet (or Of-) type contain N and C with similar abundances, hence cannot be classified as WN or WC (Ex.: nuclei of NGC 6543, IC 4997, NGC 6572, NGC 6826(?); IC 418). Similar things are found in novae.

(*c*) In discussions of ionization in nebulae (Zanstra mechanism), the discrete far ultraviolet emission or absorption features of the nucleus should be taken into account (Ex.: NGC 6543), as well as stratification effects.

(*d*) In Of-nuclei of planetaries, peculiar line selectivities appear, presumably due to fluorescence effects.

(*e*) Recommendations: Forbidden lines of metals (Ex.: [Fe II, III, VII]) are observed in nebulae. It is essential that theoretical calculations be made of the transition probabilities in [Fe II] and [Fe III]. (Presumably, the strongest [Fe II] transitions have a much higher probability than [O I] or [N II]).

2. *Interstellar Material.*

(*a*) In 1937, in collaboration with L. Rosenfeld, an interstellar molecular line (CH) was identified.

(*b*) As is apparent from Herzberg's note (*Ap. J.* **94**, 381, 1941) and from Ledoux's article (*Pop. Astr.* **49**, 513, 1941), it was my discussion of the sharp unidentified interstellar lines which led Herzberg to the attribution of three of these lines to CH^+.

(*c*) In *Lick Contr.*, Ser. II, No. 3, I gave a discussion on cometary and interstellar molecules. This was developed in a report to the I.A.U. meeting in Copenhagen.

3. *Suggestions to encourage Laboratory Work*

(*a*) On absorption spectra at low temperature (around 3° K) of solids consisting of cosmically abundant atoms (for identification of Merrill's diffuse interstellar lines in the visual region; one may be due to solid oxygen).

(*b*) On the spectra of CH^{++} (the unidentified 'interstellar' line at $\lambda 3579$ may be due to CH^{++}), NH^{+} and CN^{+}, likely to be found in interstellar absorption.

P. SWINGS

The formation of smoke particles in interstellar space was investigated by Dutch astronomers and physicists in the years after 1942. It appeared (D. ter Haar, H. C. v.d. Hulst, J. H. Oort, A. J. J. v. Woerkom, *Ned. Tijds. v. Nat.* **10**, 238, 1943; D. ter Haar, *B.A.N.* **10**, 1, 1943; *Ap. J.* **100**, 288, 1944) that it was possible to account for their formation by assuming that they were condensation products. This condensation was possible, notwithstanding the low density in interstellar space, because of the low temperature (~3° K) of the particles. The condensation seems to be dependent on the gas density, the most favourable density being 2–200 atoms per c.c. The question of the density of diatomic molecules was also studied (H. A. Kramers, D. ter Haar, *B.A.N.* **10**, 139, 1946), and it was found that, taking into account all possible reactions, the observed density of CH, CH^{+} and CN, could be explained. The mechanism of the formation of these molecules was found to be radiation capture. This radiation capture will also be the main mechanism of the formation of larger molecules.

D. TER HAAR

The properties of the solid particles in interstellar space have been investigated both from a theoretical and from an observational point of view. In the theoretical study I considered the interaction between the interstellar gas and the solid grains. The results are that the temperature of the grains is 10 to 20° K, and that all the striking atoms and ions freeze down (Cernuschi's ideas are wrong). Most of the H, He and Ne will evaporate again from the particles. The final composition must be something like ice with impurities (certainly not plain metal). Consideration of the large-scale and long-range features of the theory leads us to believe that the particles grow gradually by accretion and then suddenly vaporize during a collision of two clouds.

The observational data required first a new study of Mie's theory. The main results of this investigation were: (*a*) an increased collection of numerical data, and (*b*) a new set of formulae and curves for refractive indices near 1, both with and without absorption. The observations themselves still admit of a fairly wide range of explanations. However, the possibility of strongly absorbing particles like metal particles is definitely excluded. The effective size can be estimated very well, but the size distribution is uncertain. An interesting by-product of the theory is that particles of this size cannot show absorption lines or bands similar to the unidentified interstellar lines and bands. Albedo and phase-function are in agreement with the observations. An estimate of the ratio A/E by extrapolation of the selective extinction curve leads to about the same value (with the same degree of uncertainty) as direct measurements of this ratio.

I have recently taken spectra of the Veil nebula and other diffuse nebulae in order to obtain some observational data pertinent to Oort's theory of collisions of interstellar clouds.

H. C. VAN DE HULST

The work of the Washburn Observatory on interstellar matter was at first devoted to a survey of the regions of the sky where its presence could be detected by the reddening of standard objects. Colours were measured photoelectrically by comparing the relative response through two filter glasses. The general survey of 1332 B-stars (*Ap. J.* **91**, 20, 1940), covering essentially all known stars earlier than B5 north of $-40°$, showed a very spotty distribution of interstellar material, but in general a high concentration near the galactic plane. Absorption in space near the sun was investigated at the north pole of rotation and in the region of the galactic poles using the colours of the more numerous A-stars. Here spectral classification difficulties enter (Keenan and Babcock, *Ap. J.* **93**, 64, 1941; Morgan and Bidelman, *Ap. J.* **104**, 245, 1946). While there may be a clear space out to about 150 parsecs in the direction of Polaris, the galactic caps show about the same reddening that would be expected on the average at an equal distance in low galactic latitudes.

Following the early proofs by Mrs Rudnick (*Ap. J.* **83**, 394, 1936), Hall (*Ap. J.* **85**, 145, 1937), and Greenstein (*Ap. J.* **87**, 151, 1938) that the reddening follows approximately a λ^{-1} law, further study was undertaken over as wide a range of wave-lengths as possible. At first a moving-slit spectrophotometer was used (*Ap. J.* **90**, 209, 1939), but later six filters with effective wave-lengths ranging from 3530 to 10,300 A. were adopted. A comparison of reddened and unreddened B-stars showed (*Ap. J.* **98**, 20, 1943) a slightly 'curved' rather than a linear relation between absorption and inverse wave-length. All regions of the sky showed the same relation, indicating that the reddening portion of the interstellar medium has a uniform composition in all parts thus far investigated. The difficulty, emphasized by Greenstein (*Ap. J.* **104**, 403, 1946), that extrapolation of the observed curvature leads to an excessive ratio between total and selective absorption, was resolved when measures out to 21,000 A. with a lead-sulphide photoconductive cell (*Ap. J.* in the Press) confirmed a reverse curvature in the infra-red predicted by Oort and van de Hulst (*B.A.N.* **10**, 187, 1946).

Two surveys of the sky brightness of the Sagittarius region, one with a caesium-oxide cell at effective wave-length 10,300 A. (*Ap. J.* **106**, 235, 1947), and a second, at the Lick Observatory, with a lead-sulphide cell at effective wave-length 20,000 A. (unpublished) showed a 'bulge' along the galactic equator centred at longitude $326°{\cdot}5$. This was interpreted as radiation from the central region of the galaxy. The total photographic absorption in front of the bulge may be as small as 6 magnitudes, a value lower than previously supposed, but perhaps plausible if the central region and parts of the path to it are of Baade's Population II, where interstellar material is believed to be non-existent.

The problem of the distribution of interstellar material is intimately related to study of galactic structure. Both depend upon the discovery of distant high-luminosity objects such as B-stars and Cepheids (such as the 'Oort Cepheids', *B.A.N.* **9**, 325, 1942). The recognition of the two population types means that we must expect regions of the galaxy where such objects do not exist, and where less satisfactory standard objects such as red giants and cluster variables will be the only ones available.

Almost all the observations by the staff of the Washburn Observatory in this field have been carried out at Mount Wilson and published as *Contributions of the Mount Wilson Observatory.*

A. E. WHITFORD

The problem of the determination of the abundances of H, Na, Ca, K, and Ti in interstellar space has been investigated. The degree of ionization of Ca I, Ca II, Na I, and K I in interstellar space was recalculated, taking account of the effect of recombination to excited states. Making use of theoretically calculated continuous absorption coefficients for the excited states of the atoms in question, correction factors to the previously used equation of ionization were derived. These factors range from 3 to 1600. The problem of the extension of H I and H II regions has also been considered. It was found that the typical gas cloud within 1000 parsecs is un-ionized, with a hydrogen density around 10 atoms/c.c. The relative abundances of the elements are similar to those derived for stellar atmospheres (*Ap. J.* **108**, 242, 1948, cf. also this volume, p. 471).

In collaboration with W. A. Hiltner a survey of interstellar hydrogen emission was undertaken, using a photoelectric photometer equipped with two interference filters having maximum transmission at 4861 A. (H_β) and 4600 A. (comparison region). The photometer was attached to the 82-inch reflector of the McDonald Observatory. The intensity of fields $1^\circ.3$ in diameter was measured through the H_β and the comparison filter, alternately. Fields with stars brighter than 15^m were avoided. The intensity ratio H_β:Comparison for the night sky plus faint background stars was determined from comparison regions, partly regions outside the Milky Way, partly regions of the Milky Way which according to the investigations of Struve and Elvey with the nebular spectrograph are known to have no interstellar hydrogen emission. The ratio H_β:Comparison observed in the absence of hydrogen emission proved very constant. Presence of interstellar hydrogen emission could now be detected through an excess of the observed H_β intensity over the value derived in multiplying the observed comparison intensity by the standard H_β:Comparison factor. The faintest interstellar hydrogen emissions observed by Struve and Elvey were just measurable with this technique. The total observing time for the measure of one field was about 4 minutes.

A survey of interstellar hydrogen emission in the Milky Way from galactic longitude 90° to 200° was made. Fields at galactic latitudes +3°, 0°, and −3°, and 3° apart in galactic longitude, were measured. A region of about one hundred square degrees containing the extended emission region around S Mon was covered with fields 1° apart. (The results of the survey will be published in the *Ap. J.*)

BENGT STRÖMGREN

PROPOSALS FOR DISCUSSIONS

Several topics from the foregoing reports may perhaps be discussed profitably at the time of the General Assembly.

The suggestion by Greenstein that some agreement on terminology might be advisable, such as the choices between dust and smoke, particles and grains, extinction, absorption, and scattering.

The unification of different systems of indicating the colour of a star, as pointed out by Beals, could well be discussed. While the North Polar Sequence and Selective Areas give standards of photographic magnitudes and colours for temperature-reddened stars, nowhere are there such standards for space-reddened stars. In view of the increasing attention that must be given to total and selective space absorption in all studies of the galaxy, a joint discussion of standards for space reddening with other Commissions such as 25, Stellar Photometry, 32, Selected Areas, 36, Spectrophotometry, and perhaps others, would seem to be in order.

The need of more spectra of faint stars, especially in the southern hemisphere, applies to the work of this Commission as to others. Luminosity classes for the B-stars in the *Henry Draper Catalogue* are needed to extend the study of space reddening in the southern Milky Way.

JOEL STEBBINS
President of the Commission

Report of meeting

PRESIDENT: Prof. J. STEBBINS.

SECRETARY: Dr C. SCHALÉN.

I. DARK MATTER

(1) The proposal by Greenstein concerning some agreement on terminology (dust-smoke, particles-grains, extinction-absorption) was discussed. On the suggestion of Dr Oort it was decided to leave the matter open.

(2) The proposal by Beals for the unification of different systems of indicating the colour of a star was discussed.

OORT: We must find the stars which are unreddened and which can serve as basis, e.g. A-stars near the galactic pole.

STEBBINS: Colour is very susceptible to spectral type; early B-stars are the only ones where the classification has no importance.

(3) The need of more spectra and absolute magnitudes of faint stars especially in the Southern Hemisphere was discussed. Recommendation adopted by the Commission: Spectra of early-type stars in the Southern Hemisphere should be determined at as early a date as possible.

II. BRIGHT NEBULAE

(4) Dr Zanstra summarized the main points of a theoretical paper on scattering with redistribution and radiation pressure in a stationary nebula ready for publication.*

SPITZER: I have only general feeling that it is important to compare the abundance of elements in the planetary nebulae and the stars.

Strömgren drew attention to gaseous nebulae where the geometrical conditions are less favourable. It is even more important to know the abundance of the elements in gaseous nebulae.

Ambartsumian reported that Prof. V. V. Sobolev of the Leningrad University has worked out a general theory of the radiative equilibrium for the case of the non-coherent radiation which includes also the theory of radiative equilibrium of planetaries as a special case. The paper was printed recently in the *Astronomical Journal of U.S.S.R.*

(5) Prof. Heckmann described W. Becker's method of deriving two different colour-indices from determinations of three magnitudes. The plates and filters are chosen in such a manner that the yellow-red colour-index represents the slope of the red gradient, the blue-yellow that of the blue gradient. The colour-index difference is almost independent of interstellar reddening. Prof. Heckmann pointed out that one of the last issues of *Ap. J.* contains a summary of Dr Becker's work.

APPENDIX

A theoretical paper on scattering with redistribution and radiation pressure in a stationary nebula is ready for publication. Work done thus far on $L\alpha$ scattering in nebulae has suffered from two serious imperfections: (1) the line profile has been treated as a rectangular one, whereas actually it is a thermal Doppler profile, and (2) the scattering within this profile has been assumed to be ordinary scattering, while actually it approaches more to one in which, for any frequency absorbed, the re-emission occurs with complete redistribution over the whole of the thermal Doppler profile on account of the individual thermal velocities (Henyey, Spitzer). When these two imperfections are removed, it is shown that, for a stationary nebula of total L_c optical depth unity, the force of radiation pressure for $L\alpha$ scattering with redistribution is only about 1/300 of the $L\alpha$ radiation pressure force under the wrong assumption of ordinary scattering, or about 20 times the radiation pressure force for L_c. A paper in Russian by Prof. Sobolev of Leningrad University which deals with the same subject and leads to similar results has appeared already in 1947, as Prof. Ambartsumian points out.

Reliable and accurate determinations of the magnitudes of the central stars of all known planetaries are long overdue. These, together with Vorontsov-Velyaminov's total brightnesses, or perhaps even better total monochromatic N_1+N_2 brightnesses of the nebulae, could be used for stellar temperature determinations and parallaxes. In this case it would be desirable to determine monochromatic magnitudes for the central stars as well. For such improved material the distance criterion: bolometric magnitude of the central star or total magnitude of the nebula or some other criterion should then first be established.

* See Appendix below.

The most direct and detailed method of comparing the luminosity of a planetary nebula with its central star appears to be the determination of the quantities A_ν which express the intensity of each monochromatic picture in terms of the adjoining star spectrum. It would be very desirable if for one test case one could determine this quantity with the star in the slitless spectrogram having various degrees of extrafocality so as to find its correct value and establish what are the best conditions for determining it. This is particularly of importance since the estimates of the electron concentrations based indirectly on the writer's A_ν values (*Zs. f. Ap.* **2**, 337, 1931) are a good deal lower than more recent determinations by Menzel and Aller (*Ap. J.* **93**, 195, 1947 and **102**, 254, 1945).

H. ZANSTRA