34. COMMISSION DE LA MATIERE INTERSTELLAIRE ET DES NEBULEUSES PLANETAIRES

Report of Meetings, 26 and 27 August 1964

PRESIDENT: Bengt Strömgren.
SECRETARY: Aina Elvius.

Business Meeting

At the first meeting, on Wednesday, 26 August, the Draft Report was approved, subject to minor corrections or additions.

The President reminded the members that most IAU Commissions have Organizing Committees, whereas Commission 34 has not yet created such a committee.

L. H. Aller then spoke in favor of creating an Organizing Committee to which the President could delegate several questions for consideration. This advice should be given to the Vice-President S. B. Pikelner, supposed to be the next President of the Commission (not present at this meeting).

Scientific Meetings

PLANETARY NEBULAE

1. *T. K. Menon. Radio Observations of Planetary Nebulae.*

A report on work done by *T. K. Menon* and *Y. Terzian* at the National Radio Astronomy Observatory.

A systematic attempt was made to measure the radio spectra of 10 planetary nebulae with the 300-foot radio telescope at NRAO. Observations were made at 1410 and 750 MHz. Combining these observations with the 10 cm ones by Lynds (*Publ. nat. Radio Astr. Obs.*, **1**, no. 5, 1961) the radio spectra of the planetary nebulae were derived. The planetaries NGC 6853, NGC 6720, NGC 7293 and NGC 7662 have typical thermal spectra expected of optically thin nebulae. The planetaries NGC 6543, NGC 7009 and IC 418 show definite evidence of being optically thick at the lower frequency range, and NGC 7027 and NGC 6572 are both optically thick below 3000 MHz. The nebula NGC 3242 seems to have a non-thermal spectrum.

The observed radio frequency fluxes at the optically thin part of the spectrum were compared with the values predicted by Osterbrock (*Annual Reviews of Astronomy and Astrophysics*, **2**, 95, 1964) from measured Hβ fluxes using the recombination theory. The agreement between the observed and predicted values is in general very good. Only in a few cases are the predicted values greater than the observed ones. In these cases the flux at the optically thin part of the spectrum is based on the 10 cm observations by Lynds, which have a tendency to be systematically lower than expected from a smooth extension of the spectra. Also the interstellar extinction corrections on the Hβ fluxes made by Osterbrock and O'Dell could introduce some error in the predicted fluxes.

The most interesting result about the radio spectra is that five planetaries show effects of high optical depth even at 750 MHz. This fact is used to compute electron temperatures since at high optical depth the nebulae radiate essentially like black bodies. The derived electron temperature values are in reasonable agreement with the available optical values, except in the case of NGC7027 where there is a large uncertainty in estimating the size of the source.

Discussion

W. Liller asked whether Menon or Terzian had tried to observe neutral hydrogen in some of the optically thick planetaries. *Y. Terzian* replied that no 21 cm observations had yet been made for the objects reported on here, but such observations would be made in the future.

R. Minkowski remarked: According to a private communication, a still unpublished investigation of planetary nebulae by O. B. Slee and D. W. Orchiston with the 64 m reflector at Parkes shows results in full agreement with those reported by Menon. Observations were carried out at 11 cm, 21 cm and 48·5 cm. For the majority of the planetaries, the ratios of the flux at 11 cm to that at 21 cm are grouped around unity, in the range from 0·5 to 1·5. NGC 3242 with a ratio of 0·70 shows non-thermal radiation, as do NGC 3132, NGC 5882, IC 4593 and 4634 with ratios in the range 0·57 to 0·71. It may be noted that NGC 3242 is one of the planetaries which show structural detail suggesting the presence of a magnetic field.

2. The *Catalogue of Planetary Nebulae*, by L. Perek and L. Kohoutek, which is supposed to appear in 1965 (Publishing House of the Czechoslovak Academy of Sciences), was described by *Perek*. It will contain observed data and references to original papers, and will be arranged so that the first part contains three tables:

1. *General List*	2. *Nebulae*	3. *Central Stars*
α, δ (1950)	Accurate position	π
p_α, p_δ	Diameter	μ
l^{II}, b^{II}	Radial velocity	m
Index to detailed tables	Magnitude	Sp.
Discoverer, year of discovery	Surface brightness	
	Spectrum	

The second part of the catalogue will give finding charts, approximately 5 × 5 cm or 10′ × 10′. The numbering system for the planetaries will be based on 1° square in the galactic coordinate system.

P. Swings reminded us that just 100 years ago the first line spectrum of a planetary nebula was observed by Huggins. *Perek* then remarked that, 200 years ago, the first planetary nebula was discovered.

M. J. Seaton stressed the importance of the catalogue, and asked how the parallaxes had been estimated, as they are very difficult to determine. *Perek* replied that they had been copied from original papers by other authors.

3. *A Catalogue of Southern Planetary Nebulae* will be published by K. G. Henize and B. E. Westerlund. *Henize* gave the following report: I have surveyed the southern sky for objects showing Hα emission, using the same objective-prism camera used by Paul W. Merrill and R. Minkowski in their survey for such objects at the Mt Wilson Observatory. This camera has a red-corrected 10-inch Cooke-triplet lens and gives spectra with a dispersion of 450 Å/mm at Hα. The southern survey includes the entire sky south of $-25°$ as well as two small regions north of this limit.

Those objects which show strong Hα emission with little or no continuum have been classified as probable planetary nebulae. Additional criteria are frequently available on these plates to provide confirming evidence that the objects are indeed planetary nebulae. These criteria are: resolution of the nebular disk at Hα, resolution of the [N II] λ 6584 line from Hα, and presence of the nebular lines [O III] λ 5007 or [O I] λ 6300.

A catalogue of observed data has been compiled for 466 objects, both previously known and newly discovered, which have been classified as planetary nebulae. The data to be published include: relative intensity of Hα emission; relative intensity of the continuum, if any; the degree of resolution of the Hα emission line; the angular diameter if a disk is resolved; and the λ 6584/Hα ratio, if observable.

Of the 466 objects, 280 have been previously catalogued as planetary nebulae by other observers prior to 1961. The region of uniform survey south of −25° contains 342 objects of which 193 have been previously observed. B. Westerlund and I have obtained direct photographs with the Mt Stromlo 74-inch reflector of nearly all the 149 newly discovered objects south of −25°. Of these, 91 show nebular disks while 15 of the stellar objects show forbidden lines on objective-prism plates. The remaining 43 objects are probably at least 75 per cent planetary nebulae, but slit spectra will be required to confirm the character of the objects individually.

Dr Westerlund will report further on the direct photographs taken with the 74-inch reflector.

Westerlund reported that the catalogue of southern planetary nebulae will describe about 230 objects. 365 plates have been taken in Hα-light of the object with the 74-inch reflector of the Mt Stromlo Observatory.

The catalogue will give a classification of the objects according to shape. The following table contains the main groups and the numbers of objects in each group:

Unresolved	79
Ellipticals	76
Rings	43
Bipolar	15
Interlocking rings	8
Peculiar	7
Doubtful	3
Total	231

Dimensions, in seconds of arc, will be given for all characteristic features in the planetaries. Surface brightnesses in terms of magnitudes per circle of one minute of arc diameter will likewise be given for all important features in the objects.

The catalogue will have extensive notes about the objects and also large-scale photographs, probably 4 seconds of arc per mm, of about 90 objects.

Finding charts of all the objects, prepared at Mt Stromlo Observatory, were given to Dr L. Perek for inclusion in his general catalogue.

Finally, *Westerlund* mentioned that the listed objects are being studied by Miss Louise Webster at Mt Stromlo Observatory with the aid of Hβ, and 5007 Å [O III] photo-electric photometry and spectroscopy.

4. *M. J. Seaton. Temperatures and Luminosities of the Central Stars of Planetary Nebulae.*

This work was begun in collaboration with Mr R. J. Harman. A year ago Mr Harman was killed in a road accident while on his way to the summer meeting of the Royal Astronomical Society. The work has been completed by myself.

We determine the temperatures using standard methods, essentially as developed by Zanstra, in which one observes the star in the visible and one uses the nebular spectrum to determine the numbers of quanta beyond the H I, He I and He II limits. Various criteria are used for determining that absorption is complete. For many higher excitation objects, absorption is complete for He II but not for H I.

Distances $r(N_e)$ are determined using Hβ fluxes and densities from forbidden line ratios; these distances are not of high accuracy but they have the advantage of not depending on any

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astrophysical assumptions. Distances $r(M)$ are determined assuming the ionized hydrogen mass to be $M = 0{\cdot}14 M_{\odot}$. For nebulae optically thin for H I there is fairly good statistical agreement between $r(N_e)$ and $r(M)$, but for low excitation nebulae optically thick for H I, $r(N_e)$ tends to be smaller than $r(M)$. We use distances based on $r(N_e)$ for low excitation objects and $r(M)$ for high excitation objects.

To determine luminosities we also require star magnitudes. Further observational work on magnitude determinations is much to be desired. Our final results are plotted on an H–R diagram. During the initial stage of their evolution, during which mass ejection is still probably taking place, the central stars undergo a rapid increase in temperature and luminosity. The subsequent evolution is in general agreement with the theory of Hayashi, Hôshi and Sugimoto for stars of one solar mass or less after the exhaustion of nuclear fuels. An initial contraction at constant luminosity is halted by effects of degeneracy and is followed by cooling at constant radius down to the white dwarfs.

Discussion

J. L. Greenstein remarked: I have recently completed and published a survey of a few nuclei of planetaries of very low surface brightness. In these, line emissions of O VI are very strong, so that $T \approx 10^5$ °K is acceptable. Their estimated visual luminosities range downwards from $10^2 L_{\odot}$, reaching at least down to $10 L_{\odot}$. They form, therefore, a downwards prolongation of the sequence found to exist by Seaton. The brighter white dwarfs have unknown bolometric corrections, but reach nearly to this luminosity.

Aller replied: For several of these stars you can estimate temperatures from the spectral types (using e.g. R. M. Petrie's scale). Using McDonald Observatory spectra obtained in 1945–46 I estimated temperatures of several central stars in this way. Later Olin Wilson and I used Mt Wilson coudé data for four of these stars. It is of interest to correlate these temperatures (which are conventional spectroscopically determined values) with those obtained by more erudite methods.

Seaton: The temperatures we obtain are effective temperatures. To be more exact, they are temperatures obtained on comparing the star fluxes in the visible with the numbers of quanta beyond various limits in the ultra-violet. I think that a meaningful comparison with temperatures obtained from features in the visible can be made only on the basis of detailed model atmosphere theory. Mrs K. B. Gebbie at University College London has calculated a number of model atmospheres for the central stars and is now working on the calculation of the line spectra for these models. When this work is complete we plan to make a detailed comparison with the observed spectra.

Dr D. J. Faulkner, also at University College London, is making improved calculations for the interior models of the central stars.

Aller: He/H ratios determined by O'Dell from a small number of well-observed planetaries, and by me from a much larger number of less well-observed nebulae, are in good agreement with one another and with Seaton's value of 0·16.

Aller: To what extent is Shklovsky's estimate of the mass of the nebular shell as 0·20 solar masses justified? When Minkowski and I applied the method to the Owl Nebula we did not feel justified in using the technique to get anything more than limits on the distance.

Seaton: We take $0{\cdot}14\ M_{\odot}$ for the ionized hydrogen mass, from the work of O'Dell. This is obtained in comparing $r(N_e)$ with $r(M)$ and also by considering data on statistical parallaxes. Undoubtedly the true ionized mass is variable, but we feel that statistically significant results can be obtained for nebulae optically thin for H I using the $r(M)$ scale.

5. *E. Chvojkovâ. The Magnetic Field in Planetary Nebulae and Novae, a New Hypothesis*

The trajectories of charged particles in varying magnetic fields may be expressed by Spitzer's dispersive formula. If we extend this formula, introducing the gravity field, we obtain an important result:

Charged particles usually spiral between two reflecting levels: the magnetic mirror and the highest altitude which a spiralling particle can reach in a field of gravity.

There exists a critical particle velocity which is about half of the escape velocity. A particle spiralling between two distant reflecting levels has the minimum deviation from the magnetic vector just when it moves with this critical velocity. When, however, a particle moving with the critical velocity is reflected, both reflecting levels get identical, the particle has got 'frozen' in a given point of the magnetic field line.

That could perhaps explain some effects observed on planetaries, novae or eruptive prominences.

An increase of temperature seems to lead to a contraction up to the moment when the critical velocity has been reached. From this moment, however, the plasma tends to expand very rapidly. In spite of the fact that we deal with regions where the kinetic energy exceeds the magnetic one and the problem should be treated statistically, the tendency to contract or expand is given at any collision. That could explain why plasma jets are streaming from the stars with such an extremely high velocity.

Also, the shape of the majority of planetaries looks similar to the following model: High velocity plasma-jets streaming from polar regions are retarded by the outer plasma up to the critical velocity. The lower reflecting level arises; a part of the plasma gets to be trapped between two reflecting levels producing either a suspended polar cap or large plasma toroids following the magnetic field lines. If particles pass a 'frozen' zone they are rapidly stopped without much accelerating the 'frozen' particles. That could explain stationary plasma arcs or slowly moving plasma bunches observed on planetaries, novae or prominences. If the escape velocity is reached, the planetary looks like two bursting bubbles.

Detailed analyses will appear in *Bull. astr. Inst. Csl.*

Seaton pointed out that the ratio between the mean free path of the particles and the dimensions of the structures in planetaries and novae must be considered in the theory.

INTERSTELLAR MEDIUM

In the session on Thursday 27 August, the Interstellar Medium was discussed.

1. *J. M. Greenberg. Interstellar Grains.*

A considerable amount of interesting observational and theoretical work on the subject of interstellar grains has been done during the past three years.

From a theoretical point of view there has been a fairly exhaustive treatment of the optical properties and the consequent extinction and polarization which may be produced by dielectric ('dirty ice') grains. For convenience of computation a simplified derivation of a size distribution function for grains has been made. Based on a constant rate of growth and destruction proportional to the grain area one easily obtains the form $n(a) = n_i e^{-5\left(\frac{a}{a_i}\right)^3}$ (a = grain radius in microns) which, for $a_i = 0{\cdot}5$ microns, very closely approximates the Oort-van de Hulst curve. Using the known optical properties of ice from the far infra-red to the far ultra-violet, and various values of the size distribution parameter a_i it has been shown that $a_i = 0{\cdot}5$ microns gives a reasonably good fit in the visible part of the extinction curve but that larger values of a_i are needed to fit the extrapolated curve into the far infra-red. An attempt was made to find a

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better fit between theoretical and observed extinctions by letting the size distribution function be arbitrary (as many as six unknown parameters) and getting a least squares fit over the wavelength range of the directly observed extinction. It was found that the theoretical value of the total to selective extinction so obtained is always at least 10 per cent less than the Johnson and Morgan value of 3·0. A similar least squares analysis has been made assuming core-mantle particles (graphite or metal core, ice mantle). A variety of models give similar results in the visible, however, one choice (core radius $-0{\cdot}05\ \mu$, mantle radii distributed up to $a_1 = 0{\cdot}2\ \mu$) give a rather good fit from infinite wavelength to about $\lambda = 0{\cdot}2\ \mu$ (comparing with the observed value of far ultra-violet extinction inferred from Boggess's rocket results by Borgman). Furthermore, the absorption from the ice band at about $\lambda = 3\ \mu$ is within the upper limit established by Danielson, Wolff and Gaustad—this is not true for pure 'dirty ice' grains. Variations of the reddening law are now reasonably well established. The work of Borgman and Johnson in the far infra-red which leads to values of total to selective extinction as high as 6–7 for stars in the Orion nebulosity seems quite striking. While doubts are still being raised by Underhill and others concerning the validity of these results in a quantitative sense, there appear to be good physical reasons (local modification of grain characteristics and orientation effects) for producing such variations. With regard to the interstellar polarization there appears to be additional evidence from radio observations at 50 cm and 75 cm obtained at Dwingeloo that radio and optical polarization are correlated. This puts the theory of magnetic orientation of grains on a firmer basis. The wavelength dependence of polarization has been further investigated by Behr and, although there are considerable variations from star to star the average results for stars with reasonably homogeneous directions of polarization are consistent with the earlier work of Gehrels and also with the theoretical wavelength dependence obtained from elongated dielectric particles. There does not appear to be any difficulty in accounting theoretically for the observed amount of polarization relative to extinction produced by 'dirty ice' grains nor for that matter by core-mantle grains, particularly if the cores have such anisotropic optical properties as graphite. Further speculations on the physics of the diffuse interstellar lines have been made. Unsöld's work on λ 4430 based on the theory of absorption by small plasma spheres is very interesting but its rather specialized requirements make it somewhat doubtful. However, all other proposed mechanisms may almost certainly be excluded. The calculations based on atomically (or molecularly) dispersed absorbers in 'dirty ice' grains have shown that it is impossible to obtain a distribution of grain radii which simultaneously produces λ 4430 extinction and the observed reddening curve. It is still perhaps possible that a significant modification of this conclusion would be made by considering the source of diffuse lines as being produced by atoms or molecules dispersed in the dielectric mantles of core-mantle particles.

Discussion

Anne B. Underhill pointed out that the departures from a universal reddening law shown by Borgman and by others apparently to occur for certain groups of O type stars embedded in nebulosity, are derived on the assumption that the correct intrinsic colors are known for the stars in question. Astrophysical studies indicate that spectral type for stars of type B1 and earlier are not necessarily a unique indication of the intrinsic colors of these stars. The actual spectral distribution is strongly dependent on the considerable possible dispersion in spectral detail. R. L. Wildey has recently published (*Ap. J. Supp.*, **8**, no. 84, 1964, Fig. 12) intrinsic colors for a group of O stars. There is a dispersion of at least 0·3 magnitude at any one type and very little of this can be due to remaining errors in correction for reddening. Such a dispersion in the colors could cause the observed 'deviation' in the reddening law. Furthermore, it is conceivable that the observed colors are contaminated by circumstellar emission lines. Many strong lines could occur in the infra-red. It may only be a chance coincidence but the (1–0) and (2–0) bands of H_2 quadrupole emission occur at $2{\cdot}2\ \mu$ and $1{\cdot}2\ \mu$, which are the centers of some of the infra-red bands used by Johnson and Borgman.

K. Hallam commented on the use of early OB stars for determining the wavelength dependence of interstellar extinction: in the case of very highly obscured stars, the effects of the interstellar extinction become completely dominant. In this connection the stars in the association VI Cygni are good examples. For less obscured stars, one needs to be more careful in selecting stars for which the spectral gradient is least sensitive to errors in spectral classification.

K. Hallam further remarked with regard to the location of the turn-over in the ultra-violet that from multicolor photometry extending to 3200Å he had found two cases where the turn-over occurs in the accessible terrestrial ultra-violet. One of these is θ Orionis, and the other is VI Cyg no. 9.

Behr commented on the color dependence of polarization: Although there is still a spectacular disagreement between the results of different observers, there seems to be a significant difference in the color dependence of individual stars. The observations show a much flatter curve for stars where the line of sight forms only a small angle to the lines of magnetic force, and a greater drop towards the infra-red, if the angle is nearly 90°.

2. *K. H. Schmidt* (Jena, Germany). *On the Sizes of the Interstellar Dust Grains.*

From the observations of wavelength dependence of the interstellar extinction and polarization alone it is difficult to decide on the sizes of the interstellar dust grains. The determination of the albedo in reflection nebulae may give part of the additional information needed. Gürtler found in the Orion nebula the following albedo (*UBV* system);

U: 0·90 B: 0·48 V: 0·26

This wavelength dependence is in qualitative agreement with that expected for graphite particles without ice mantles. But the existence of an intergalactic dust cloud discovered some years ago by Hoffmeister is an argument against the graphite grains because there is no mechanism which can concentrate the particles in a cloud in the intergalactic space.

An indirect method may be used in deciding on the sizes of the dust grains. Lambrecht and Schmidt have shown that the abundance of the interstellar hydrogen molecule is determined by the sizes of the particles. From a discussion of the force perpendicular to the galactic plane Dorschner, Gürtler and Schmidt concluded that the abundance of the interstellar H_2 molecule is as high as about 70 to 80 per cent of the total content of interstellar hydrogen. Therefore, we can expect the diameters of the interstellar dust grains to be of the order of 10^{-5} cm.

Discussion

Greenberg remarked that the total surface area is approximately the same for all kinds of particles suggested to occur in interstellar space. The formation of H_2 probably depends on the surface area and would thus be independent of the nature of the interstellar particles.

H. C. van de Hulst pointed out that we still know very little about the process of formation of H_2 and our knowledge should not be extrapolated too far.

J. E. Gaustad made the following remarks: As Dr Greenberg has already said, interstellar grains composed of ice should produce an absorption band at 3·1 microns. This band is the ν_3 vibration of the water molecule, but shifted by 0·4 μ and enhanced by a factor of 30 over the same band in water vapor. Among the stars observed in the second flight of the balloon telescope Stratoscope II were μ Cephei, a highly reddened M supergiant, and α Orionis, an unreddened star of very similar spectral type. Comparison of the infra-red spectra of these two stars showed no trace of a band at 3·1 μ. The upper limit which can be set on the band strength is a factor of four less than the strength predicted from the standard van de Hulst model of the grains. Impurities in the grains are unlikely to affect the band strength substantially, for the distortion of the molecular potential is of the short range nature of hydrogen bonding, which normally remains effective up to very high dilution factors.

Van de Hulst asked whether the conclusions could be based on any laboratory work at the temperatures of interstellar grains.

Gaustad: There exist no measurements of absolute intensities at low temperatures, but at least the width of the ice band does not change between 0°C and −190°C, which suggests that temperature is not an important factor.

3. *B. Donn. An Approach to the Theory of Interstellar Grains.*

Several physico-chemical developments which are of considerable significance for the study of interstellar grains began in the period 1945–50. Four particularly relevant topics are experimental and theoretical research in (*a*) nucleation of condensing vapors; (*b*) screw-dislocation mechanism for crystal growth, particularly appropriate at low temperatures; (*c*) low temperature chemistry including free radical surface reactions; and (*d*) radiation chemistry at low temperatures. The problems investigated include those for which only rough estimates were possible when the extensive astronomical research on interstellar grains was carried out between 1940 and 1950.

Considerable progress can be made by applying these recent developments. A detailed analysis is under way and will be carried out in three phases: (*a*) crystal nucleation and growth in space neglecting chemical reactions; (*b*) the chemistry of interstellar gas and grains and (*c*) a synthesis of parts (*a*) and (*b*).

Tentative results indicate that condensing grains would be relatively pure, nonvolatile material with an irregular, filamentary shape. A grain with a large proportion of volatile elements is not expected to be composed of primarily simple molecules.

Experiments designed to clarify the interstellar problem are possible and are also essential to a proper analysis.

4. *M. Rudkjøbing. Photoelectric Observations of* λ 4430 *Line Intensities* (work done by H. Kristenson and M. Rudkjøbing)

An index of the strength of the interstellar 4430 Å line has been measured for stars of spectral types O6 to A3 brighter than 9^m in the Milky Way north of +20° declination.

A photo-multiplier cell was used with two interference filters, that have transmission bands centered on 4430 Å and half widths of 22 and 98 Å. The index is calculated as the logarithm, in stellar magnitude scale, of the ratio of the registrations with the two filters of integrations during 15 seconds, after subtraction of background intensities.

About 150 stars were observed with the Haute-Provence 32-inch Cassegrain telescope and about 225 with the 20-inch Aarhus instrument. A mean error of $\pm 0\overset{m}{.}006$ was obtained with some 10 repetitions of the measurements for 9^m stars with the larger and for 8^m stars with the smaller instrument. This error corresponds to somewhat more than 1 per cent of the continuum in terms of central intensities as given by Duke (*Ap. J.*, **113**, 100, 1950).

The zero point of the index varies with spectral type over a range of $0\overset{m}{.}03$ when found from comparisons with Duke's results, in which part of the variation may be inherent.

A relation between our index and the $B - V$ excess as observed by Hiltner (*Ap. J. Suppl.*, **2**, 389, 1956) and corrected with Johnson's (*Lowell Obs. Bull.*, no. 90, 1958) zero points seems to be established within observational errors, including zero point uncertainties, for B2 – B9 stars over a range of $0\overset{m}{.}1$ in the index corresponding to about 1^m in the $B - V$ excess.

The strongly reddened stars observed are situated within the Cygnus rift. Observations in other obscured regions are necessary, therefore, for a decision of, whether or not the relation found is a general one.

Discussion

P. J. Treanor: At the Vatican Observatory we are currently measuring the central intensity of the 4430 feature from microphotometric measurements of objective prism spectra with dispersions of 80Å/mm. We too believe that the strength of this feature may in some cases serve to determine the extinction independently of color measurements. Since this feature is currently being measured in terms of different parameters, it seems important that the various scales should be calibrated against accurate absolute measurements of equivalent width and central intensities determined with high dispersion. There is need for more accurately determined standards of this kind, and for further studies of the profile of the feature.

5. *H. Lambrecht. On the Influence of the UV Spectra of O and B Stars on the Physical State of the Interstellar Medium.*

1. *The Interstellar* H_2 *Molecule.* Gold, Gould and Salpeter (*Ap. J.*, **138,** 408, 1963, here called GGS) and Lambrecht and K. H. Schmidt (*Astr. Nachr.*, **288,** 11, 1964 = LS) have independently shown that there must be an equilibrium in the formation and dissociation of H_2 in interstellar space and that the most effective dissociation mechanism is the close approach of interstellar clouds to O and B stars. Thereby the clouds will be heated to H II regions with Strömgren radii determined by the density of the UV radiation beyond the Lyman limit. A reduction of the UV flux from the stars reduces the Strömgren radii and also the dissociation probability α of the H_2. LS have computed α with the 'observed' radii of H II regions from the 1390 MHz radio measurements of Westerhout (*Bull. astr. Inst. Netherlds*, **14,** 215, 1958): $\alpha_{LS} = 1{\cdot}6 \times 10^{-16}\ s^{-1}$. GGS have calculated the radii and get $\alpha_C = 3{\cdot}9 \times 10^{-16}\ s^{-1}$. A reduction of the black body flux at the temperatures of O and B stars by a factor of 5 in the UV gives $\alpha = 1{\cdot}6 \times 10^{-16}$ which exactly agrees with the 'observed' α_{LS}. This numerical agreement is, of course, accidental but it seems very certain from this result that there must be a reduction of the UV radiation of O and B stars connected with a reduction of the dissociation probability of H_2. Independently of these considerations one can estimate the reduced Strömgren radii by the use of two relations, each of which gives the fraction f of the H II volume in units of the total volume of interstellar gas. One gets a reduction factor 3 for the UV radiation. Using this reduction factor we can now estimate the numerical values of some parameters of importance for the interstellar gas; with the reduced Strömgren radii and the α_{LS} value the mean square $\overline{n_0^2}$ of the total interstellar hydrogen density by number is found to be $\overline{n_0^2} = 78\ cm^{-6}$. Further $f = 0{\cdot}0019$. The interstellar clouds (H I and H II) occupy the fraction $F = 0{\cdot}06$ of a given volume of space. These values give n_0 (clouds) $= 36\ cm^{-3}$ and the mean density over a larger volume $\overline{n_0} = 2\ cm^{-3}$. The 21-cm observations give a mean neutral hydrogen density near the Sun: $\overline{n_{HI}} = 0{\cdot}8\ cm^{-3}$. Finally, *from all these density values the conclusion is drawn that the fraction of* H_2 *must be high in the interstellar gas.* The ratio of the H_2 density (by mass) to the total interstellar hydrogen density must be as high as about 0·6 to 0·7. These values are, of course, very uncertain but they will be of the right order.

2. *The Interstellar Ca/Na Ratio and the Radiation Field.* The so called underabundance of interstellar Ca can have various causes. One of them can be the assumption of a wrong interstellar radiation field especially in the UV. If one computes with the mean observed interstellar Ca II/Na I ratio the radiation field which gives an interstellar Ca abundance in agreement with stellar atmospheres one gets a high UV depression of the radiation field. But because of the very large scattering of the Ca II/Na I values (between 0·2 and 2·9) it seems very improbable that such a solution represents the astrophysical reality. As in all interstellar researches one must now observe and calculate local values and detailed structures also of the various radiation fields within the stellar system. A first step in this direction are the calculations by Zimmermann of the radiation fields in the neighborhood of the Sun and in various galactic latitudes using for the UV the measurements obtained with rockets and the new models computed by Underhill.

Discussion

P. Swings: Professor Lambrecht has stressed the importance of the abundance of the 'interstellar' H_2 molecules and of their localization. We are anxious to have observations of the far ultra-violet resonance absorption lines of H_2 with space vehicles, or possibly of the forbidden infra-red lines. In the meantime the observations of 'interstellar' molecules concern only the optical observations of CH, CH^+ and CN, and the radio observations of OH. These molecules appear very localized, and one may even wonder—as P. W. Merrill used to—whether they are not 'circumstellar' rather than 'interstellar'. The sharp lines of CH, CH^+ and CN have been found on high dispersion spectrograms of early-type nearby stars, on which they sometimes were as intense as (or even more intense than) the interstellar lines of Ca^+ and Na. On the other hand, the molecular lines do not seem to have been observed on low dispersion spectrograms of distant stars in which the interstellar Ca^+ and Na lines are extremely strong. This seems to indicate that the molecules are strongly localized, much more so than Ca^+ and Na. The same conclusion is reached on the basis of the presence of CN radicals on the *two* lowest rotational levels, and not only on the lowest. It is probable that a sufficient population on the second rotational level requires the (relative) proximity to a star (see Liège Publication no. 300, 1948). The abundances of 'interstellar' molecules which are often quoted may be quite erroneous.

G. Münch: Regarding the question raised by Prof. Swings in connection with the strength of molecular lines in distant stars, I wish to mention that recently I discovered a group of stars associated with an emission nebula in Cepheus, all of which show CN lines stronger by a factor of 10 than in any other star known before. This and other examples show that the distribution of interstellar radicals is extremely spotty, but clearly interstellar in nature.

D. McNally: While agreeing with Prof. Lambrecht's remarks on the importance of local phenomena in determining molecular abundances, I am perturbed by the use of the Oort-Spitzer mechanism for dissociating H_2. It would seem that a close approach of an H I cloud to a hot star would lead not only to dissociation of H_2 but to ionization of H and possible disruption of the cloud. If the cloud were accelerated as in the Oort-Spitzer mechanism no essential dissociation of the H_2 would result.

6. *Y. Terzian. Radio Emission from* H II *Regions.*

Observations with the 300-foot radiotelescope were made of IC 410, NGC 2175, M 16 and NGC 6820 at the radio frequencies of 1410, 750, 405 and 234 MHz. The derived flux densities indicate that all the observed sources have a thermal spectrum.

Theoretical radio spectra were computed for these sources at different electron temperatures, using the observed 1410 MHz brightness temperature distribution. The results have shown that these nebulae are still optically thin at 234 MHz. Flux density measurements around 50 MHz are needed in order to derive electron temperatures.

The galactic plane around M 16 and NGC 6820 has been observed to be very wide. The plane also has shown a fine structure that has not been resolved before. The radio isophotes of the H II regions clearly define the shape and size of the nebulae, since radio observations are not influenced by interstellar absorption. Radio isophotes have been constructed of the observed four regions from the 1410 MHz observations (the half power beam width is 10 minutes of arc).

Spherical models were made for the H II regions and one-dimensional electron density distributions were computed for electron temperatures ranging from 5 000 to 15 000°K. Density minima were found at the center of the nebulae NGC 2175 and NGC 6820.

Strömgren sphere radii were computed including the scattering of radiation (following Pottasch, *Ap. J.* 1960), and the results were compared with the radii obtained from the models.

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The following table gives the corrected Strömgren sphere radii s_2, the model radii, the derived mean densities and masses and also age estimates for these regions following the method used by Kahn and Menon (*Proc. nat. Acad. Sci.* 1961). Ages of the same order can also be obtained using some other more realistic methods (Vandervoort, private communication 1964).

H II Region	s_2 (pc)	Model radius (pc)	$M/M_\odot$	$\overline{N_e}$ (cm^{-3})	Age (years)
IC 410	31·8	24·4	14 000	14	$<63 \times 10^3$
NGC 2175	19·5	17·4	4 000	16	44×10^3
M 16	21·1	20·3	12 500	30	$<53 \times 10^3$
NGC 6820	27·5	27·6	12 000	7	180×10^3