12. COMMISSION DE LA RADIATION ET DE LA STRUCTURE DE L'ATMOSPHERE SOLAIRE

Report of Meetings

PRESIDENT: L. Goldberg.
SECRETARY: Miss E. A. Müller.

First meeting, 16 August 1961

Draft Report. The President announced that any errors in the *Draft Report* should be corrected at this meeting and additions could be included only if they were very brief. The *Draft Report* was approved by all members without any changes.

SCIENTIFIC DISCUSSION

The first paper on the agenda was given by R. Tousey on the spectrum of the Sun between 170 and 700 Å which was obtained by W. E. Austin, J. D. Purcell, and R. Tousey of the Naval Research Laboratory on 1961 June 21. The rocket reached a peak altitude of 197 km. Stray light background fog was completely eliminated by placing an aluminum film of 1000 Å thickness in front of the slit of the spectrograph, which employed a 40 cm radius 600 line/mm grating at 85° incidence. The aluminum film was opaque for λ850 Å and transmitted from 700 Å to the L III edge at 170 Å. Approximately 50 emission lines were photographed between 170 and 310 Å in first and second orders, and some in third and fourth orders. From 310 to 700 Å only a few lines were recorded, because of attenuation by N_2 remaining overhead. Wave-lengths have been established to one or two tenths of an angstrom. Surprisingly few lines agree with lines in the Ultra-violet Multiplet Table of Mrs Moore. He II (1) at 304 Å, possibly He II (2) at 256·7, and several higher members of this series are present. The lines near 336 and 361 Å may be the D lines of Fe XVI. Faintly present are O VI (4) at 173·08, 172·93 Å. A moderately strong line at 182·3 Å appears to be Hα of C VI. The spectrum agrees well with H. E. Hinteregger's photo-electrically scanned spectrum, but contains more lines and has ten or more times greater resolution. To the questions by H. Zirin, J. T. Jefferies, and G. Athay, Dr Tousey answered that the relative intensities in the different orders have not yet been determined, the decrement in L II was not yet reduced to intensities and that the flight was not high enough to secure accurate total line intensities.

Referring to Dr Tousey's identification of the emission line at λ256·7 with He II Ly β, R. N. Thomas commented that J. B. Zirker and R. N. Thomas tried to predict the relative intensity of He II Ly α:Ly β, and that they found a value much greater than observed. Charlotte Pecker suggested that $2s2p^2\ ^2P$-$2s^22p\ ^2P^\circ$ of Si X at 256·6 lies as close to the emission feature as does He II Ly β (256·3). She and Thomas made a preliminary calculation of this Si X emission line including just collisional excitation of the ^2P level. For values of n_e giving reasonable agreement with H. E. Hinteregger's observed intensities of the emission feature—(which lie in the range $n_e \sim 10^9$)—they found large optical depths in the line, so the calculations are now being extended to include coronal self-emission as an excitation mechanism. Mrs Pecker points out that with the excitation of this ^2P level one should observe other transitions from this level than to the ground term, and other transitions involving terms intermediate to the ^2P and ground terms. In a detailed analysis of the rocket spectra of W. A. Rense, she has found a large number of wave-length coincidences that suggest the presence of these transitions in the solar spectrum. A particularly interesting one is the forbidden transition ^2P-^2S, arising from the same upper level as the λ256·6 line. Preliminary calculations by Mrs Pecker and

Thomas suggest a different sensitivity of the emission in visual (forbidden) and rocket (permitted) lines to the value of n_e if the optical depth is high enough, thus a sensitivity of the intensity ratio of these lines to coronal condensations. Mrs Pecker emphasizes the extreme utility of such intercomparison of rocket UV and visual lines in investigating the problem of coronal condensations, and therefore the necessity for adequate discussion of the transfer problem to include coronal self-emission. Similar investigations were carried out of the ions Mg VIII and Al IX which have the same configuration, and attempts are being made to get better structure of the Fe XIV term diagram. Dr Tousey pointed out that on his spectrograms the emission line identified with He II Ly β at 256 is rather diffuse on the long wave-length side and that the line 256·6 of Si X may very well be there but much weaker.

Z. Suemoto then reported on a model of the chromosphere proposed by F. Moriyama and extended by Moriyama and Suemoto to the transient region chromosphere-corona. The observed radio emission data of the quiet Sun at sunspot minimum in the dm and cm range are combined with the optical observations of the brightness distribution of the helium lines and the Balmer continuum. The proposed model is a spicular model in which the radio emitting regions as well as the helium emitting regions occupy about 10% of the entire solar disk. Adopting the electron density of the order of 10^{11} at an electron temperature of 20 000°, and subsequent densities in such a way as to ensure the pressure balance, they find the geometrical thickness of the whole transient layer to be of the order of about 100 km. This model is supported by their 1958 eclipse observations of the flash spectrum in which the spicular structure is revealed even for weak hydrogen and helium lines down to about 1500 km.

The next paper was given by M. Rigutti on the (0.0), (1.0) and (2.0) bands of the CN red system ($\sim\lambda$ 10000 Å) in the solar spectrum. The spectra were obtained at the Dominion Observatory in Ottawa in 1959 with the grating spectrograph and a simple carbon arc in air as a source. The (0.0) band was observed in the second order with a dispersion of about 1·2 Å/mm, and the (1.0) and (2.0) bands were observed in the third order with a dispersion of about 0·6 Å/mm. The origin of the bands and the observable transitions were computed and the results were compared with the observed solar spectrum. With a good degree of certainty it was possible to identify 32 solar lines pertaining to the (0.0) band and 5 solar lines belonging to the (1.0) band of CN. The analysis of the (2.0) is in progress. The physical characteristics of the CN molecule are being studied by J. G. Phillips by means of electronic computers.

A brief discussion followed among R. N. Thomas, L. Goldberg, Miss E. A. Müller, and J. C. Pecker on the influence of non-LTE on the Fe abundance in the solar atmosphere. We refer to the Report of the meeting of Sub-Commission 29*a* of 22 August when this problem was discussed in more detail.

M. Minnaert then reported on a study of the central intensities of Fraunhofer lines. The Utrecht Atlas and the McMath-Hulbert photo-electric tracings of the solar spectrum in the visible region are compared. Corresponding central intensities measured in both records differ appreciably if the lines are not corrected for instrumental profile. However, one must bear in mind that the instrumental profile for the Utrecht Atlas is about five times wider than that for the Michigan tracings. After correcting the lines for instrumental profile, Minnaert finds very good agreement between the central intensities of both records. J. Waddell commented that reliable central intensities of strong lines, that is, correct to within 0·1% can only be achieved by the complete elimination of scattered light and the effects of Rowland ghosts, such as is performed in the system of the Sacramento Peak Observatory. He wondered about the degree of accuracy in the observed agreement of the central intensities in the two records. Professor Minnaert answered that for faint and medium strong lines the central intensities were certainly correct within a few per cent. He believes that some of the scatter observed in the results is due to real changes in the lines and requires further investigation. To the questions by J.-C. Pecker and by F. W. Jäger, Professor Minnaert answered that the method of Voigt functions and Elste's tables were employed to correct for instrumental profile and that stray light and ghosts were taken into account as well as possible. R. Michard pointed out that the central intensity of a Fraunhofer line fluctuates by 10-15% because of the granular structure of the solar atmosphere and that a mean value of the central intensity is only of statistical value.

The last contribution to this session was given by R. Giovanelli reporting on some work by P. Wilson in Sydney, who had developed methods for applying the theory of radiative transfer in non-uniform media to the study of the distribution of the source function and of the attenuation coefficient in photospheric structures such as granules and penumbral filaments. As a starting point, he requires the center-limb variation of contrast, which must be corrected for the contrast transfer function of the telescope. For a visual demonstration of the loss of resolution due to foreshortening towards the limb one of Schwarzschild's granulation pictures was re-photographed at various angles to the normal with cameras simulating telescopes of various diameters. The simulated center-limb photographs show changes rather like those actually observed. Dr Giovanelli points out that it appears to be an open matter at present whether the observations reflect anything other than the combination of foreshortening and finite telescope resolution or whether they do reveal information on the three-dimensional structure of the photosphere. R. B. Leighton believes that the elongation of the granulation observed towards the limb is probably due to foreshortening, whereas J. Rösch claims that one can observe real solar features near the limb.

Second and third meetings, 18 and 19 August 1961

ACTING CHAIRMAN: J. W. Evans

THE SOLAR GRANULATION

Both sessions were devoted to a discussion on the topic of the Solar Granulation, the program being as follows.

A. Continuum Studies of Granulation

  1. *J. Rösch.* Results drawn from Photographs of the Photosphere obtained from the Ground.
  2. *M. Schwarzschild.* Results drawn from Photographs of the Solar Granulation taken from the Stratosphere.
  3. *C. Macris.* Mean Distance Between Photospheric Granules and Its Change With Solar Activity.

B. Spectral Line Studies of Granulation

  1. *N. V. Steshenko.* The Investigation of the Magnetic Fields and Radial Velocities in the Photosphere and Chromosphere.
  2. *O. C. Mohler.* The Fine Structure of the Solar Chromosphere.
  3. *R. B. Leighton.* Oscillations in the Solar Atmosphere.
  4. *J. W. Evans* and *R. Michard.* Oscillatory Motion in the Upper Photosphere.

C. Photospheric Models

  1. *K. H. Böhm.* Photospheric Models Incorporating Granulation.

D. Fraunhofer Line Profiles

  1. *J. E. Blamont.* A New Method to Measure Fraunhofer Line Profiles.

A. CONTINUUM STUDIES OF GRANULATION

Paper 1—*J. Rösch*

J. Rösch described some results derived from photographs of the photosphere taken from the ground at the Pic du Midi, and showed motion pictures of the granulation which formed the basis of his investigation. Referring to Dr Giovanelli's remark during the first session of this meeting Dr Rösch stressed the fact that pictures taken at various angles to the normal of a plane image of photospheric granules do not truly reproduce the pictures of the photosphere taken at the same angles, since the solar granules are three dimensional. The elongation of the granules appears only at very great angles and even on pictures quite near the limb bright granules can be recognized which probably pertain to plage regions. This indicates that also near the limb solar features can be observed and that limb photographs of the granules can give information about the variation of the photospheric structure with depth. The study of the morphology of the granules includes the different shapes (coffee grain, rosette, horseshoe, rings, etc.) and the mean diameter *d* of the granules which is obtained from the mean distance of the centers of neighboring granules. The observed intensity ratio I_M/I_m between the brightest and the least bright points yields the mean temperature fluctuation ΔT after correction for the limits of the instrumental resolving power. The results derived for two effective wave-lengths are collected in the following table:

Wave-length, λ	Mean diam. *d*	I_M/I_m	In 80% of the cases	I_M/I_m corrected	ΔT
4610 ± 20 Å	2″·5	1·14	$1{\cdot}10 < I_M/I_m < 1{\cdot}18$	1·22	250°
6000 ± 100 Å	2″·6	1·16	$1{\cdot}13 < I_M/I_m < 1{\cdot}19$	1·25	350°

The difference in ΔT found in the two wave-lengths reflects the different photospheric levels to which they refer and should be used in determining the variation of the optical depth with wave-length. Near the limb the intensity ratio (granule/background) is more difficult to determine because of (*a*) the decrease in contrast, and (*b*) the presence of bright granules of plages which should be treated separately. A preliminary study yielded a contrast of about 5% at 6″ from the limb, and at 20″ from the limb the contrast was about 8% for ordinary granules and about 20% for the granules of plage regions. In the λ6000 Å region about 20% of the granules show a tendency to bisect, the average distance between the two parts being 1″·0 and about 10% of the granules are ring shaped with a mean diameter of 1″·6. The evolution and lifetime of the granules can best be studied individually on a film composed of 28 pictures taken at one minute interval. A film composed of pictures taken every 3 seconds does not show any real changes in the granules but only deformations due to atmospheric turbulence. In general one observes that after a granule is formed its diameter begins to increase until it reaches about 2″ at which moment it breaks up into several small granules which vanish at the place they appeared. This evolutionary cycle occurs within about 10 minutes, but granules of average dimension have been seen to subsist up to 20 minutes.

Paper 2—*M. Schwarzschild*

M. Schwarzschild reported on some results obtained from granulation photographs taken with a 12-inch balloon-borne telescope during 6 flights made in 1957 and 1959. An impersonal statistical analysis was carried out which gave the auto-correlation function of the granulation intensity in space as well as in time. The auto-correlation function of photospheric brightness as a function of distance at one given time yields the average diameter of the granules, which is defined as twice the distance in which the auto-correlation function drops to one half. Dr Schwarzschild pointed out that this definition of the average size of the granules should not be confused with Dr Rösch's definition which is based on the distance between centers of granules. The auto-correlation function of photospheric brightness as a function of time at one given place yields the average life-time of granules, which is defined as twice the time interval in which the auto-correlation function drops to one half. The life-time appears to be a function of the size of the granules, the larger granules live longer than the smaller ones. Finally, the space correlation function was used to derive the r.m.s. intensity fluctuation, $\{(\Delta I)^2\}^{\frac{1}{2}}$, which after correction for instrumental profile gave the r.m.s. temperature fluctuation, $\{(\Delta T)^2\}^{\frac{1}{2}}$. Schwarzschild's results are collected in the following table:

Mean diameter d	Life-time mean t	$\{(\Delta I)^2\}^{\frac{1}{2}}$ (observed)	$\{(\Delta I)^2\}^{\frac{1}{2}}$ (corrected)	$\{(\Delta T)^2\}^{\frac{1}{2}}$
700 km	8 min.	± 0·046 ± 0·050	± 0·073 ± 0·072	± 90° K

Dr Schwarzschild stressed the fact that Dr Rösch's intensity contrast is not the same as the r.m.s. intensity fluctuations used in this investigation. Therefore, he expects Dr Rösch's ΔT to be at least twice as large as the r.m.s. temperature fluctuation derived here which most probably is not greater than 100 °K at a mean wave-length of λ5450 Å ± 400 Å.

Paper 3—C. Macris

The third paper on the solar granulation observed in white light was given by C. Macris who reported on a possible variation of the size of the photospheric granules within a solar cycle. On a series of photographs of excellent quality the mean distance of the granules was measured and correlated to the mean area of sunspots as determined by Greenwich. It was found that the observed variation of the mean distance of the granules as a function of spot area can best be represented by a hyperbola rather than by a straight line. Dr Macris pointed out that the material employed was not at all homogeneous. The observations were made by various astronomers and under different conditions. The results seem to indicate, however, that the size of the granules—and hence the number of granules—is a function of the solar activity. He stressed the importance for further more numerous and homogeneous observations of the photospheric granulation during the period of one entire solar cycle.

Discussion

R. N. Thomas enquired whether center-limb variations of the intensity and temperature fluctuations had already been studied. F. N. Edmonds replied that he had begun such studies on Dr Schwarzschild's 1957 photographs and found that the r.m.s. intensity fluctuation remains constant from the center to about $\theta = 20°$, then increases to a maximum at about $\theta = 50°$, decreases to a minimum at about $\theta = 75°$ and then increases again near the limb. He believes, however, that the observed increase near the limb is probably due to another effect than the center-limb variation of the intensity fluctuation. The r.m.s. temperature fluctuation that he derived is 200 °K at the disk's center and 250 °K at about $\theta = 50°$. J. Rösch remarked that during the eclipse of 1961 February 15 they took center-to-limb pictures in order to measure the variation of the contrast across the solar disk. These measurements are now in progress.

B. SPECTRAL LINE STUDIES OF GRANULATION

Paper 1—N. V. Steshenko

The first paper concerning spectral line studies of granulation was given by N. V. Steshenko. He described an investigation of the longitudinal magnetic fields and radial velocities in the photosphere and chromosphere carried out mainly by W. E. Stepanov with the magnetograph and the radial velocity recorder of the Crimean Astrophysical Observatory. Observations in the H_3 and K_3 lines of Ca II showed that in the chromosphere large regions exist of ascending and descending gases which extend up to 200 000 km. The motion in these regions has the character of large-scale turbulence. The characteristic scale of the elements is 5 000–20 000 km and their life-times are of the order of seven hours. In the undisturbed chromosphere the total flow of the ascending mass is practically equal to that of the descending gases. In flocculi the flow of the descending gas exceeds that of the ascending gas by a factor of 4. Apparently the excess of the descending mass is compensated by the ejection of matter during non-stationary processes (flares, moustaches, surges). In the chromosphere a correlation is found between the magnetic fields and the motions in the gases. The photosphere was studied mainly in the light of the Fe I line $\lambda 5250$ Å. In the photosphere the velocity fields and the magnetic fields have much more complicated structure and no correlation between them is recognizable. The regions of ascending and descending gases extend to about $1{\cdot}5 \times 10^5$ km. The largest velocities were observed over sunspots where values up to 450 km/sec were measured. Dr Steshenko also briefly described his attempt to measure magnetic fields of separate granules. The measurements in the Fe I line $\lambda 6302$ Å were made relative to the nearby telluric line. A quarter wave-length plate was placed in front of the slit of the spectrograph, thus producing two images of the spectrum with opposite polarization. The accuracy of the magnetic field measurements is hampered by turbulence in the spectrograph producing errors of up to ± 23 gauss. The conclusion drawn from the best quality observations are that (1) in individual granules of $1''$–$1''{\cdot}5$ in diameter the longitudinal magnetic fields, if they exist, are of the order of 40–60 gauss, (2) in groups of granules with diameters of $3''$–$6''$ the longitudinal fields are of the order of 50–60 gauss and, as a rule, the strongest fields coincide with the regions of largest radial velocities.

Discussion

In the discussion that followed this paper, M. Schwarzschild stressed the importance of Dr Steshenko's results, if they can be substantiated, because the theoreticians expect turbulent magnetic fields in the photosphere which should be observable in the granules. To R. Giovanelli's question as to whether the results refer to quiet or active regions, Dr Steshenko replied that the observations were made over quiet regions. R. B. Leighton reported that he also had looked for longitudinal fields in granules. He observed field strengths in the neighborhood of sunspots which are similar to Dr Steshenko's values, but he found no fields exceeding 20 gauss in granules of quiet regions. Also, R. Michard mentioned that he had not detected longitudinal fields in individual granules, but that in groups of granules he had observed fields up to 50 gauss. Trying to settle the argument H. Zirin suggested to Dr Steshenko that his observations may refer to small groups of bright granules which possibly belonged to small plage regions of which we know that they are connected with magnetic fields. Dr Steshenko claimed, however, that the regions he had studied did not necessarily contain bright granules, but that he had simply selected randomly small groups of granules.

Paper 2—O. C. Mohler

In his paper on the fine structure of the solar chromosphere O. C. Mohler first gave a summary of what had been learned about the chromospheric structure from spectroheliographic observations of various investigators starting with the work of L. and M. d'Azambuja in Meudon. Some additional conclusions can be drawn from motion pictures in the Hα and the K line of Ca II which were produced at the McMath-Hulbert Observatory. They show that the life-times of the moving granulations are long, changing conspicuously in size and brightness but remaining recognizable for hours. In the polar regions the changes in configuration, size and brightness are less rapid than in the equatorial belts. Interpreted as velocities, the changes correspond to 600–700 m/sec. These velocity measurements, however, are difficult and the values not exact. The undisturbed Sun apparently undergoes quasi-periodic changes that may either be real, or the result of variations in image quality. Spectroheliographic results must be compared and identified completely with the small structures that are observable near the centers of the strong Fraunhofer lines. Dr Mohler, therefore, drew attention to the main results that were obtained in recent years from direct photographs of some representative lines secured with the McMath-Hulbert vacuum spectrograph. He then reported on the recent investigation of the Na D_1 line by Edith Müller who found random velocities of 360, 404, and 438 m/sec at distances from the line center of 80, 50, 0 mÅ, respectively. These results indicate an increase in random velocities of the small structures with height, in the region where D_1 is formed. The directions of the shifts in the core are not correlated with the directions of the shifts in the outer line regions. Furthermore, measurements made to trace the change in correlation of the shifts at different distances from the line center show that high correlation is achieved only in the outermost wings of the line. In sum, he results derived from measurements of the small-scale structures within the spectrum lines indicate that (1) random velocities from 200-1000 m/sec are found; (2) the brightness of the individual elements and their velocities show very low correlation; (3) for metallic lines the random velocities increase with height in the atmosphere; (4) Hα, Hβ and K of Ca II show no height dependence of velocity; (5) preferred sizes of the elements in the uppermost layers of the chromosphere are 6″ and 20″. The comparison of the spectroheliographic and spectrographic results imply some sort of chromospheric structure based on the photospheric granulation. The structure seems to extend continuously from the level of the photosphere to the level of formation for the centers of Hα and K. At low levels the motions are somewhat systematic and are arranged in ascending and descending streams, but at the highest levels the situation is confused and motions of descent may even dominate. Possibly periodic variations of the vertical velocities may be superposed on a continuous outward flow. There seem to be no parts of the chromosphere that are at rest with respect to the photosphere.

Discussion

R. G. Athay asked whether or not the motions observed in Hα were completely random. Both O. C. Mohler and R. B. Leighton agreed that the situation in Hα was very difficult to interpret and that there may exist organized motions rather than purely random, inasmuch as there seems to be an indication of a correlation between direction of motion and brightness. R. N. Thomas made a strong motion for detailed investigations of small-scale structures in all levels of the photosphere and chromosphere in order to substantiate the connection of the photospheric granulation with the chromospheric inhomogeneities. R. Giovanelli drew attention to some results that he and J. T. Jefferies had obtained from pictures of velocity distributions in the chromosphere which were prepared in Sydney by suitably processing filtergrams secured with a 1/8Å bi-refringent filter in the wings of Hα. At a resolution of 5″-10″ they found that at each of the intervals $\Delta\lambda = 0{\cdot}2$, $0{\cdot}5$, $0{\cdot}7$, and $1{\cdot}0$Å, the direction of motion correlates well with the local brightness of the chromosphere, dark chromospheric granules almost always showing downward motion. Strong downward motions occur in columns descending from top to bottom of the chromosphere, coinciding with the dark points forming the large-scale chromospheric network. There are also isolated rising columns which, however, have not been detected at the lowest levels and have less obvious connection with brightness features. Between these columns, from bottom to top, a finer-scale velocity structure develops, providing the dominant velocity pattern in the upper regions.

Paper 3—R. B. Leighton

R. B. Leighton then reported on his investigation of the oscillations in the solar atmosphere. He obtained spectroheliograms showing the line-of-sight component of local velocities by using an adaptation of a technique previously employed for studying magnetic fields. The photographs indicate that the entire solar surface is covered with a network of large-scale velocity "cells" which involve predominantly horizontal motions. Within each cell, the matter moves from the center toward the outer boundary. The mean diameter is about $1{\cdot}5 \times 10^4$ km; typical velocities are about 0·5 km/sec and the life-times of the order of many hours. The mean separation between two such cells is about $3{\cdot}5 \times 10^4$ km. There are about 5 000 of them on the whole Sun. There is a similarity between these cells and the bright chromospheric network seen on Ca II spectroheliograms. Their properties suggest that they constitute a "super granulation" system of convection currents originating at considerable depths within the Sun. Several kinds of observations of the small-scale velocity field strongly suggest that three essential factors are observed which are involved in the transport of energy from the photosphere to the chromosphere: (1) A strong correlation between brightness and velocity is observed in the lower levels of the photosphere, with bright elements moving upward. The corresponding mechanical energy transport amounts to about 1 watt/cm^2. The correlation passes through zero within the wings of the Na D_1 line and is reversed at higher levels. (2) The small-scale vertical velocities are not at all random but are strongly oscillatory in their time behavior with a period of 296 ± 3 sec. The energy contained in the oscillation is about 160 joules/cm^2 and the oscillation decays with a time constant of about 400 sec. (3) There is a corresponding oscillation in the brightness elements of the lower chromosphere.

Discussion

Answering L. Goldberg's question, Dr Leighton said that according to his observations the ratio of the horizontal to vertical components is of the order of 0·4, whereas Dr Michard finds that both components are of the same order of magnitude. This is a question of level in the solar atmosphere to which the observations refer. M. Schwarzschild emphasized the great importance of Dr Leighton's observations which suggest oscillatory motions in the solar atmosphere, and J. C. Pecker reminded the audience of the fact that such oscillatory motions had been predicted theoretically already over ten years ago by L. Biermann and by E. Schatzman.

Paper 4—J. W. Evans and R. Michard

R. Michard then described a detailed study by J. W. Evans and himself of two time-sequences of high-dispersion solar spectra taken at 40 seconds intervals. A motion picture of these spectra secured with careful guiding during periods of good image quality at the Sacramento Peak Observatory formed the basis of their investigation of local oscillatory motions in the Sun's atmosphere. The detailed study of the lines Mg b_2, Ti I $\lambda 5173{\cdot}75$, and Fe I $\lambda 5171{\cdot}61$ lead to the following preliminary results. The details of Doppler shifts are accurately reproduced in all lines, except for some systematic differences in amplitude. Oscillatory and roughly sinusoidal motion constitutes most of the sight-line velocity field at the center of the solar disk. In curves of velocity against time for a given point, sinusoidal elements persisting during one to two periods are frequently found. Strong "wave" motion occupies roughly 1/3 of the time for any point and also 1/3 of the solar surface at any time. In between are spaces and times with small, more or less erratic, velocities. The mean value of the periods of oscillation is found to be 260 ± 30 sec for the Ti line and 236 ± 30 sec for the Mg line, and the difference between the two lines is expected to be real. The mean value of the amplitudes of the waves is 0·80 km/sec for the Mg line and about half this value for the faint Ti line. This is in good agreement with the ratio of the r.m.s. velocities for the two lines at the center of the disk. The Fe line shows intermediate values between the Mg and the Ti line. The dimensions of wave fronts range from 1000 to 5000 km. The velocity curve of the Mg line lags behind the faint Ti line by about 10 to 12 seconds, indicating that the wave is progressing upwards. No relation between period and amplitude of the waves and no evidence of strong damping was found. The observations can be interpreted in terms of longitudinal pressure waves propagating in the solar atmosphere, generally upwards, with more or less the theoretically expected change of phase and amplitude with height. There seems to be evidence that each bright granule before fading produces a wave motion which begins with a violet shift. The mean lag between peak granule brightness and violet shift maximum is 40 sec. The center-to-limb observations of time-sequence spectra indicate a sharp limb decrease of observable wave motions. This decrease, however, is influenced by different factors and does not necessarily mean a strong predominance of vertical wave propagation. The elements near the limb show no oscillatory character and the life-times of the most pronounced shifts exceed the 10 minutes duration of the sequence. The horizontal velocity component appears to be independent of depth. The authors also pointed out the importance of the image resolution for observing the wave motions which will be blurred by inadequate resolution.

C. PHOTOSPHERIC MODELS

Paper 1—K. H. Böhm

The observational papers on solar granulation were followed by K. H. Böhm's theoretical paper on photospheric models including the effects of granulation. The first type of studies he considered are those which infer the observed granulation data upon the physical properties of the photosphere. He critically discussed the observational data of the continuum and the line spectra and he pointed out the difficulties involved in the interpretation of the various observations. He then examined the two lines of thought in the theory of granulation: (*a*) the overshooting of convective motions from the hydrogen convection zone into the upper stable part of the photosphere, and (*b*) the assembly of acoustic and probably gravity waves which have been generated by the turbulent motions in the hydrogen convection zone. The second type of studies examines the hydrodynamics of the solar hydrogen convection zone and the waves generated by non-stationary convection. Dr Böhm critically discussed the well-known mixing-length theory and the more recent methods suggested by Malkus and by Schwarzschild, Ledoux and Spiegel which both make use of a Fourier analysis of the turbulent velocity field. He then reported on a program in progress under his direction at Berkeley using the IBM 704 in which the Fourier analysis method is extended to the more complicated case of the solar hydrogen convection zone. The calculations take into account simultaneously the facts that in the solar hydrogen convection zone (1) the density, temperature, radiative conductivity and excess temperature gradient vary by several orders of magnitude, and (2) the overshooting into the stable photosphere is possible. The preliminary results show that the most unstable eddies are no longer those with a scale comparable to the thickness of the whole zone as is the case in an almost homogeneous atmosphere. Neglecting viscosity and radiative conduction he finds that the most unstable modes are those with an infinitely small horizontal scale and which are confined to an infinitely thin layer at the top of the convection zone. When the radiative conductivity is taken into account, the scale of most of the unstable modes becomes finite, because the temperature fluctuations are smoothed out by radiative conduction in the smallest eddies. Simplified calculations gave 300 to 400 km for the scale of the most unstable modes. This indicates that the observed size of the granules may be partly already understood as being the size of the fastest growing eddies. The overshooting turns out to be larger for larger eddies than for smaller ones. Furthermore, he finds that the motions become essentially horizontal above $\tau = 0{\cdot}5$ which is in agreement with the observations.

D. FRAUNHOFER LINE PROFILES

Paper 1—J. E. Blamont

The last paper on the agenda was a brief report by J. E. Blamont on a new method of measuring profiles of Fraunhofer lines. The magnetic scanning method which he had previously employed to measure the sodium day-glow was applied to study the profile of the strontium resonance line at λ4607 Å. An atomic beam of Sr is illuminated by sunlight between the poles of an electromagnet which displaces the position of the resonance line due to the Zeeman effect. The resonance line of the beam is observed parallel to the field by a photomultiplier and a circular analyzer. The profile of the line was observed several times with a resolution of the order of 10^{-3} Å and a signal-to-noise ratio of the order of 15. The stability of the beam permits observations to be carried out during several hours. Preliminary results indicate a redshift at the center of the solar disk which corresponds to the predicted value of the relativistic redshift.

DISCUSSION

J.-C. Pecker called attention to the fact that most determinations of velocity distributions refer to higher photospheric levels than the measurements of intensity fluctuations which are made in the continuum spectrum. Fraunhofer lines which originate in deep layers, such as for instance the infra-red oxygen lines, should be used to determine the velocity distribution of those layers in which the intensity fluctuations can be studied. Referring to Dr Böhm's paper, Dr Pecker mentioned that for a three-stream model one needs to know essentially two parameters aside from a mean model derived from continuum observations. These two parameters are the $\Delta T = T_{\text{hot}} - T_{\text{intermed}}$ and the horizontal scale h which fixes the dimensions of the hot, cold, and intermediate columns. The observations of the granulation yield the approximate values $\Delta T \sim 100°$ and $h \sim 700$ km. However, the center-to-limb observations of spectral lines made by Lefèvre and Pecker lead to $h \sim 300$ km for $\Delta T \sim 500°$ (Böhm's model). If one takes smaller values of ΔT even smaller values of h are found. This contradiction may be reconciled if one considers differences in excitation temperature for the granules and the inter-granules, *i.e.*, if one makes a distinction between the $(T_{\text{exc}} - T_e)$ of the granules and of the inter-granular regions. The effects could be calculated by methods similar to those developed by R. N. Thomas and his colleagues at Boulder and at Paris.

J. Rösch commented that they hope to increase their definition (at most by a factor of 2) in order to obtain more accurate measurements of the r.m.s. intensity fluctuations. He pointed out that his method of determining the ΔT from granulation pictures refers to some kind of a three-stream model in which, indeed, he finds the horizontal dimensions of the columns in good agreement with those suggested by Dr Pecker.

R. Michard opposed Dr Pecker's comment on the difference in excitation temperature in the line and in the continuum which may influence the ΔT. Instead Dr Michard stressed the evidence for oscillatory fluctuations in brightness at the line center which are much more important.

K. H. Böhm said that one should allow for pressure fluctuations but they may not influence the line profiles appreciably. A brief discussion followed between R. Lüst and K. H. Böhm on the relative proportion of energy going into longer and shorter acoustic waves.

R. G. Athay suggested that if the observed Doppler shifts in the Fraunhofer lines are due to progressive waves, then two effects should stand out in the data: (1) the maximum Doppler velocity should show a phase lag from faint to strong lines that is of the order of a minute or so; and (2) the strong lines with saturated Doppler cores should show a Doppler shift that moves progressively from the wings of the lines to the centers, again with a time scale of the order of minutes.

Some final comments on the granulation problem were delivered by M. Schwarzschild. He stressed the importance of accurate measurements of the r.m.s. intensity fluctuations, such as Dr Rösch is planning. However, he considered Dr Böhm's theoretical calculations to be the most effective attack to the problem of the physical properties in the photosphere. Dr Schwarzschild then suggested to stick to the formal separation of the two types of modes, the convective and the wave modes. The intensity fluctuations observed in the granulation seem to be almost entirely due to the convective mode. On the other hand, the velocity distributions indicate that they are due in part by wave modes. The papers by Leighton and by Evans and Michard show the outstanding feature that the wave mode has a preferred period. Dr Schwarzschild suggested the model of a "leaky standing mode" which may be described as bumps by convection modes which leak upwards. He also mentioned that chromospheric pulsations may very well exist. Dr Michard agreed with Dr Schwarzschild on the existence of two types of modes which are revealed in the velocity distribution: the horizontal component does not seem to vary from center to limb, and the vertical component shows oscillatory motions.

Fourth meeting, 23 August 1961

CHAIRMAN: R. Giovanelli.

In this session an international co-operative program was discussed for observing chromospheric granulation. The chairman of the session was Dr R. Giovanelli who pointed out the necessity for such a co-operative effort in order to study the large-scale chromospheric structures observed in Hα which last for periods of 12 to 24 hours. The requirements for such a program are:

(*a*) Good weather during a period of a couple of weeks, and good seeing conditions.

(*b*) A monochromator or filter with a narrow passband, preferably of 0·2 Å width.

(*c*) Willingness to take a minimum of two Hα pictures per day during a pre-selected period of a couple of weeks.

Dr Giovanelli stressed the importance of a narrow passband which is necessary for separating the different structures observed in different regions of the Hα line. The Hα fine structure is very much the same in the range between −0·2 and +0·2 Å from the Hα line center. The appearance of Hα pictures taken between about −0·5 and −0·4 or +0·4 and +0·5 Å from the line center is quite different; long chains of very small fine dark dots appear between brighter regions. Further away from the line center, between about ±1·0 and ±0·7 Å the structures become much simpler.

Members of the Commission who are willing to join in this co-operative program were asked to specify their Hα images, to quote the period of best weather conditions at their location, and to suggest other observatories which perhaps may join in the program. Thus the following preliminary list was made:

Observatory	Observer	Specifications	Period of Good Weather
Sydney	Giovanelli	0·2 Å passband	Sept.—June
Arcetri	Righini	full disk, 66 mm image	May—Sept.
Capri	Kiepenheuer	0·5 Å passband small part of disk	Oct.—March
Lockhead	Moreton	small part of disk	Jan.—Dec.
Pulkovo	Gnevyshev	spectroheliograph 5 cm image	—
Crimea	—	spectroheliograph 10 cm image	May—Sept.
Tokyo (?)	—	0·5 Å passband	poor seeing
Sacramento Peak (?)	—	full disk	Sept.—Nov.
Mt. Wilson (??)	—	—	May—Sept. early morning
Meudon (??)	—	80 mm image	?
McMath-Hulbert (??)	—	—	?

It was concluded that the best months for the program were May, June and September. K. O. Kiepenheuer pointed out the difficulties involved in the analysis of the observations taken with different instruments.

A Working Committee of three members was formed:
R. Giovanelli, chairman; K. O. Kiepenheuer; A. B. Severny,
and it was decided that this committee would write a letter to all interested observatories concerning the co-operative program and including samples of pictures showing the essential features that one wishes to study.

12*a*. SOUS-COMMISSION DES ECLIPSES DU SOLEIL

Report of Meetings

PRESIDENT: R. O. Redman.

SECRETARY: J. Houtgast.

First meeting, 17 August 1961

DRAFT REPORT

In opening a brief discussion on the *Draft Report*, the President apologised for a number of omissions, which would be rectified. The Report was then adopted without further correction.

COMMUNICATIONS

Athay called attention to chromospheric observations that we still need. The chief shortcomings are in the ultra-violet and infra-red. We need measurements over a greater range of height, both for lines and continuous spectrum, including the Balmer continuum; line profiles of increased accuracy; studies of the relative behaviour of certain lines of He I, Ca I, Mg I, etc. He would like to see more study of central intensities, starting in the Fraunhofer spectrum of the disk and extending through the transition to the chromosphere, and also of coronal intensities down to heights as low as possible. He stressed the importance of more knowledge of variations of the chromosphere through the solar cycle. He showed some of the results obtained from the H.A.O. eclipse observations.

Houtgast reported observations made by Dutch observers during the eclipses of 1959 October 2 and 1961 February 15. These include photo-electric measurements of the darkening at the limb by T. de Groot and photographic observations by Koelbloed of the higher Balmer lines, the wings of H and K of Ca II, and of the transition from photosphere to chromosphere in some parts of the spectrum. Hα and Hβ were obtained in different phases of the 1961 eclipse, with high resolution (0·8 Å/mm).

Houtgast would like more measures of Hα and K in the high chromosphere, say between 10 000 and 15 000 km, because the observations of 1954 indicate an increase of the logarithmic gradient above 10 000 km for the K line and a comparison with Hα should lead to interesting conclusions about the state of the chromosphere at that height.

As to the low chromosphere, he emphasised the need for high time-resolution and for that reason intended at the next opportunity to use the moving film technique.

Suemoto said that he has a great deal of material still in course of measurement, from the 1958 eclipse, where he had photographed the chromospheric spectrum with a slitless spectrograph, using a large grating at high incidence. The observations show many details in the