12. COMMISSION DE LA RADIATION SOLAIRE ET DE LA SPECTROSCOPIE SOLAIRE

PRÉSIDENT: M. MINNAERT.

MEMBRES: MM. Abbot, Abetti, Harold D. Babcock, Barabashev, Brück, P Carrasco, Chalonge, Chapman, d'Azambuja, Edlén, J. W Evans, Evershed, Goldberg, Lyot†, Melnikov, Menzel, Migeotte, Nicholson, Nicolet, Plaskett, Righini, Rutllant, Sitnik, ten Bruggencate, Thiessen, Waldmeier, Wildt, Woolley.

This report summarizes the research which has been made on solar radiation and spectroscopy from 1948 to the beginning of 1951, as derived from publications and from personal letters of the members. Following the tradition of the last *Transactions*, the emphasis was put on observational work while typical theoretical papers have been mentioned only by a bibliographical quotation. The study of the solar radiation in the radio region was considered to belong to the scope of the Commission on Radio-Astronomy.

GENERAL

We want to draw attention to the translation of Unsöld's *Physik der Sternatmosphären* into Russian by Mustel (Moscow, 1949). An especially valuable chapter has been added by the translator on the latest results in this field.

SOLAR CONSTANT

On Dr Abbot's retirement, the investigations at the Astrophysical Observatory of the Smithsonian Institution were directed by Dr Loyal B. Aldrich. Measurements of the solar constant were made daily, if possible, at Montezuma (Chile), and at Table Mountain (California). A few days of solar constant measurements were secured at Miami (Florida), at sea level with a view to determining the atmospheric transmission at individual wavelengths between 0·35 and 2·5 A.

Many improvements have been made in solar constant apparatus. As much scrutiny and search for errors are required, the daily values are not published for a considerable time. Ten-day and monthly mean values were published up to the end of 1947. The last absolute measurements of 1947 with improved pyrheliometers have entirely confirmed the earlier determinations and yielded again a value of 1·90 cal. cm.$^{-2}$ min.$^{-1}$ for the solar constant. Since then, from different sides, critical remarks have been made concerning the methods of observation and reduction, followed by the Smithsonian observers.

(*a*) Wegener proposes to correct for the temperature of the pyrheliometer envelope, which would change the solar constant by 30%. But Aldrich and Abbot refute these considerations.

(*b*) Schatzman derives from the rocket observations, that Abbot's allowance of 3·44% for the far ultra-violet was too high and should be reduced to 1%, which would result in a correction of −2·44% to the accepted solar constant and would yield 1·854. Allen, considering more critically this same correction, shows that the ultra-violet allowance was not overestimated by Abbot, but rather slightly underestimated (by 0·7%), he thinks that Abbot neglected the far infra-red and wants therefore an allowance of 3%. So finally a correction of +3·7% ought to be applied to Abbot, making the solar constant 1·970. Nicolet, after a careful analysis of the whole procedure, concludes that there is no reason to modify Abbot's U.V. allowance; the far infra-red should be only 0·8% higher than Abbot's.

We may conclude with Nicolet, that Abbot's U.V. and I.R. corrections cannot well be improved, but that they are liable to considerable uncertainty and that their error cannot be estimated.

Author	Ultra-violet correction	Infra-red correction
Abbot before 1908	+1·58 %	+0·55 %
Abbot after 1908	3·44	2·0
Schatzman	1	2
Allen	4·1	5
Nicolet	3·38	2·8

(*c*) In Abbot's reduction, a 'compensating effect' of the order of 3% is taken into account, which would almost compensate for the U.V. and I.R. corrections (*Smiths. Ann.* **3**, 41, **5**, 109; **6**, 62). After a critical examination, Minnaert comes to the conclusion that this effect exists only partly. The solar constant thus should be raised to perhaps 1·92.

(*d*) Nicolet, after a revision of all data, making the best available assumptions about the energy wave-length curve and assuming the middle part of Mulders' curve to be right in absolute value, concludes that the solar constant should be raised by 0·06 cal. and that it should become finally 2·00. This increase is especially due to a modified energy distribution between 1μ and 2μ.

It is clear that independent new measurements are urgently needed, preferably made by methods different from those of the Smithsonian observers. Some pyrheliometer results of the Commonwealth Observatory, provisionally reduced, seem to be in agreement with a solar constant of 1·97. Chalonge and his collaborators Peyturaux, Pierce and Lewis, determined the absolute brightness (brilliance) of the solar disk at selected wave-lengths, especially in the infra-red, by comparison with a calibrated tungsten ribbon lamp or with a black body. Schüepp did the same at some places in the visible spectrum, his measurements yield values between 1·96 and 2·03.

A value near 2·00 cal. cm.$^{-2}$ min.$^{-1}$ seems for the moment the most probable value of the solar constant.

A new determination of the Sun's stellar magnitude was made by Woolley and Gascoigne; greater precision was obtained by comparing the spectra of the Sun and Sirius and by measuring monochromatic magnitudes at four wave-lengths. On the IPv scale the Sun's magnitude is found to be −26·9. A re-discussion of the magnitude of Sirius by de Vaucouleurs yields a practically identical result. Another careful measurement by photo-electric methods was made by Nikonova, who found −26·69 on the IPv scale.

VARIATIONS OF THE SOLAR CONSTANT

Abbot, from the Montezuma measurements over 1923–47, found periodic variations, the periods being integral submultiples of 273 months $= 22\frac{3}{4}$ years. He studied the correlation between the fluctuations, found in the solar constant, and the fluctuations in precipitation, temperature, frequency of hurricanes. By making use of the periodicities of 6·6 and 27 days, he was able to make predictions with respect to temperature and precipitation; he states that these predictions were confirmed.

Link finds a correlation between the brightness of the Moon and the supposed variations of the solar constant. Since the lunar variations are considerably greater, he attributes part of the lunar radiation to fluorescence, caused by the solar ultra-violet radiation, which is considered to vary in much greater proportion than the visible radiation.

RADIATION OF THE SKY NEAR THE SUN

Fracastoro constructed a very simple and practical camera, without lenses or mirrors but with suitable diaphragms. The radiation of an annular zone around the Sun was measured with a barrier layer photocell. Measurements were made by Abetti, Righini and Fracastoro in order to choose the location for a coronograph.

Krat, from measurements of the aureole around the Sun, due to the terrestrial atmosphere, pointed out that the light, scattered over the sunspots, etc., may amount to 30% of the photospheric intensity.

CENTRE-LIMB DARKENING

New measurements were made by:

Krat	Visual region	Photographic photometry
Minnaert *et al.*	Visual region, limb	Photographic photometry
ten Bruggencate *et al.*	Visual region, limb	Photographic photometry
Fujita	5200–5800 A., limb	Eclipse photometry
Peyturaux	6700–23000 A., near infra-red	Lead sulphide cell
Pierce *et al.*	$0{\cdot}5\mu$–$10{\cdot}2\mu$	Thermocouple
Pierce	$4{\cdot}5\mu$–18μ	Thermocouple

From the work of Minnaert *et al.* and ten Bruggencate *et al.* it becomes clear that the limb darkening can be ascertained on direct images, up to 99·5 % of the radius or even farther. Especially beautiful is the method of ten Bruggencate, who chose the moment of a partial solar eclipse, and compared the intensity distribution at the limb of the Sun with that at the limb of the Moon. The second one gives information on the apparatus curve and the scintillation; from this the first one may be corrected and reduced.

The observations of Peyturaux in the near infra-red seemed to show that the minimum absorption is found at 2μ, and not at $1{\cdot}6\mu$ as assumed earlier. Afterwards this result proved erroneous; it was due to a slight error in Abbot's energy curve.

The results of Pierce in the far infra-red are the first ever reached in this region.

Measurements at the extreme limb have been made at total eclipses (cf. Commission 13).

LIMB POLARIZATION

By photo-electric photometry, Lyot was able to detect a polarization of the order 10^{-4} near the extreme limb. This effect was attributed to scattering by free electrons. The polarization of the emitted radiation has been calculated for pure scattering by Chandrasekhar and has been found to be 11 %. However, due to thermal absorption, this amount of polarization is considerably decreased; at the temperature of the Sun, the theorists Pecker and Code, in fair mutual agreement, find a polarization of precisely the observed order. Voigt afterwards showed that the Rayleigh scattering is preponderant over the scattering by free electrons.

Proisy investigated the refractive index of the solar gases and the influence of the refraction on the limb darkening; this influence becomes only observable near the extreme limb, beyond 99·9 % of the radius.

ENERGY–WAVE-LENGTH CURVES

Chalonge and his collaborators have corrected their earlier (1946) results for the lack of resolving power of their spectrograph. Results for the centre of the disk:

$$\begin{array}{lll} \lambda 5000-\lambda 3700 & T_1=7130^\circ & I=0{\cdot}600\, B_{\text{Planck}} \\ <\lambda 3700 & T_2=5900^\circ & \end{array}$$

There is a serious discrepancy between these results and earlier work of Kienle (*A.N* **275**, 32, 1947), who found a temperature of 7540°, connecting the U.V. window with the blue. A more definitive solution would be important, since Chalonge suspects the presence of a new ultra-violet absorbing agent.

In the ultra-violet part of the spectrum the continuous background of the *Utrecht Atlas* was ascertained by Michard. He repeated the measurements of the total absorption due to the Fraunhofer lines in all wave-length regions, the ultra-violet being for the first time measured in a reliable way; the result $\eta=0{\cdot}124$ was obtained. Miss Bell made also measurements of the total line absorption from 2600 to 6000 A.

A careful study of the near infra-red region was important, because there the limb darkening had shown interesting anomalies. By comparing the solar spectrum to that of a tungsten ribbon lamp, Peyturaux found that the brightness between $1{\cdot}5\mu$ and

$2{\cdot}2\mu$ was smaller than according to Abbot's curve, probably the minimum absorption from these data will be found at $1{\cdot}6\mu$ as theoretically expected. This result is especially important in connection with the results of Pierce and Aller, who were not able to reconcile theory and observation if they accepted Abbot's curve. Neven and de Jager, using the new measurements, reached complete agreement unto $2{\cdot}5\mu$, between $2{\cdot}5\mu$ and 10μ they suspect a new absorbing agent.

Pierce and Lewis are comparing with photocells the centre of the disk to a black body source; their investigations extend up to 10μ.

Chalonge and his collaborators showed the importance of a comparison between the colour temperature T_c and the brightness temperature T_b in different regions of the spectrum. Where κ_λ increases with λ, $T_c > T_b$, and conversely. The ratio $p = B(T_b) : B(T_c)$ varies in the spectral sequence and is for the Sun: 0·63 ($\lambda > 3700$) or 2·00 ($\lambda < 3700$).

TABLES OF FRAUNHOFER LINES

The revised Rowland Table is being thoroughly studied by Mrs Sitterly and by Babcock in view of a new revision. A great number of new identifications and term designations have been found. This new revision will include also the equivalent widths of the lines, which are being measured at Utrecht from the Utrecht photometric atlas. For $\lambda < \lambda\lambda 3000$–3600 A., new plates taken by Babcock will be measured. By January 1, 1951, the equivalent widths had been measured between $\lambda 8700$ and $\lambda 6000$. A photometric catalogue of the section $\lambda 8700$–6500 has been published already, as a complement to Babcock and Moore's infra-red catalogue.

FAR ULTRA-VIOLET SPECTRUM SURVEYS

Babcock, Moore, Coffeen investigated the end of the solar spectrum at the height of the Mount Wilson Observatory and described the lines between $\lambda 2935$ and $\lambda 3063$.

Rocket spectra were obtained by Hopfield and Clearman, and by Durand c.s. They extend from 2100 to 2900 A. and have been photographed at heights up to 75 km. Especially the lines of Si and Mg are very broad.

Purcell, Tousey, Wanatabe found that phosphorescent Ca—Mn sulphate showed thermoluminescence, when it had been exposed to the solar radiation at 125–150 km. They are able to conclude that rays with $\lambda < 1300$ A. must be present in some intensity at these heights.

According to Burnight, at heights reached by rockets, plates are sometimes impressed by soft X-ray radiation ($\lambda < 4$ A.).

INFRA-RED SPECTRUM SURVEYS

An excellent review of recent advances in this field has been given by Goldberg.

The astronomers of the McMath-Hulbert Observatory have achieved outstanding progress by the publication of their *Photometric Atlas of the Infra-red Solar Spectrum*, $\lambda 8400$–25,000, at a scale of 3·5 mm./A., recorded by means of a lead sulphide cell on 250 tracings. Two preliminary lists have already appeared in print. The accompanying catalogue will be ready in the summer of 1951.

Fisher and Knopf at Northwestern University have recorded the laboratory spectrum of Fe I in the region 1–2μ. Every line observed in the laboratory has been found also in the Sun.

Chapman, Shaw, Williams at Ohio also studied the solar spectrum with great dispersion up to 6μ. Shaw, Chapman, Howard and Oxholm gave a complete record and catalogue from 3·0 to $5{\cdot}2\mu$; in this region only one solar line has been found.

In the beginning of 1950, Migeotte (Liége) transferred his infra-red spectrograph to the Jungfraujoch Observatory. By March 1950 the instrument had been adapted to the new conditions and observations were started. The spectrum was recorded between

2·8μ and 4μ with an echelette grating of 7200 lines per inch and a PbSe cell; from 4μ to 10μ, with an echelette grating of 3600 lines and a Perkins Elmers thermopile and amplifier. The records show more detail than the best American observations, partly because the gratings were more perfect, but chiefly because of the very dry atmosphere. Many lines are found which were covered by H_2O absorption at other stations. Some lines recorded as Si I and Mg I by others appear to be due to H_2O. From February 1951 on, new observations will be made of the spectrum till beyond 10μ. A photo-conductive PbTe cell will be used up to 5·5μ.

TELLURIC LINES

Aldrich has prepared a double spectrobolometer, which is used at Table Mountain to observe the atmospheric ozone band near 10μ; every day the solar constant is measured. Vigroux (Paris) studied the fine structure of the ozone bands between 3μ and 10μ with the spectrograph of Migeotte at Jungfraujoch.

The CH_4 bands and CO, discovered by Migeotte at Columbus, were detected by him also at Jungfraujoch, he concludes that these gases are not restricted to industrial areas, but must be considered as normal components of our atmosphere; the occurrence of NO is still dubious. The fine structure and many details of infra-red N_2O, CH_4, CO, H_2O bands have been studied at the McMath-Hulbert Observatory and by Migeotte. A special study has been made of the CH_4- and CO_2-bands.

Babcock stresses the wave-length constancy of O_2 lines, as demonstrated by the extensive investigation of Babcock and St John (*Ap. J* 1922). Effects recently considered by theorists are apparently too small to shift the wave-length by more than 0·001 A.

FORBIDDEN LINES

Bowen and Cabannes and Dufay independently found the three forbidden auroral [O I] lines in absorption. Shortly afterwards, Cabannes and Dufay also discovered two multiplets of forbidden [Fe I].

WAVE-LENGTH VARIATIONS, DISPLACEMENTS OF FRAUNHOFER LINES

Evershed compared the wave-lengths of some iron lines to those of neighbouring standard atmospheric lines. In an interval of thirty-four years, the wave-lengths of the solar lines seemed to have decreased by 0·003–0·007 A, the decrease being the same at the centre and at the limb. In the years 1946–49, two lines decreased by 0·006 and 0·008 A. In 1950 the lines show a general increase. Another iron line at 6280 A remained unaltered throughout the whole period of years.

By means of high precision interferometry, Miss Adam measured fourteen lines with respect to oxygen lines, for thirteen points across the polar diameter. The observed shifts are interpreted in the following way:

Centre	Einstein + Lindholm + Doppler
Limb	Einstein + O + O

The Lindholm shift is connected to the collisional broadening, which increases with the pressure. The required Doppler effect could be explained only by a system of ascending currents of at least 10 km./sec., which would be inconsistent with our knowledge of the solar atmosphere. Spitzer, however, makes it plausible that the Lindholm shift in this case is likely to be towards the violet rather than to the red. Thus the observed shift could be explained as follows:

Centre	Einstein + Lindholm
Limb	Einstein − O

INTERFEROMETRIC MEASUREMENTS OF LINE PROFILES

Treanor places a short etalon behind the spectrum of the Sun formed by the Oxford solar spectroscope. In the focal plane of a camera, he obtains an interference pattern in which wave-length measurements are possible with a precision of about 0·001 A. The interferometric spectrum is displayed without overlap of orders and continuously, so that the line profiles may be easily measured.

FRAUNHOFER LINE PROFILES

It has now become clear what precise information may be drawn from the study of Fraunhofer line profiles about temperature and turbulence in the solar atmosphere. From the *line widths* we derive the sum of kinetic temperature + macroturbulence + microturbulence. By comparison between elements with very different atomic weights we are able to separate the kinetic temperature from the total turbulence. From the form of the *curve of growth* we find the sum of kinetic temperature + microturbulence. This, compared between elements of different atomic weight, must give again a separation between the kinetic temperature and the microturbulence. A comparison between the total absorption by lines of different E.P. will yield the excitation temperature which may be different from the kinetic temperature. Thus systematic methods are available and there is even the possibility of checking the results. In practice, many difficulties occur and a complete application of these principles has not yet been made. An additional complication is that temperature and turbulence are functions of depth.

Pierce and Goldberg, studying the widths of faint lines, gave special attention to the comparison between lines of several elements of different atomic weight. They found a kinetic temperature of 16·000° and no turbulence. These results were confirmed by an extensive study of line-widths, due to Miss Bell: she finds a kinetic temperature of 11·500° in the lower reversing layer, increasing to 20·000° in the high reversing layer; the total turbulence does not exceed 0·7 km./sec. These results are at variance with earlier findings.

Allen compared the profiles of twenty faint lines at various positions of the disk. The widths increase as one approaches the limb; the manner of this variation shows the reversing layer to be in a state of non-isotropic large-scale turbulence, with a vertical velocity of 1·74 km./sec. and a horizontal one of 2·79 km./sec. The equivalent widths of the faintest lines increase uniformly towards the limb; somewhat stronger lines show a maximum near $\cos\theta = 0{\cdot}3$. The same maximum near $\cos\theta = 0{\cdot}3$ has been found by Righini and Barocas, for Ti-lines of medium strength, by Houtgast for very different lines, all of medium strength; by J. C. Pecker, Ch. Pecker and Peyturaux for some faint lines of CH and C_2. Suemoto investigated fifty faint lines, lines for which $\eta = \kappa_\lambda/\bar{\kappa}$ decreases more rapidly with increasing depth, showed a stronger limb-strengthening; and reversely. The anisotropy of the turbulence was not found confirmed by Houtgast.

Theories of line profiles and of their centre-limb variation have been developed by Chandrasekhar, Harris, Minnaert, Pecker, Suemoto, Unsöld, Hattori.

Two systematic observations of the hydrogen Balmer lines have been achieved, the profiles were studied at different points of the solar disk. The work of ten Bruggencate refers to the lines H_α–H_δ, the profiles cannot be entirely explained on the basis of the classical model. The authors assume that the second energy level shows super-excitation in the highest solar layers. De Jager extended his work to all measurable Balmer lines and (partly in collaboration with Neven) to the Paschen and Brackett lines in the near infra-red. He found that these lines are formed by non-coherent scattering; thermal absorption, fluorescence, cyclic transitions play only a negligible role. The combination of statistical broadening and collisional broadening has not yet been described by theory in a satisfactory way. An earlier solar model of the author was improved; below $\tau = 2{\cdot}4$ the atmosphere was found to be in convective equilibrium.

Giovanelli developed an entirely independent theory of the hydrogen lines, not based on equilibrium assumptions.

The PD-series of Mg, which had already drawn the attention of solar physicists, was thoroughly studied by Voigt. The profiles were explained by damping, due to collisions with H-atoms and electrons. Below $\tau = 2$, the atmosphere was found to be in convective equilibrium (cf. de Jager). Miss Bell, for the same lines, suggests that the van der Waals effect predominates. Ishizu studied the far U.V. Mg-lines in rocket spectra.

Miyamoto investigated the residual intensity and the K_2 emission in the Ca^+ line. The chromosphere is very opaque for the core radiation. The quanta, created by electron collision within the Doppler core, escape through the less opaque wings by non-coherent frequency redistribution. The wing extension of the K_2 emission ceases where the chromosphere becomes transparent for that frequency. The fluctuations of chromospheric density determine the residual intensity.

CURVE OF GROWTH—ABUNDANCES—IDENTIFICATIONS

The following authors constructed curves of growth and derived temperatures:

Author	Kinetic temperature + microturbulence	Excitation temperature
Bell	15·000°–17·000°	4700°–5300°
Claas	11·500	5000
Demidova	11·700	4700
Gottschalk*	—	4800
Melnikov	—	4600
Pierce and Goldberg	19·500	4680
Sandage and Hill	17·000	3790
Voinova	14·000	4080
Unsöld	—	5675
Wright	—	4900

Carter, basing his work on his laboratory measurements of the Fe line intensities, found that terms of odd parity give slightly stronger absorption lines than even terms. This seems due to pressure broadening.

By the work of Greenstein, Wrubel, Pecker, the small differences in shape were put into evidence between the theoretical curves of growth for different stellar models and different wave-lengths. Any results about kinetic temperature + microturbulence are uncertain if the curve of growth has not been constructed for the right model. Claas showed how to construct a curve of growth, free from such ambiguities and precisely adapted to the stellar model, this procedure should be followed for all exact work.

From a systematic study of the solar spectrum, Unsöld derived the abundance of twenty-seven elements in the solar gases. This is the most general spectral analysis of the Sun made up to now. A similar analysis has been carried out by Claas, using only faint and medium strong lines, and combining the method of the weight functions with that of the curve of growth. The agreement between Unsöld and Claas is excellent, differences being partly due to a detailed consideration of the thickness of the absorbing layer by Claas.

An important systematic investigation of the spectrum of the Sun (and solar type stars) was carried out by Wright. Beautiful curves of growth were obtained. For 21 elements abundances were determined, based, however, on rather rough f values; this explains some considerable divergencies from the results of Unsöld and Claas (Mg, Zn).

Present cross-section determinations predict an abundance ratio N/C near 30, which considerably disagrees from the observations of the solar spectrum ($N/C \simeq 3$). This result becomes still more striking, if the conclusion of Pecker is confirmed, who from the spectrum finds an even higher C abundance than previously assumed. An upper limit for the C^{13} abundance was derived by Greenstein *et al.*, who found the proportion $C^{13} : C^{12}$ smaller than 1 : 36.

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* It is not clear, whether the temperature here derived is an excitation temperature.

No trace of He^3 was found by Greenstein, which agrees with the predictions of nuclear theory. The abundance of Li^7, determined by Greenstein and Richardson, agrees very well with the result of Claas ($H/Li = 10^{11}$). The ratio Li^6/Li^7 is less than 0·25 and may be the same as on Earth, 0·08.

The presence of indium and osmium in the Sun became almost certain (Babcock, Moore, Coffeen, loc. cit. pp. 298–300). The Raffety band of CH has now been very probably identified in the solar spectrum by Tcheng-Kien.

SPECTRUM OF THE GRANULATION

In the spectrum of a beautifully defined, large-scale solar image, M. Schwarzschild measured slight local shifts of the spectral lines, evidencing random motions of the order of 0·4 km./sec. By comparison with other results, it becomes clear that this is the statistical velocity of the big volume elements, not resolved into separate units.

RADIATION OF FACULAE

Waldmeier investigated the contrast of the faculae against the photosphere and showed that they are produced by a high temperature layer near $\tau = 0{\cdot}6$.

SPECTRUM OF SUNSPOTS

From the continuous spectrum of spots, Krat derived an effective temperature of 4340° From the Ca and Ca^+ lines, the electron pressure in the spot was found to be 1/40 of the electron pressure in the photosphere. Lines of hydrogen, titanium and iron have also been measured.

Goldberg noticed the strong widening of the infra-red lines in sunspots, which must be due to the Zeeman effect. Michard investigated how the Evershed effect depends on the distance from the limb, the magnetic field and the spot area. Öhman used with success a Savart polariscope instead of the usual compound $\lambda/4$ plate for the measurement of magnetic fields in spots.

SPECTRUM OF FLARES, PROMINENCES AND CHROMOSPHERE

Between $\lambda 4861$ and $\lambda 7065$ Waldmeier counted ninety-three emission lines, observed in flares or in prominences, most of them for the first time. Besides H and He, also multiplets of Na, Mg, Si, Ca, Sc, Ti, V, Cr, Fe, Ni, Y, Ba, La were found.

Ellison described the characteristic properties of flares, as derived from nine years of observations. Profiles are given of the H_α line in emission (flares) and in absorption (concomitant surge). The asymmetry of the emission profile is explained by absorption in the cloud ejected from the Sun. In his description of the great flare of 1946, July 25, several lines are found which complement Waldmeier's list. An interesting discussion took place in *Nature* concerning the origin of the broadening of Balmer lines in flares. Since the measured width of H_β in flares is smaller than that of H_α, some authors conclude that the broadening is not due to the Stark effect. An explanation in terms of the Zeeman effect seems equally difficult, for no comparable broadening is found in other emission lines. An interpretation by Doppler effect would require a temperature of the order of 10^6 degrees—cf. recent observations by Švestka, *B.A.C.* **2**, 1951.

Mustel and Severny measured the profiles of the Balmer lines H and K in the spectrum of flares. Some time after the start of the flare, they observe how the profile in the wings is raised, this they ascribe to the absorption of Ly radiation and to the subsequent recombination in the second level. The flares are found to occur at a height of 2500 km. in the chromosphere.

Suemoto investigated the profiles of H_ϵ, H and K in flares and flocculi and found that they might be explained by an electron temperature of 70,000°

For nineteen flares, classified in the classes 1, 2, 3, Ballario determined by photometry the brightness with respect to the surrounding chromosphere or with respect to the continuous spectrum.

Very small prominences, investigated by Miss Hedeman, show radial velocities of H_α from 50 km./sec. to −50 km./sec. and widths from 0·8 to 2·7 A.

The staff of the McMath-Hulbert Observatory plans to investigate systematically the spectra of flares and prominences, concurrently with the motion pictures of prominences.

Zanstra, basing his considerations on measurements of Lyot, showed that the high polarization measured in the continuous spectrum of prominences corresponds to the electron scattering; the much lower polarization of the emission lines might be expected to correspond with atomic scattering, but is indeed so much smaller, that other processes must be involved. Thiessen was able to give a more complete explanation, by considering the influence of general or local magnetic fields.

Theories of the excitation and ionization in the chromosphere and in the corona have been developed by Thomas, Miyamoto, Mustel, Wurm, Shklovsky, Zanstra. Most authors agree that equilibrium equations cannot be applied. Wurm and Zanstra calculated the intensity of the continuous spectrum of the chromosphere and the prominence at both sides of the Balmer limit; by comparison with the observations, a function of the electron concentration and electron temperature may be determined. Ueno suggests that the continuous spectrum of the chromosphere should disappear progressively from the violet to the red and that the inverse process should occur at the Balmer and Paschen limits. Ishizu draws attention to the abnormal intensity of the infra-red O I multiplet in the flash spectrum which he explains by an increased population of the lower level. Theories of the radiation in flares are due to Giovanelli, Shklovski and others.

Hattori studied theoretically the interesting transition from absorption to emission lines during the flash. Shibata and his collaborators compared the intensities of emission lines in a highly excited chromospheric region with a normal region and found that especially Fe I and Ni I lines are weakened, while Fe II and Si II are unaffected and H, He I and He II are strengthened.

THE CORONA

We only mention the detailed photometry of the 1941 corona by the Leningrad Observatory (183 pages) and the study of coronal forms, published by Bugoslavskaya (187 pages). These properly belong to Commission 13. Saito, following van de Hulst and Öhman, separated the brightness of the corona proper from the brightness of the zodiacal light. He found that the coronal intensity varies with an amplitude of 35% in the 11-year period. A similar separation was made by Bogorodsku and Khinkulova. In both papers, the anisotropic scattering is taken into account. Cf. also Takakubo.

New observations of the polarization of the continuous radiation were made by Saito in one colour; he tried to explain earlier deviations from the theoretical curve; the observed vibrations were not perfectly tangential to the limb. Vashakidze studied the polarization of the interior corona and found deviations up to 29°; the polarization was stronger near the equator than near the poles. Saito calculated theoretical brightness and polarization for an oblate corona.

The identification of the coronal line λ5694·42 is considered as dubious by Shklovsky; but it is confirmed by Waldmeier, who assumes that the newly detected coronal line λ5445·2 is another component of this Ca XV transition. Woolley and Allen, Shklovsky, Yakovkin tried to compute from the spectrum the probable composition of the corona. The intensity of the lines 5303 and 6374 at about sixty points around the solar disk has been estimated at Arosa on 700 days during the whole solar cycle 1939–49; this very rich material has been published in full by Waldmeier.

Shajn found that the emission lines of the corona show a steeper decrease from the limb outward than the continuous spectrum. The lines may be subdivided into groups, according to the way in which they vary from one eclipse to another or according to their dependence on heliographic latitude. These groups appear to be correlated with the ionization potentials after Edlén.

The broadening of the Fraunhofer lines by electron scattering in the corona has been studied by van Houten theoretically. In this connection it seems necessary to call the attention of the eclipse observers to the discrepancy between the results of Grotrian (*Zs. Ap.* **3**, 199, 1931) who observed the H and K lines as shallow depressions in the continuous spectrum of the corona, and those of Shajn (*Izvest. Krymsk. Obs.* **1**, 115, 1947), who did not find any trace of them.

GENERAL MAGNETIC FIELD

In 1948 Babcock reported that careful observations during the last ten years had shown that temporarily a general magnetic field between 6 and 60 gauss is found, while at other moments the field is zero or even negative. At the end of 1950 he confirmed this conclusion, deduced from very precise measurements with powerful means. Fields of 30 to 40 gauss were observed in 1940, having a polarity like the Earth; in 1946 similar fields of 20 to 40 gauss were found on two days, on one day a field of the same order but with opposite polarity; on many days in 1940, '41, '43, '44, '46, '47, mostly when the solar activity was great, no definite evidence of a field was detected. The general magnetic field is thus variable.

From observations of his own during the years 1947–48, Thiessen concluded that there was no field greater than 5 gauss, the mean of the results indicating even a very small negative field.

Recently an entirely different method of measurement was applied, which had already been used by Hale and his collaborators in 1932 (*Carnegie Institution of Washington Yearbook*, 1933, p. 143). Instead of measuring the shift between the two oppositely polarized components, the polarization in a line wing is determined by a photoelectrical device. The method is independent of small local Doppler shifts and may detect a longitudinal field of the order of 1 gauss. It has been recently perfected by Thiessen and has also been applied by Kiepenheuer.

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M. MINNAERT
President of the Commission

Report of meeting. 5 September 1952

PRESIDENT: Prof. M. G. J. MINNAERT.

SECRETARY: Prof. M. NICOLET.

The President referred to the untimely death of Bernard Lyot, an eminent member of the Commission. He then presented some additions to the Draft Report, which were approved by the Commission. The following proposition was discussed and adopted for transmission to the Joint Commission on Spectroscopy:

> The Commission on Solar Radiation and Solar Spectroscopy expresses the hope that the broadening of spectral lines by collisions with helium atoms will be studied experimentally, with a view to deriving afterwards the influence of collisions by atomic hydrogen.

Four important subjects within the scope of the Commission were now selected and proposed for discussion. 1, the solar constant; 2, the energy distribution in the continuous solar spectrum; 3, the photoelectric investigation of line profiles; 4, the interferometry of the solar spectrum.

1. The problem of the solar constant was presented by Nicolet. He explained how important it would be to have a method of measurement, independent of that of Langley and Abbot. A new determination may be obtained by subdividing the problem: measuring (*a*) the absolute value of the radiation at one suitable wave-length or at a few specific wave-lengths; and then (*b*) the relative energy distribution in the spectrum, special attention being given to the ultra-violet and infra-red extremities. Another independent determination may be obtained by means of rockets, at altitudes where the radiation of the sky and the absorption of the terrestrial atmosphere are practically negligible, and where the measured total radiation hardly needs to be corrected.

2. Minnaert presented a short survey of the present state of our knowledge of the spectral energy distribution. Below 4000 A. the measurements are very difficult, because the continuous spectrum is almost entirely covered by Fraunhofer lines. Between $\lambda 4000$ and $\lambda 6000$ there still seems to be a marked discrepancy with photospheric theory; since this region is not particularly difficult, the measurements should be repeated and improved. From 6000 A. to 3μ the data appear to be satisfactory and well explained by theory. Finally, the region between 3μ and 10μ must be investigated further by means of the great infra-red spectrographs.

Miss H. Dodson reported on the programmes of the McMath-Hulbert Observatory, where this last region is especially explored and where absolute measurements of the radiation will also be made by comparison with a black body and with carbon or tungsten standards. D. Chalonge presented the project of Peytureaux, who is planning photoelectrical measurements of the energy distribution between 3000 A. and 23000 A., by means of a quartz monochromator. The dispersion is sufficient for the isolation of the 'windows' (13 A./mm. at 3000 A., 50 A./mm. at 6000 A., 110 A./mm. at the end of the spectrum). Absolute intensities will be obtained by direct comparison with a black body.

3. Van de Hulst presented a theoretical study by A. J. Coleman (Applied Maths. Dept., University of Toronto) of the lineshifts in the solar spectrum. The theory of relativity leaves open different possibilities for the precise amount of the relativity shift. Very precise wave-length measurements of suitable lines should therefore provide valuable information.

4. The photoelectric investigation of line profiles has recently become of increasing importance. The various methods used by workers in this field were discussed. The chairman pointed out that one of the main difficulties is the varying transmission of the atmosphere, which distorts the profiles. It seems that in the main two methods of avoiding this trouble are available: either to work very quickly, or to work most slowly and to make comparisons with the intensity of a fixed point in the spectrum.

(*a*) Method of Hiltner and Code, presented by Kiepenheuer (*J.O.S.A.* **40**, 149, 1950). One slit slides over the spectrum to be investigated, the other is placed at a fixed point.

Behind each slit there is a photo-cell, whose current is amplified. Both cells are connected to a Brown recorder, which starts revolving and moves a resistor, until a balance is obtained. The position of the resistor is a direct measure of the *ratio* between the two photo-currents. By this method, considerable changes in seeing are eliminated in stellar photometry; for the solar spectrum, changes in atmospheric transmission would be compensated.

(*b*) Method of the Pulkovo Observatory, presented by Severny (*Publ. Pulkovo*, **19**, 140, 1952; *R.A.S.* **29**, 86, 1952). N. Ph. Kuprievich, under the direction of O. A. Melnikov, tried different possibilities, both the electrometer and the photo-multiplier and galvanometer. Records were obtained, either on photographic paper or on ordinary paper with a recorder. Compensation for the varying atmospheric transmission by modifying the amplitude of the record was tried. These methods were all found to be unsatisfactory for various reasons. A high-speed spectro-electro-photometer was therefore constructed. A diffraction grating, which gave a dispersion of about 3 A./mm., was used in autocollimation; a slit was moved along the spectrum at a speed of about 4 mm. per second. The current from a photo-multiplier which was behind the slit was transmitted to a D.C. amplifier, with detector and stabilizer; the record was obtained from an oscillograph using a moving film, the magnification in the direction of the dispersion being 20. With such a speed, control of atmospheric transmission is not necessary; in a few minutes, the whole spectrum can be recorded.

(*c*) Method of the Simeis Observatory, presented also by Severny (Nikonov & Severny, *Doklady Acad. Nauk U.S.S.R.* **77**, no. 2, 1951). The dispersion of the grating is 2·4 A./mm. The second slit has a width corresponding to 0·1 A. and moves with a speed of about 1 mm./sec. The photo-multiplier behind the slit is directly connected to the galvanometer, amplification not being necessary. For controlling the constancy of atmospheric transmission, a constant part of the spectrum is thrown at intervals on to a second multiplier, and check marks are obtained.

(*d*) Method of Brück, Dunsink Observatory. This is to be a continuation of the work done by Brück at Cambridge just before the war. At that time, a photo-cell with D.C. amplifier was used; in order to get a sufficiently great sensitivity, a high grid leak resistance was necessary, and to attain the necessary stability the whole photometer was enclosed in a vacuum. The chief disadvantage of the method was that the instrument had a relatively high time constant, so that the slit had to travel at the slow rate of only 1 A./min. This causes difficulties in photo-electric recording, arising from variation in sky transparency. A second slit was therefore introduced, which received light from a fixed region of the spectrum, tests of the transparency being thus made at regular intervals. At Dunsink, it is hoped to overcome the difficulty by using two photomultipliers, coupled to the same power unit, one of them recording continuously the transparency of the sky. The photoelectric apparatus now in use is more than a hundred times more sensitive than the original and has also a very short time constant, so that a much faster rate of travel of the slit can be used. The spectrograph has a 21-ft. concave grating, and is coupled to a vertical solar telescope.

(*e*) Method of the Utrecht Observatory, described by de Jager. The slit has a length of 5 mm., the width is variable between 0·01 and 1 mm.; it moves through the spectrum with a speed of 2 mm./sec.; the dispersion in the first order of the grating is 4 A./mm. A small gas-filled CsO cell, mounted behind the slit, is sensitive to wave-lengths between the ultra-violet and 7500 A. Possible variations of sky transparency are compensated by using a second slit, fixed with respect to the spectrum, behind which is a photo-cell of the same type.

The voltages of both photo-cells are obtained from the same supply, and the anodes of both cells are connected to the two grids of a double triode. The difference between the anode currents is multiplied by a D.C. feedback amplifier. One of the first amplifier tubes has a logarithmic characteristic curve.

(*f*) Method of the Institut d'Astrophysique at Paris. Laffineur explained the principle of the *logometer*, an instrument which is in regular use for electrotechnical purposes and which measures not the difference, but the ratio between two currents. By the use of this instrument a direct compensation for variations in sky transparency becomes easy.

Houtgast emphasized that the application of photo-electric methods is only justified if the spectrum itself is obtained with sufficient resolution. A discussion on the interferometric methods would therefore be very important. This was adjourned till the next meeting of the Commission.

5. Kiepenheuer proposed to use Lyot's new type of photo-electric coronal photometer for the measurement of the total output of H_α-quanta from a flare in units of the undisturbed continuum. Such a method would be independent of the flare, of the line profile and of the line shape. An instrument of this kind was built by Lyot to measure the Sun's brightness in H_α, by using the zenith sky light. A similar instrument is now under construction at Freiburg-im-Breisgau for the photometry of flares and faculae.

6. Finally, a motion was proposed by Severny, which was adopted after a short discussion between Menzel, Minnaert, Thiessen and van de Hulst.

In order to understand the physical nature of long period variations of solar activity, systematic measurements of the general magnetic field and of its local variations would be important. It is desirable that these measurements should be made by the various different methods recently developed, and the results should be intercompared. It would therefore be very valuable if several solar observatories with rich experience in this field would undertake such systematic measurements during a period of 11 or 22 years.

The meeting was then adjourned.

The second part of the session in combination with Commission 36 was devoted to problems concerning the solar radiation, M. Minnaert in the Chair.

As a complement to the discussions during the first session, recent methods of interferometric solar spectroscopy were discussed.

Dr Treanor stressed the advantages of the Fabry & Perot interferometer, especially if this instrument is placed behind the spectrograph. He described the optical arrangement as used by him at the Oxford Observatory.

Dr ten Bruggencate set forth the advantages of the Lummer plate, by which it is possible to obtain interferometer spectra of an individual point of the Sun's disk. In his opinion, the instrument is considerably brighter than other interferometers.