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

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MEMBRES: MM. Abbot, Babcock, Carrasco, Carroll, Chapman, d'Azambuja, Dingle, Evershed, Lyot, Menzel, Milne, Minnaert, Mlle C. E. Moore, MM. Pannekoek, Pettit, H. H. Plaskett, Russell, Stetson, Unsöld, Woolley.

The majority of the members of the Commission have been good enough to send in full reports regarding subjects of interest to this Commission. Extracts from them relating to questions which may be the subject of useful discussion at the forthcoming meeting in Paris are given below; references to research undertaken during the last three years, particulars of which are readily available in recent astronomical publications, are omitted.

THE COMMISSION'S FIELD OF WORK

The new Commission meets for the first time since the old Commission 12 was divided up, it is therefore now advisable to define its field of work. Babcock discusses the possible overlapping of Commissions 12 and 14. He suggests "for consideration some changes in the functions of these two Commissions". Commission 12 is already quite large and covers a broad field of work. It would naturally include the preparation of Tables of the Solar Spectrum, which is part of the duty of No. 14. He thinks that the principal business of No. 14 is to provide a system of standard wave-lengths covering the region of the spectrum accessible to astrophysical observation and homogeneous with the scale used in the ultra-violet for laboratory measurements. As soon as this work is brought to a satisfactory state he would favour the discharge of Commission 14 and leave all further work on the solar spectrum to No. 12. Possibly it will be wise, if No. 14 is later discharged, to divide No. 12 at that time in such a way as to separate the work on solar radiation from that on solar spectroscopy.

On the same subject Dr Minnaert writes:

"The field of work of our Commission is not very clearly determined. Some of our problems belong more to Commission 36 on Spectrophotometry; generally speaking, I am uncertain if questions relating to intensity measurements in spectral lines of the sun must be classified as solar spectroscopy or as spectrophotometry. I shall propose to the Commission for spectrophotometry that a small number of Fraunhofer lines, carefully selected, should be investigated at different observatories, and that the results should be compared, with full data concerning the method of measurement and of control. This research can be made effectively in the solar spectrum, but I think that nevertheless it is more of general spectrophotometric importance.

"The work of Mulders, more recently commented on by Wesselink, shows that the main point concerning the solar radiation which is left undecided, is the distribution of the energy in the ultra-violet past $\lambda 4000$. I think that the necessity of measurements in that region must be emphasised again and again. Closely related to that problem is the determination of the solar radiation near $\lambda 2000$ where Meyer and his collaborators have shown that a trace of a measurable radiation can be recorded. The importance of these results is extremely great, because the deviations

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from thermodynamic equilibrium in the solar spectrum depend on the deviations of the UV radiation from the black body spectrum. Unsöld has shown that a factor 10 or 20 is possible, but from a private communication of Zanstra I understand that this is an overestimate. In all cases, we should urge that Meyer calibrates his apparatus on an absolute scale, so that a rough estimate of the solar radiation near $\lambda 2000$ outside the atmosphere becomes possible. I think that the full importance of such an estimate for Solar Physics is perhaps not wholly and generally understood. From this point of view, work near $\lambda 2000$ will be useful for Solar Physics, long before any Fraunhofer line can be discovered in this region.

"With respect to the theory of the solar spectrum, we badly need more values of the quantum-mechanical transition probabilities f for different atoms. If our Commission could draw the attention of physicists to that question they would certainly be able to calculate more f values theoretically or to determine them from laboratory experiments.

"Different subjects could be treated at our meeting at Paris. I think that we should select two or three topics and have an interesting discussion about them. For instance: 'The origin of the continuous spectrum of the sun.' 'The Adams-Russell effect,' etc."

Solar Radiation

Abbot reports as follows on the researches of the Smithsonian Astrophysical Observatory: Field stations for the daily measurement of the solar constant of radiation are maintained at Table Mountain, California; Montezuma, Chile and Mount St Katherine near Mount Sinai in Egypt. Owing to the volcanic eruption in southern Chile, the observations at Montezuma were interrupted for a time. This occasion was seized to improve the experimental outfit, and revise the methods of reduction there. Observations from Montezuma are now in regular progress and their daily results are broadcast from Washington.

Analysis of solar variation having disclosed seven periodicities, varying from 7 to 68 months in length, which combined make up almost totally the variation of solar radiation, two forecasts each for 2 years in advance were published. Both of them have now been compared with the event and show agreement within the experimental error.

Abbot, with several computers, is engaged in the analysis of weather changes as related to the variation of the sun. Preliminary results seem promising. He hopes to publish a general account of these studies early in the year 1935.

A publication of the values of the solar constant of radiation from 1931 to 1934 inclusive, is contemplated early in 1935.

Plaskett reports that a determination of the energy distribution and surface brightness of the sun as function of position on the disc is to be secured in Oxford.

Solar Spectroscopy

New tables and infra red spectrum

Miss C. E. Moore reports on the three tables she compiled in 1933–4. "A Multiple Table", "Atomic Lines in the Spectrum", and "Term Designations for Excitation Potentials." They contain much interesting data for the study of the physical conditions of the photosphere and of the spots and also in connection with stellar spectra. With the aid of the large collection of spectrographic material at Princeton further work on the identification of lines in the solar spectrum is being continued.

Babcock, Miss Moore, and Hoge are making an extensive investigation of the infra-red solar spectrum covering the region from λ6600 to about λ13000. This publication, according to the report of Babcock and Moore, will include about 6000 lines and will contain wave-lengths, intensities, identifications, and lower and higher excitation potentials. The measurement is about completed and it is hoped that the book will be published within a year. An important investigation is now in hand to determine the intensities on a scale approaching, as nearly as possible, that of Rowland, and for the identification of solar and telluric lines. The study of the infra-red laboratory spectra by Meggers and Kiess has greatly facilitated and extended the work of identification, notably for *Si*, which accounts for many strong solar lines. Similarly, the presence of *P* has been detected and more solar lines have been attributed to *S*. The arc spectrum of *Fe* is rich in the infra-red and its solar lines are more predominant there than in the visible. Practically all previously observed laboratory lines of this element are present and more than 100 have recently been identified by prediction.

Several problems relating to the infra-red solar work suggest themselves. In regions clear of atmospheric lines a study of equivalent widths of selected lines should be made. Russell plans to revise the calibration of the Rowland intensity scale for the purpose of redetermining the abundance of elements in the sun. Accurate and more extensive laboratory data on wave-lengths and analysis are necessary before the problem of identifications can be completed.

In the coming sun-spot maximum it is hoped to secure better photographs of the spot spectrum from the violet through the infra-red. At present the spot material in the infra-red is extremely fragmentary.

Plaskett reports that a determination of wave-lengths, line intensities and identifications in the region λ10,000 to 20,000 A is to be followed in Oxford.

Calibration of the Rowland scale

Minnaert reports that "Mulders has finished this calibration with the exception only of the ultra-violet beyond λ3800. In his diagrams the equivalent widths are found for lines of the several Rowland intensities throughout the spectrum. Altogether about 8 per cent. of the solar energy has disappeared in the Fraunhofer lines. The intensity distribution in the solar spectrum seems to deviate considerably from that of a black body.

Intensity and profile of Fraunhofer lines

Research work under this head has been actively pursued at Utrecht, Cambridge, and other observatories.

St John suggests that: "in the determinations of the absolute absorption value of the solar absorption lines there is a wide range. It would seem desirable to concentrate upon a few regions to test out methods. Perhaps a centre in Commission 12 might be organised for the purpose. One region I would suggest, viz. λλ6190–6310, has been selected by Mr Babcock, which Miss Moore is using as standards in determining the Rowland intensities of the lines to the red of λ7330, the limit of the Rowland table. Miss Moore's experience fits her for this work and when the absolute values of the standards used are agreed upon the absorption in the infra-red over some five thousands Angstroms will be known. Similar methods can be used for regions to the violet."

In collaboration with H. Grenat, d'Azambuja has undertaken research for the purpose of recording the profiles of Fraunhofer's lines without having recourse to

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photography. The advantages are obvious, because many troublesome problems whose solutions always lead to sensible errors are eliminated. D'Azambuja reports that the spectrograph employed is the quadruple spectrograph at Meudon with three prisms and 7 metre camera with a resolving power of 100,000 which gives a spectrum without ghosts and almost entirely free from diffused light. The outline of the profile is obtained by shifting the selective slit in front of the spectrum simultaneously and synchronously by means of the micrometer screw for adjusting the spectrograph; the sensitive paper is in front of the galvanometer as in the ordinary registering microphotometers. A certain number of profiles were obtained in the autumn of 1932, the apparatus was then altered to record, contemporaneously with the profile, a reference mark on the adjacent continuous spectrum for the study of the sky's transparency during the observation, and the variations in the opening of the slit caused by the heat of the solar image. The investigation is now (spring of 1935) being resumed.

The intensity at the centre of about 100 of Fraunhofer's lines of ionized and neutral atoms and of cyanogen bands between $\lambda 3750$ and $\lambda 3940$ at the centre of the solar disc and at the polar and equatorial limbs has been determined at Arcetri. A systematic difference has been detected, the intensities at the poles are, as a rule, greater than at the equator, showing that the absorption conditions in polar regions are slightly greater and approach more closely to those at the centre than to those at the equator. Since this fact may be correlated to the difference of temperature which should exist between the equatorial and polar regions, according to the more recent solar theories, it would be as well to have it confirmed experimentally by further research.

Variability of Fraunhofer lines

Minnaert reports as follows: "A series of observations made in 1928 by Mr W. Bleeker and not yet published, had shown that the depths of the lines [H] and [K] were subject to irregular variations. The measurements were made on spectra of sky light, taken every consecutive day with a spectrograph of small dispersion. The correlation with the fluctuations of the solar constant was surprisingly high."

A new series of measurements was undertaken by Mr van der Meer. A terrestrial absorption line of didymium nitrate was photographed every time together with the solar spectrum. The fluctuations of [H] and [K] are faint now, and they run parallel with the fluctuations found in the artificial line, due to errors in the photometry. It seems probable that the constancy now found is related to the minimum of sunspots. For the future the comparison with the terrestrial line is to be considered as a necessary control.

In the last few months a systematic search has been undertaken concerning possible variations of fainter lines extending over a number of plates taken during the years 1919–35. As yet there are no definite indications for such variations, while the method followed is sufficiently delicate to reveal variations of 10 per cent. in the total absorption.

Perepelkin at Poulkovo has determined the relative intensity of the lines $H\epsilon$ and [H] at the foot of the prominences. Besides the variation from one prominence to another, the intensity appears to vary with solar activity, perhaps because of the existence of limited regions in the photosphere where there is a preponderance of radiation of short wave-length which tends to increase the intensity of $H\epsilon$. Other research by Perepelkin shows that the decrement of the Balmer series ($H\epsilon/H\beta$, $H\delta/H\beta$, $H\gamma/H\beta$) is strictly connected with the relation of the intensities $H\epsilon$/[H].

Reversing layer (nomenclature)

According to Menzel the ambiguous designation "reversing layer" suggested by Young, when the constitution of the solar atmosphere was not sufficiently well known, should now be abandoned (*Observatory*, March 1935) because it tends to create confusion and might be wrongly interpreted.

The question of finding a name for the stratum producing the Fraunhofer absorption still remains. Though it now appears that the greater part of the line absorption takes place below the reversing layer as originally defined, the phrase might be applied to the stratum producing the dark lines if it were not for the fact that an unambiguous terminology is available. The term "Fraunhofer layer" immediately suggests the level responsible for the Fraunhofer absorption.

Spectrum of the chromosphere

On observations made at Mount Wilson on the chromospheric spectrum without an eclipse, Babcock reports: "Preliminary high-dispersion observations of the chromospheric spectrum by H. W. Babcock at Mount Wilson have shown the presence of various lines having considerable astrophysical interest. Most prominent are the great lines of *Ca* II near λ8600, the important groups of oxygen lines near λ7775 and λ8446, and nine wide diffuse members of the Paschen series of hydrogen. Weaker lines are being measured on the same spectrograms and further observations are projected in this interesting but rather difficult region. The green auroral line, λ5577 and the coronal line λ5303 have been noted as very weak emission lines in the spectrum of the lower chromosphere. In the infra-red some interesting cases of obliteration of normal solar absorption lines are found, analogous to those noted by previous observers in the visible.

Chromospheric data obtained in this way assist not only in the solution of problems involving higher levels in the sun's atmosphere, but also in the interpretation of the normal spectrum of the disc.

Menzel, from the observations made by him and J. H. Moore at the 1930 and 1932 eclipses, is making an extensive photometric determination of the flash spectra from λ3200 to λ6600.

Spectrum of the corona

Observations on the corona without an eclipse made by Lyot in 1930–31 at Pic du Midi are well known. Other observations of the spectrum of the corona were made by the same observer at Jungfraujoch where he determined the intensity of the green and red coronal lines at a distance of about 55″ within the limb. It was found that the red line behaves differently to the green, and that the coronal streamers were at much higher latitudes in 1934 than in 1931.

Solar rotation and its supposed variability

During the last few years numerous determinations of the period of the sun's rotation have been made, but it must be said that general agreement is still lacking between the values obtained at different observatories. An exhaustive discussion of the systematic errors that can throw light upon the much debated question of the variability of the sun's rotation is therefore not possible.

St John reported as follows: "Solar rotation is yet in an unsatisfactory state, both as to its absolute value and as to its constancy. We are continuing the observations on the equatorial rotation with the 150 ft. under the same conditions. For six years the rotational velocity at the equator has been steadily rising from 1·90 to 1·99 km./sec. and appears to be halting as if around a maximum. We shall continue the observations, and at the same time study the effects of changing conditions of observation. The two problems now under investigation are the effects of atmospheric and instrumental scattering and an as yet unexplained effect depending upon the separation of the spectra on the photographic plate. I would suggest to solar observers the investigation of these two questions."

With regard to this problem it may be observed that the determinations based upon the motions of the sunspots give a mean value for the sun's rotation corresponding to a linear velocity of 2·02 km./sec., and, as far as one can judge from results obtained by a method of doubtful accuracy, it appears that that value has kept constant during the last eighty years.

If the results obtained with spectroscopic methods at Mount Wilson and Edinburgh (where the longest series of observations since 1915 have been made) (*Rend. R. Accad. dei Lincei*, **19**, p. 826) are compared it will be seen that in one or the other results, or in both, systematic errors must exist. One cannot therefore obtain from them any correlation between the velocity of rotation and the maxima and minima of solar activity. (*Trans. Int. Astr. Union* **4**, p. 42.) On the other hand, taking the observations at Mount Wilson made with the powerful 150 foot solar tower and with the 75 foot spectrograph with every precaution to ensure homogeneous results, one must admit that it is difficult to assert that the differences amounting to 0·11 km./sec., between 1923 and 1933, are due to errors of observation, when the mean error must be of the order of ±0·01 km./sec. Attention may, however, be drawn to the values in the table below, obtained at different observatories with different instruments, from the time when spectroscopic determinations first began up to date. The table is taken from Mitchell's *Eclipses of the Sun* and has been brought up to date by him.

Year	Velocity at equator km./sec.	Observatory
1900	2·08	Upsala
1904	2·04	Edinburgh
1907	2·06	Mt Wilson
1908	2·05	Mt Wilson
1909	2·08	Edinburgh
1911	1·96	Ottawa, Cambridge
1912	2·00	Ottawa, Pittsburgh
1913	1·96	Ottawa, Kodaikanal
1914	1·94	Mt Wilson
1915	1·94	Mt Wilson, Edinburgh, Ottawa
1916	1·94	Mt Wilson, Edinburgh, Ottawa
1917	1·94	Mt Wilson, Edinburgh
1918	1·94	Mt Wilson, Edinburgh
1919	1·92	Mt Wilson
1920	1·95	Mt Wilson, Edinburgh
1921	1·91	Mt Wilson
1922	1·94	Mt Wilson, Edinburgh
1923	1·89	Mt Wilson
1924	1·97	Mt Wilson, Edinburgh
1926	1·96	Edinburgh, Poulkovo
1928	1·95	Mt Wilson, Edinburgh, Poulkovo
1929	1·94	Mt Wilson, Edinburgh
1930	1·93	Mt Wilson, Arcetri, Potsdam, Poulkovo, Edinburgh
1931	1·94	Mt Wilson, Edinburgh
1932	1·98	Mt Wilson, Edinburgh, Ewhurst, Poulkovo
1933	2·00	Mt Wilson
1934	1·97	Arcetri

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	Min.	Max.
Sun spots	1913·6	1905·6
	1923·6	1917·6
	1933·9	1928·5

It does not appear possible to deduce any periodicity from the velocities in the table above, especially as less powerful instruments were in use previous to 1911 and because the earlier values are the result of visual observation. Taking the mean values obtained by the various observers since 1912 (*R. Accad. dei Lincei, loc. cit.*), it is evident that we approach a mean value that appears to have remained constant from 1912 to the present epoch (1934).

A discussion on the systematic errors and a coordinated programme of work for the future are necessary to clear up the various questions which present themselves in the determination of the sun's period of rotation.

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