observations proposed will be carried out on the mornings of the two days preceding the eclipse and on the two days following, in addition to the actual morning of the eclipse. The transmissions on which observations are made will extend for a period of two to four hours on each of these days.

How far the results of the experiments proposed will be valuable in checking present hypotheses of the propagation of wireless waves or in providing new information on this subject cannot, of course, be definitely stated beforehand.

O. F. B.

Astrophysical Eclipse Problems.

By Prof. H. Dingle.

If direct observation of the sun were our only means of investigating the form of our luminary, we should learn little more than that it is an incandescent rotating sphere. The spectroscope makes possible the beginnings of a structural analysis by revealing an absorption spectrum—that is, a continuous spectrum crossed by relatively dark lines. This assures us that, broadly speaking, the sun consists of two portions—an interior responsible for the continuous spectrum, and an atmosphere the constituents of which selectively absorb some of the light of the interior, each according to its kind. Whatever can be learnt from the continuous spectrum characterises the interior, while the study of the dark lines—the Fraunhofer lines—is the study of the atmosphere. In the ordinary solar spectrum, of course, both continuous and dark line spectra appear together. Neither can be obtained, in the first instance, apart from the other, so that the separate analysis of 'interior' and 'atmosphere' is greatly complicated. Some measure of success has nevertheless been achieved; for example, the effective temperature corresponding to the light from the interior has been determined from the continuous spectrum, while the spectroheliograph affords some knowledge of the distribution of a few types of atom in the solar atmosphere. But on the whole it may be said that the inevitable association, in the ordinary solar spectrum, of the atmospheric lines and the photospheric background is a great hindrance to the complete study of the respective regions of the sun—and particularly that of the atmosphere.

Observations of the sun's limb, where the atmosphere might be expected to appear alone and to show a bright line spectrum, reveal only that it is too thin (in angular measure) to do so. Even the spectroscopic method devised independently by Lockyer and Janssen in 1868 shows only the higher reaches of the atmosphere at the limb, and it was not until 1896 that it was finally established that there exists a bright line limb spectrum at all comparable with the Fraunhofer lines. Since that time the long-focus instruments at the Mount Wilson Observatory have given images of the sun with sufficient depth of atmosphere for the bright line spectrum to be observed, but when produced in this way the lines are still encumbered by the Fraunhofer spectrum, and the facilities afforded for detailed study of the solar atmosphere leave much to be desired. Only during a solar eclipse, when the photosphere is at least partly obscured by the moon, can a pure atmospheric spectrum be obtained, so that for our knowledge of the structure of the sun's atmosphere—the solar meteorology, as it may be called—we still rely mainly on eclipse observations.

Three aspects of the bright line, or 'flash' spectrum, are studied in modern eclipse research; namely, the wave-lengths of the lines, their relative intensities, and the distribution in the solar atmosphere of the atoms or ions responsible for them. It appears probable that the determination of wave-lengths will in future be attempted only by the method described below (p. 91) by Prof. Fowler, for which totality is not necessary. It need not, therefore, be referred to here except to point out its uses in the identification of the lines and the recognition of disturbing influences in the event of displacements being established with respect to terrestrial standards or the Fraunhofer spectrum. Two facts must be borne in mind in this connexion. First, the Fraunhofer spectrum is observed more or less radially, and the flash spectrum tangentially, so that there may be differences in the thickness and state of motion of the regions of the atmosphere observed; secondly, the lowest layers of the atmosphere can be observed only through an envelope of the higher layers, and any difference of wave-length at different levels will broaden the lines and possibly give rise to unsymmetrical reversals when the lines are examined microphotometrically.

The question of the relative intensities of the lines has greatly increased in importance with the development of modern spectroscopic theory. It is intimately bound up with the question of the distribution of atoms and ions in the sun's atmosphere; for the intensity of a spectrum line depends both on the number of atoms of the proper kind which are present, and on the physical conditions tending to make them emit that particular line. It is necessary, therefore, not only to compare the relative intensities of different lines, but to investigate also the variation in intensity of each line in different regions of the atmosphere. Since it is only the atmosphere at the limb which is being studied, this is equivalent to a determination of the variation of intensity along each line, supposing a radial or tangential slit to be employed.

This investigation is attended by considerable difficulties. Not only is there the complication already referred to (namely, that the ends of the lines representing the lowest levels may contain light from the higher levels also), but also the diffused light in the earth's atmosphere tends to fill the slit and make the distribution of light in the spectrum line differ from that in the corresponding regions of the sun's atmosphere. This effect is very pronounced in misty weather, and on such occasions, when a radial slit has been used, bright lines have been observed to extend even over the whole diameter of the dark moon. Objective prism spectrograms (*i.e.* spectrograms obtained by placing a prism before the object glass of an astronomical telescope, and using neither slit nor collimator) in which each ' line ' is a crescent image of the region of the solar atmosphere emitting the corresponding wave-length, do not suffer from this defect, for the diffused light, entering the telescope from all directions, is simply spread over the photographic plate to produce an imperceptible fogging. In these spectra the lengths of the arcs measure the heights in the sun's atmosphere reached by the corresponding emitting sources, but irregularities in the moon's limb and other interfering agencies invest the results with a considerable amount of indefiniteness. All photographic methods of attacking this problem have to cope with the further difficulty of non-uniform sensitivity of the plates to light of different wave-lengths ; thus, two lines of the same length in different parts of the spectrum do not necessarily arise from emitting sources similarly distributed in the sun's atmosphere. Results obtained from many eclipses will have to be carefully analysed and compared before trustworthy conclusions in any degree of completeness can be reached.

The beautiful photographs obtained by Merfield at the eclipse of January 1926 suggest that the method employed by him (it was in part proposed also by Lockyer in 1896, but clouds prevented the trial) might yield valuable results. It consists in photographing an objective prism flash spectrum on a plate moving uniformly at right angles to the direction of dispersion, immediately in front of the plate being a narrow slit, lying along the spectrum, so as to reduce the instantaneous image of each ' arc ' practically to a point. The resulting spectrum then appears as a set of parallel lines of various lengths, and it is proposed to determine the heights reached by the corresponding emitting sources from a measurement of the rate of change of intensity along the lines. It remains to be seen what degree of success the method is capable of yielding when the actual determinations have been made.

When the general distribution of the various types of atom and ion in the solar atmosphere has been reliably determined, the application of recent spectrum theory will give much information concerning the physical conditions existing there. A particular investigation of this character is being undertaken on June 29, in which attempts will be made to determine the relative intensities in the chromosphere of the Ca^+ diffuse 'doublet' at $\lambda\lambda 8498$-8662 in the infra-red, and the bright counterparts of the well-known H and K Fraunhofer lines in the violet. The result should have considerable significance in connexion with the theory of the calcium chromosphere proposed by Milne. Photographs extending still further into the infra-red, up to about $\lambda 15,000$, are also to be attempted.

These eclipse researches into the constitution of the sun's atmosphere are of great interest and importance, but they must always play second fiddle to the study of the corona, because it is only during a total eclipse of the sun that the corona can be observed at all. The investigations referred to above are greatly facilitated by the intrusion of the moon, but they could be carried out in some manner if the moon did not exist. (It must not be forgotten, however, how much the methods employed on the uneclipsed sun owe to knowledge gained originally from eclipse observations.) But if there were no moon, or if the moon were slightly farther from the earth than it is, we should not to this day suspect even the existence of the corona. It is obvious, therefore, that whatever else may be neglected at a total eclipse, all possible information must be obtained with regard to the corona.

Our absolute knowledge of the corona may be summed up very briefly. It is an intricate solar envelope the form of which varies with the phase of the sunspot period, while its light, which is partly polarised, consists of a combination, in varying proportions, of unknown bright lines, continuous spectrum, and Fraunhofer spectrum. Considering that the corona is observable, on the average, for at most about three minutes every two years or so, it is not surprising that our knowledge of it is so rudimentary. Single observations have no definitive value ; they need confirmation at subsequent eclipses. In the case of the corona they have perhaps more often been contradicted, so that uncertainty exists whether the observations are at fault or whether the corona has changed. In these circumstances progress is necessarily slow, and many records must be accumulated before conviction can be reached.

A record, as complete as possible, of the form of the corona at each observable eclipse has been kept for some years, and must of course be continued indefinitely. In time this should reveal any obvious periodic changes of form or structure which may exist in addition to the already known relation with the sunspot period. The connexion between the corona and the solar prominences might also be elucidated from such a record. The difficulties, however, are enormous, for not only are there long gaps between successive photographs or drawings, but also at each eclipse the coronal light seen is at each point an unanalysable integration of light emitted along a chord of the coronal shell, and does not represent a simple plane section of the shell. The changes in the form of the corona appear to be slow. Attempts have been made to detect them by observing the same eclipse near sunrise and sunset, but the results are inconclusive. Further attempts are desirable. For such observations to be successful there must be convenient sites near the two ends of the belt of totality and the sun must be unclouded at both stations—a combination of circumstances which very rarely occurs.

The total light of the corona still awaits a satisfactory determination. It no doubt varies from one eclipse to another, and might be correlated with the sunspot period. Still more important, perhaps, is the law of variation of light with distance from the sun's limb. Several widely differing formulæ have been proposed, and here again there are probably changes from one eclipse to another. The heat radiation of the corona was measured by Abbot in 1908, but further determinations would be of much value. The very delicate apparatus designed by Callendar for use in the 1905 eclipse, which was spoilt by clouds, might give valuable results in this direction of research.

The spectrum of the corona and its connexion with the sunspot period are as yet very imperfectly understood. The portion of the light which gives a Fraunhofer spectrum comes from the middle and outer corona, and is undoubtedly reflected or scattered sunlight. Experiments on the amount and kind of polarisation of this light at different distances from the sun's limb are necessary to afford an insight into the mechanism of the reflection or scattering, and hence into the physical constitution of the corona. Such experiments have been made at many previous eclipses, but the difficulties of interpreting the results are so great that further investigations by the most trustworthy methods are necessary. The continuous spectrum of the inner corona may also be due to photospheric light, but there are reasons for thinking that it originates in the corona itself. Confirmation is difficult, but the evidence most obviously necessary is that of the curve of distribution of energy throughout the spectrum.

The line spectrum of the corona offers perhaps the largest field for investigation. None of its lines has yet been recognised in the laboratory, and its composition is very uncertain. Much progress has been made in disentangling it from the chromospheric spectrum, but finality has not yet been reached, and the faintness of the spectrum makes it almost certain that the present lists of lines are far from complete. Variations in the relative intensities of the lines at different eclipses suggest that it is a superposition of two or more spectra. Several attempts, on numerical as well as observational bases, have been made to classify the lines into groups, but the results so far are not consistent. The spectrophotometric measures initiated by the British expedition to Sumatra in January 1926 indicate a promising method of classification in terms of the variation of intensity along the lines. When such data have been obtained at a number of eclipses, accidental similarities can be eliminated and possibly definite conclusions arrived at.

The precise wave-lengths of the coronal lines are important for both laboratory identification and measurement of motions in the line of sight. There is so little agreement as yet between the various sets of measures available that further determinations with the highest possible degree of accuracy are of the greatest importance. It may be hoped that Prof. Fowler's experience this month with high-dispersion photographs of the 'flash' spectrum will show that the same method is practicable with the corona—at least so far as the brighter lines are concerned. The line spectrum of the corona appears to be relatively brighter at maximum than at minimum of the sunspot period, so that the coming eclipse should be favourable for the various investigations connected with it.

It will be realised that the outstanding astrophysical eclipse problems are 'many and various.' We may reasonably hope that, granted fair weather, our English eclipse will lead to important extensions of our knowledge of the sun.

Spectroscopic Observations during a Partial Eclipse of the Sun.

By Prof. A. Fowler, F.R.S.

It is common knowledge that the chromosphere and prominences which surround the visible surface of the sun cannot be seen in the telescope at ordinary times because they are less bright than the diffused light of the sky on which they are superposed. They can, however, be observed by combining the telescope and spectroscope in the manner discovered by Lockyer and Janssen in 1868. The spectroscope being adjusted on the bright red line of hydrogen (Hα), and an image of the sun being focussed tangentially to the slit, the diffused sky light is spread out into a continuous spectrum (crossed by dark lines) and is thereby so much reduced in intensity that the bright hydrogen line from the chromosphere, or from a prominence, becomes easily visible. To see the actual forms of the chromosphere and prominences, it is only necessary to open the slit rather wide.

Other bright lines besides Hα, including the yellow line of helium, D_3, and the hydrogen line Hβ, may be observed in the same manner, but they are not numerous when instruments of moderate size are employed. Spectroscopic observations with large telescopes at ordinary times, or with ordinary instruments during total eclipses, however, have shown that as the sun's edge is approached the bright line spectrum increases in complexity and finally exhibits a multitude of bright lines which originate in a region extending less than two seconds of arc above the photosphere, the apparent diameter of the sun being nearly two thousand seconds of arc.

When observations are made near the central line during a total eclipse, the spectrum of this shallow layer suddenly bursts into view at the beginning of totality, and almost as quickly disappears; it reappears for two or three seconds just before the end of totality, at the point of contact of the sun and moon. On account of its brief duration under these conditions, the spectrum of this shallow layer which surrounds the sun has been called the 'flash spectrum,' and the layer itself the 'flash stratum.' It is here that a large proportion of the absorption which produces the dark Fraunhofer lines of the ordinary solar spectrum takes place, and the flash stratum is accordingly also known as the 'reversing layer' of the sun.

Overlying the reversing layer, but not sharply divided from it, to a total height of about ten seconds of arc above the photosphere, is the chromosphere. This has not a smooth continuous surface, but is roughly serrated, and the prominences, which are sometimes very brilliant and reach to enormous heights, rise out of the chromosphere.

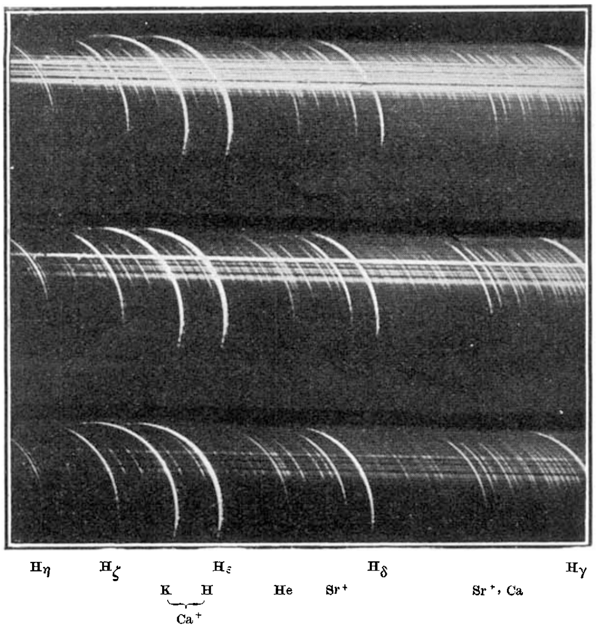

FIG. 1.—Flash spectra: portion of the first large plate taken with a 6-in. prismatic camera in India, 1898. By Prof. A. Fowler.

On ordinary occasions, with telescopes of moderate size, it is not possible to observe the spectrum of the reversing layer, because of the 'boiling' due to atmospheric tremors, which blends the bright lines from the thin stratum with the brighter spectrum of the edge of the sun's disc. Occasionally, however, there is a disturbance at some place near the sun's limb, and the reversing layer may then be so far elevated that a large number of bright lines can be differentiated from the photospheric spectrum. With the large instru-