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 ($H\alpha$), 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 $H\alpha$, including the yellow line of helium, D_3, and the hydrogen line $H\beta$, 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.

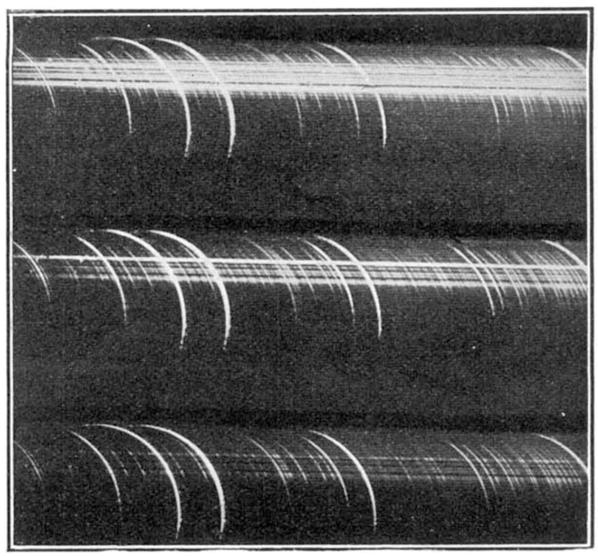

Fig. 1.—Flash spectra : portion of the first large plate taken with a 6-in. prismatic camera in India, 1898. By Prof. A. Fowler.

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 instruments available at the Mount Wilson Observatory, bright lines have been photographed in large numbers without an eclipse, but even here the flash spectrum is somewhat confused by that of superposed sunlight.

It is during total eclipses of the sun that the flash spectrum can be most effectively observed. The reversing layer is then revealed for a brief time on a comparatively dark background, with no interference from the bright disc of the sun. Its spectrum has frequently been successfully photographed by the use of slit spectrographs of ordinary type, and by the use of prismatic cameras or slitless spectroscopes. With the latter form of spectrograph a spectrum taken near the beginning of totality consists of a succession of curved images of the portions of the chromosphere and reversing layer visible at the moment of exposure, each representing a spectrum line, and having a length depending on the height of the gas or vapour which produces it. The nature of such photographs will be gathered from Fig. 1, which reproduces a small part of a plate containing ten such spectra taken at intervals of about one second, beginning a few seconds before the commencement of totality in India in 1898. In these photographs the reversing layer is represented by the numerous short arcs which appear in the middle of each spectrum, and the chromosphere by the longer arcs, among which those of calcium H and K, hydrogen and helium are very conspicuous. The bright streaks of continuous spectrum originate from specks of the sun's disc which were visible through irregularities in the edge of the moon.

Such photographs bring out many important features of the bright line spectra, but for various reasons they do not yield wave-lengths of a high degree of accuracy. Excellent photographs have also been secured with slit spectrographs, but in observations during totality, the dispersive power which can be utilised is limited by the short duration of the phenomena.

In order to obtain an increased duration of the flash spectrum, Evershed, in the eclipse of 1900, selected a station near the edge of the zone of totality. In these circumstances it will easily be understood that the dark moon must glide tangentially with respect to one point on the sun, so that the flash spectrum can be effectively observed near that point for a considerably longer time than from a place near the central line. Thus, using a prismatic camera, Evershed succeeded in obtaining good photographs of the flash spectrum during a period of about half a minute, and the illumination of the sky throughout this period was sufficiently reduced to allow of the fainter lines being registered on the plates.

Observations of the large partial eclipse which was visible in England on April 17, 1912, indicated another means of observing the flash spectrum for a comparatively long time, and suggested that photographs might be taken with instruments of large dispersion, comparable with those used for the sun itself. This possibility is opened up by the fact that at the cusps of the partially eclipsed sun the flash and chromospheric layers project to a greater distance than their radial depths. This will readily be understood from the diagrammatic representation in Fig. 2.

At South Kensington the magnitude of the

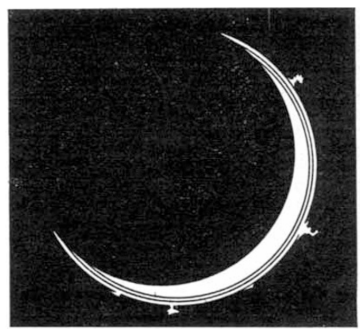

Fig. 2.

eclipse of 1912 at central phase was 0·92, and visual observations by Fowler showed that the flash spectrum could be effectively observed at the cusps during about thirty minutes. Some gain in visibility of the bright lines was first noted when the magnitude of the eclipse was 0·55, while the apparently complete flash spectrum was visible when the magnitude of the eclipse was 0·8 or greater (*Monthly Notices, R.A.S.*, **72,** 538). Similar observations were made at Cambridge by Prof. Newall (*Monthly Notices, R.A.S.*, **72,** 536).

In view of these observations, it seems possible to employ spectrographs of greater power than any hitherto used in eclipse work, and to impress comparison spectra for the accurate determination of wave-lengths. It may thus be hoped to obtain data for the investigation, among other things, of possible small displacements of the bright lines such as are already known in connexion with the Fraunhofer lines.

It was intended to make this experiment in Russia on Aug. 21, 1914, but owing to the outbreak of the War the expedition had to be abandoned, and the instruments were not returned to England until 1924. It is now planned to employ practically the same equipment during the eclipse of June 29 this year.

Although slightly better conditions might be obtained by the occupation of a station somewhat nearer the central line of eclipse, the instruments are being erected on the roof of the Imperial College of Science at South Kensington. The magnitude of the eclipse there at central phase will be 0·96, and the experience of 1912 indicates that this will be ample for the purpose in view. Any advantage likely to be gained by going farther north would, it is thought, not sufficiently compensate for the loss of the facilities afforded by the College laboratories and workshops. Prof. Sampson has also taken this view and will attempt similar work at the Royal Observatory, Edinburgh, where the greatest magnitude of the eclipse will be 0·98.

A large partial eclipse also provides a very favourable opportunity of investigating the spectrum of the sun near the limb. The observations at Mount Wilson have already shown that this spectrum differs very considerably from that given by the centre of the disc, but observations during a large partial eclipse may have the advantage that there will be no scattered light from the central parts of the disc superposed on the light emanating from near the sun's edge.

The spectrograph to be employed at South Kensington has a concave grating of 10 feet radius in an Eagle mounting, and will be adjusted for the second order spectrum so as to avoid undue astigmatism. An image of the sun about 2 inches in diameter will be formed in the plane of the slit by a 6-inch objective, which will receive light from a cœlostat after reflection from a second mirror. Adjustments are provided for maintaining the image of a cusp on the desired part of the slit, and it is expected that the exposures required will not be so long as to cover an undesirable range of solar latitude as the cusp changes its position on the sun. The requisite astronomical data for South Kensington have been specially computed by Dr. L. J. Comrie of the "Nautical Almanac" Office.

The Forms of the Solar Corona and their Origin.

By Dr. William J. S. Lockyer.

It is only during total solar eclipses, when the moon comes exactly between the earth and the sun, and cuts off all the brilliant light of the disc, that an outer solar atmosphere of an exquisite pearly hue known as the 'corona' is revealed. Without such eclipses, this atmosphere, even with the aid of any of the great and ingenious optical means available to-day, would still be unknown. The corona is of very considerable extent, far exceeding, in proportion to the size of the solar disc, that of our own in relation to the size of the earth.

It is well known that the form of the corona varies in shape and brilliancy very considerably. Sometimes the form is very irregular, the coronal matter being extensively distributed all round the solar disc, embracing both the solar poles and the equator. This form is termed 'polar,' 'irregular,' or 'maximum,' as coronal streamers are situated near the solar poles (Fig. 1).

On other occasions the polar regions are conspicuous by the complete absence of streamers, and in their place beautifully curved rifts or plumes are seen, the long streamers being restricted more to the equatorial regions. This type of corona is termed 'equatorial' or 'minimum,' and is sometimes referred to as of a 'wind-vane' form, as it resembles this object (Fig. 2).

Finally, there is a third and also very pronounced shape which is intermediate between the above two forms. This is termed the 'intermediate' type or 'square' corona. In this case the streamers are generally concentrated in mid-solar latitudes, leaving the poles and equator comparatively free from any large coronal extensions.

The use of the terms 'maximum' and 'minimum' with regard to the shape of the solar corona referred to the epochs of sunspot maximum and minimum, and it suggested a connexion with the periodic variation in the spotted area of the sun's surface. Until a few years ago, it was generally concluded that sunspots were therefore the origin of the coronal forms, and their waxing and waning was reflected in the changes of these forms.

Sunspots, however, do not appear at or anywhere near the solar poles; the highest latitude they ever attain is only 45°, and then they are only of very small area. On the other hand, large coronal streamers and prominent rays are sometimes situated in very high latitudes; in fact, at times they are very near or at the poles, and consequently quite outside the regions of spot activity.

Moreover, at the epochs of greatest spotted area, the mean latitude of spots is only about 18°; yet it is precisely at about those epochs that the coronal streamers appear at the poles, and the coronal forms are described as 'maximum' or 'polar.'