SOLAR ECLIPSE PROBLEMS.

By GEORGE E. HALE.

THE writer, as secretary of the Eclipse Committee of the Astronomical and Astrophysical Society of America, has received so many requests for suggestions from intending observers of the coming total eclipse that it has seemed advisable to bring together, for the convenience of those who may not have ready access to astrophysical literature, various data bearing upon some of the more important problems which this eclipse may help to solve. As no total eclipse of the Sun has been visible in the United States since 1889 it may be expected that many individuals and institutions will be anxious to take advantage of the present opportunity. Considered merely as a spectacle, the eclipse will amply repay those who may journey far to see it. But if the maximum scientific return is to be derived from this rare phenomenon, every intending observer must familiarize himself with the results obtained at previous eclipses, devote much time to the consideration of the questions still demanding solution, and give particular attention to the design of the apparatus required for the work selected. It fortunately happens that valuable scientific results can be obtained with simple and inexpensive instruments. The unsolved problems, too, are numerous and varied, offering a wide field for choice, and appealing to the individual tastes of many observers. It is only necessary to chose intelligently, basing the decision upon one's previous experience in observational work and a consideration of available instruments. If possible, there should also be some measure of coöperation between different parties, and here the Eclipse Committee stands ready to lend its aid.

The eclipse will occur on May 28, 1900, between 8 A. M. and 9 A. M. The central line of the shadow will cross the states of Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi, and Louisiana, the duration of totality decreasing from $1^m\ 46^s$ on the Atlantic seaboard to $1^m\ 18^s$ near New Orleans. The advantage due to a longer duration of the total phase is more than offset, however, by the much greater probability of cloudiness at points near the ocean, as shown by the survey of cloud conditions recently made under the supervision of the United States Weather Bureau. From these observations it appears that the chances of fair weather are best on the highland of the southern portions of the Appalachian Mountains.[1] It is to be hoped, however, that all of the stations will not be confined to this region, as there are many reasons why they should be distributed all along the line of totality.

In preparing a plan of operations it is first necessary to remember that the eclipse will be a short one, even for those who may view it from the Atlantic coast. Other things being equal, it therefore will not be desirable to undertake observations which cannot be successfully completed within a space of little more than a minute. Thus it would hardly be advisable to attempt to photograph the fainter portions of the spectrum of the corona on this occasion, and it is exceedingly doubtful whether it would be worth while to repeat the hitherto unsuccessful attempts to measure spectroscopically the period of rotation of the corona. Although some reference to such experiments may be found in this paper, it will probably be best to reserve these observations for the Sumatra eclipse, when totality will last over six minutes. On the other hand, the spectrum of the reversing layer can be photographed next May to good advantage, especially, as Mr. Evershed has pointed out, at stations not far removed from the edges of the shadow path. Many other phenomena can be advantageously studied during the total phase, provided the observer will limit himself to some well-defined piece of work, which must not be too comprehensive in its scope.

[1] See *Weather Bureau Bulletin*, No. 27. In addition to statistics of cloudiness, this bulletin contains much valuable information regarding suitable sites for stations, hotel accommodations, etc.

The suggestions offered in the following paragraphs make no pretensions to fullness of scope or adequacy of treatment. They are in no sense intended to take the place of "Instructions" to eclipse observers, and it is not supposed that they will be of service to experienced astrophysicists, except possibly in recalling certain matters which are sometimes overlooked. To amateurs possessing small instruments, and to others who have had little practical experience in solar work, it is hoped that they may be of some value.

1. NAKED-EYE DRAWINGS OF THE CORONA.

The experience of previous eclipses has shown that drawings of the corona for the most part serve no useful purpose, unless it be to illustrate the personal peculiarities of the draftsman. At the present time, when everyone who possesses a suitable camera may secure a photograph which can be relied upon, it seems quite superfluous to devote the brief time of totality to sketching. Naked-eye observations are specially referred to here. If drawings are made it should be only after long and faithful drill, and the more limited the region drawn the better.

2. DRAWINGS AT THE TELESCOPE.

What has been said regarding naked-eye drawings applies with much less force to drawings made with the aid of a telescope. According to the testimony of the best observers the most successful large-scale photographs hitherto made fail to reveal the most interesting details of the coronal structure. These details can be seen with telescopes of from three to six inches aperture, and an observer practiced in rapid sketching should be able to secure a valuable record if he confines his attention to a limited region. Concentration of this kind, especially if the field of view is small, should eliminate many of the distractions which so seriously interfere with naked-eye observations. It is particularly to be desired that some observers should devote their attention to the lower corona in the immediate vicinity of large prominences. Those who would be likely to distinguish an active prominence by a glance at its form would do well to record the coronal details near it. Others should sketch the polar streamers close to the Moon's limb, and attention may also be given to the structure of the outer corona, both in the polar and equatorial streamers. It is evident that coöperation of some sort is desirable in this work, in order that the various parts of the corona may receive proper attention.

3. COLOR OF THE CORONA AND PROMINENCES.

Reliable information regarding the color of the prominences and various parts of the corona is much to be desired. But if the record of observations is to be of real service, it must consist of something more definite than fanciful similes, such as are likely to be called forth by the excitement of the moment. The colors must be well and clearly defined, and if possible referred to some standards of color, prepared for the purpose. If a telescope is not employed the observations will be much facilitated by the use of a field or opera-glass, provided instrumental color is not introduced in this way. The presence of the prominences greatly interferes with determinations of the color of the corona, and in such observations it would be advantageous to occult them with a small disk in the focal plane of the telescope.

The importance of noting the color of the prominences rests upon the fact that Tacchini and others have observed the so-called "white prominences," of which an adequate explanation has yet to be offered. The subject has been discussed by the present writer in an article entitled "The Effect of a Total Eclipse of the Sun on the Visibility of the Solar Prominences,"[1] where Tacchini's observations are fully described. To mention only a single case, it may be said that at the eclipse of 1886 Tacchini distinctly saw an enormous white prominence, which appeared on the photographs of the inner corona, but could not be seen with the spectroscope in the $H\alpha$ line either before or

[1] This JOURNAL. 3, 374, 1896.

after totality. In the article referred to I have suggested that the white color of such a prominence may be due to the comparative faintness of the less refrangible lines in its spectrum, whereas the calcium lines H and K were of their normal intensity. Objective prism photographs of the chromosphere and prominences have indeed shown marked variations in the relative intensity of prominence lines, but it is not yet certain that a "white prominence" could be caused in this way. From this point of view it would be well to compare together the colors of a small number of prominences, as seen in a field-glass or telescope, noting the degree of redness in each case. Such observations should of course be supplemented by work with the spectroscope whenever possible. Photographs of the "flash" spectrum made with an objective prism will be very useful in this connection. If circumstances permit, the chromosphere and prominences will be photographed in the K line with the large spectroheliograph of the Yerkes Observatory at the time of totality for purposes of comparison.

4. SMALL SCALE PHOTOGRAPHS OF THE CORONA.

Every possessor of a suitable camera is equipped with apparatus sufficient to give valuable results in photographing the corona. As Mr. Maunder has pointed out in his interesting discussion of the results obtained at the recent Indian eclipse, with lenses of focal length not greater than five feet and ratio of aperture to focal length not less than $\frac{1}{15}$ it is not necessary to have an equatorial mounting for the camera when the exposure does not exceed one half second. It must not be supposed, however, that it is only necessary to point any camera at the Sun and make a snap exposure. Such a procedure might possibly produce a good picture of the corona, but the most valuable results will be obtained by those who observe a few simple precautions:

a. It is advantageous to use lenses of considerable focal length (from 30 to 60 inches) provided the angular aperture is not too small. Such lenses should show the corona on a scale large enough to bring out many important details. Very short focus lenses will be useful for long-exposure photographs of the coronal streamers, if mounted equatorially and moved by clock-work.

b. Light and unsteady camera boxes should not be employed. A strong wooden box of the proper length is much more suitable than a camera having leather bellows.

c. It is of great importance that the camera box should be very solidly mounted, so that it will not be affected by the wind and not easily set into vibration by any cause. Unless an equatorial mounting is to be used it will be advantageous to screw the wooden camera box to the top of a post firmly planted in the ground. The optical axis of the lens should point toward the Sun at the middle of totality. Unless the focal length of the lens exceeds 5 feet, or the diameter of the field is very small, it will be unnecessary to change the position of the camera during totality.

d. The lens can be most accurately focused by photographing star trails, a series of exposures being made for different positions of the lens. After the best focus has been ascertained the lens should be firmly clamped in place.

e. The results obtained at the Indian eclipse demonstrate the great advantage of using multiple coated plates. It will be best to employ triple or quadruple coated plates, and as a further safeguard the plates may also be given a suitable backing in order to still further reduce the danger of solarization. With such plates it is possible with an equatorially mounted camera to obtain the faint outer extensions of the corona without serious interference from the bright inner corona. However, too much should not be left to the plates, for the care exercised in development is of the greatest importance.

f. With the most rapid plates it would appear from the results discussed by Mr. Maunder that for an aperture of $\frac{f}{15}$,[1]

[1] For other angular apertures the exposure may be considered to vary inversely as $\left(\frac{f}{a}\right)^2$.

exposures of from $\frac{1}{60}$ second to $\frac{1}{45}$ second will suffice for the prominences and $\frac{1}{10}$ second to $\frac{1}{6}$ second for the inner corona. Such short exposures can of course be given only with the aid of a suitable shutter. A greater extent of the corona may be obtained with exposures from $\frac{1}{2}$ to $\frac{3}{4}$ second. Mr. Maunder believes that in order to obtain a photograph of the corona as a whole the exposures should not exceed one second. It is evident that most of the exposures so far referred to are easily within the reach of those who employ fixed cameras. If it is desired to secure the great extensions of the corona, which at the Indian eclipse were traced to a distance of nearly fourteen lunar radii from the Sun, the camera must be mounted on an equatorial telescope provided with a driving-clock. In this case the exposure might well continue throughout the entire time of totality, but great care should be taken to cap the lens several seconds before the expected reappearance of sunlight. It is desirable to have several lenses of different focal lengths carried by the same equatorial mounting. The long focus lenses, giving large solar images, should be used in photographing the prominences and the structure of the inner corona, while the short focus lenses may be employed to record the long streamers.

g. Care must be taken to provide for the accurate orientation of all photographs, as it is highly important that the north and south points of the image shall be known. If the plate stands in a vertical position, as it may when a heliostat is used, a fine plumb line hanging immediately in front of it will give satisfactory results. In the more common case, where a camera pointing at the Sun is employed, a series of rapid exposures made with reduced aperture during the partial phase, while the Sun moves across the stationary plate, will serve the purpose.

It is to be hoped that during the coming eclipse cameras in the hands of amateur observers will be distributed all along the line of totality in the United States, in Spain, and in Algeria.

A comparison of such a series of photographs might lead to very valuable results.[1]

5. PHOTOGRAPHS OF THE CORONA DURING THE PARTIAL PHASE.

During the recent Indian eclipse Mrs. Walter Maunder, using a triple coated plate and a Dallmeyer stigmatic lens of 1½ inches aperture and 9 inches focal length, succeeded in securing a photograph of the inner corona 39 seconds after the end of totality. As Mr. and Mrs. Maunder point out in the report to which such frequent reference has been made, it will be advisable to repeat and extend these experiments at the coming eclipse. The problem of photographing the corona in full sunlight is one which has received a great deal of attention, but hitherto without tangible result. It may be doubted whether the use of multiple coated plates will be sufficient of itself to overcome the great obstacle of atmospheric glare, but it is not impossible that the corona can be photographed in this way during partial eclipses. A series of exposures made before and after totality on multiple coated and heavily backed plates should be of value, especially if the image of the photosphere is prevented from falling on the sensitive film. An occulting disk before the plate should therefore be employed if possible. Mr. Maunder believes that with an aperture of $\frac{f}{15}$ the exposures out of totality should range from $\frac{1}{5}$ second down to $\frac{1}{50}$ second.

6. PHOTOGRAPHIC SEARCH FOR POSSIBLE INTRA-MERCURIAL PLANETS.

The possibility that planets may exist within the orbit of Mercury has led to many attempts to detect such objects under the favorable conditions presented by a total solar eclipse. As the unsuccessful visual observations made at previous eclipses tend to indicate that no very bright planet is likely to be found, preparations should be made to record all objects, down to the

[1] In this connection one cannot do better than consult the *Report on the Indian Eclipse of 1898*, recently issued by the British Astronomical Association. Many of the above suggestions are derived from this source.

lowest attainable magnitude, in the region about the Sun. Except by a most fortunate chance nothing can be expected to result from visual observations. Even if the region were divided among a great number of observers, little could be done in the brief space of totality, and disputes would be likely to arise on account of the uncertainties inseparable from hurried work. It would therefore seem inadvisable to waste effort on visual observations, but a thorough photographic search should undoubtedly be made. In undertaking such a search the following considerations are among those which should be borne in mind:

a. The lens should combine the greatest possible rapidity of action with the largest possible field. Good portrait lenses having an aperture of about $\frac{f}{5}$ should give well-defined star images over a field about nine degrees in diameter on a flat plate. Experiments recently made by Professor Wadsworth and Mr. Brashear show that the diameter of the field can be greatly increased by the use of concave plates of suitable curvature. It is advisable to employ lenses in pairs, in order that suspected images may be verified on an exactly similar plate made with another lens. In addition to portrait lenses it will probably be advantageous to use rapid rectilinear lenses giving very large fields.

b. The suitability of a lens, the best exposure time, and the proper development can all be ascertained by photographing stars under conditions as nearly as possible like those prevailing during totality, when the general illumination will probably be not very different from that of a clear sky half an hour after sunset. The maximum exposure given should be a few seconds less than the computed duration of totality, for in order to avoid the possibility of complete loss it will be advisable at the eclipse to cap the lens an appreciable time before the Sun is expected to reappear. Such experiments will enable one to select the lens best adapted for the purpose, to determine approximately the exposure time giving the greatest number of stars, and to form an idea of the number of stars likely to be recorded during the eclipse. Professor W. H. Pickering, who has great confidence in the photographic method, finds from experiment that it should be possible, under eclipse conditions, to photograph stars as faint as the sixth magnitude.

c. The camera should be carried by a good equatorial mounting, provided with driving-clock. Care should be taken in adjusting the instrument, for without perfect following the maximum photographic effect of course cannot be obtained.

d. Those who possess large portrait lenses of great angular aperture, but lack a suitable mounting, will do well to try photographing star trails under the conditions named above. It is probable that even with a fixed camera the chances of success would be decidedly greater than in the case of visual observations.

e. It goes without saying that the most rapid plates obtainable should be used. How far it will be safe to push the development can be roughly determined from the preliminary experiments.

f. In order to cover the largest possible area of sky it is very desirable that parties planning to undertake this work should coöperate, each devoting its attention to a particular region. All persons provided with suitable instruments, who are willing to participate in a general plan of operations, are invited to address the Eclipse Committee.

It may be added that Professor Newcomb, whose suggestions are embodied in the above paragraphs, considers a photographic search for possible intra-Mercurial planets as one of the most important pieces of work that can now be attempted during total eclipses of the Sun.

7. LARGE SCALE PHOTOGRAPHS OF THE CORONA AND PROMINENCES.

Portrait lens photographs of the corona, while of great value for certain purposes, are on too small a scale to permit the finer structure of the corona and prominences to be recorded. For this purpose the largest possible images are required. The results obtained at recent eclipses with objectives of great focal length indicate the value of this method. The lens may be pointed directly at the Sun and used in a fixed position with a moving photographic plate, or it may be mounted with its axis horizontal, and supplied with light by a heliostat or coelostat. A double mirror heliostat or a coelostat should be used in preference to a single mirror heliostat (unless this be of the polar form), as no large instrument of the latter type, so far as the writer is informed, has ever been made to drive accurately. If the mirrors show any tendency to distortion by the Sun's heat they should be screened until a few seconds before totality. Of the lens it may be said that it is doubtful whether any advantage will result from the use of focal lengths much greater than 75 or 100 times the aperture. A consideration of the size of the silver grains would indicate that with perfect seeing the full visual resolving power of the objective should be realized when the focal length is about 50 times the aperture. Excellent results have, however, been obtained with objectives whose focal lengths are as much as 120 times the aperture. But it must not be forgotten that for an objective of given aperture the exposure time and the effects due to poor seeing and inaccuracies of the coelostat or heliostat increase rapidly with the focal length. Hence one should not go too far in his desire to secure a large focal image of the corona.

It is probable that a photographic objective of comparatively short focus (say $\frac{f}{16}$), if used in conjunction with a suitable enlarging lens, would give results but little inferior to those obtained with the apparatus described above. This would have the advantage of requiring only a small equatorial mounting, but it might be difficult to avoid setting the instrument into vibration when changing plate-holders. All apparatus used in large scale photography must of course have stable foundations and adequate protection from the wind.

It will probably be advantageous to use multiple coated and backed plates, particularly for the longer exposures. The approximate lengths of exposures may be calculated from the data given in section 4.

The device employed at the Indian eclipse by Mr. Burckhalter, for the purpose of giving to each part of the corona an exposure inversely proportional to its brightness, merits more general use. It consists of a revolving disk, mounted concentrically with the Sun's image, and admitting light to the plate through an aperture of suitable form. The width of the opening at a given point cannot be exactly known until an expression giving the (photographic) brightness of the corona as a function of the distance from the Sun's limb has been found. Nevertheless, data sufficient for practical purposes are available, and there should be no difficulty in repeating Mr. Burckhalter's experiments.

8. DISTRIBUTION OF "CORONIUM."

It is a matter of considerable importance to determine whether "coronium"—the gas whose spectrum is characterized by the bright green line formerly known as "1474 *K*"—forms a structureless envelope about the Sun, or conforms in appearance to the corona. In other words, does the bright green line pass without marked change of intensity over coronal rifts and streamers, as Tennant long ago found it to do? It is evident that this question may be tested in several ways. One of the simplest is that employed by Maunder at the Indian eclipse of 1898. A small direct-vision prism was inserted in one of the eyepieces of a binocular of about two inches aperture. It was thus possible to compare the corona, as seen directly with one eye, with its monochromatic green image, as seen with the other. Thus the distribution of coronium could be ascertained with rapidity and certainty. Unless adequate shade glasses are used the Sun should not be observed with such an instrument before the beginning of totality, as the eye is likely to be temporarily injured by the brilliancy of the image. This was Mr. Maunder's experience, and as a result he was able to see the faint green image only after mid-totality had passed. No trace of rifts or rays could be distinguished by this observer. On account of its small size and convenience, a prismatic binocular will be very suitable for persons who wish to make useful observations, but are not in a position to provide elaborate and expensive instruments. Care must be taken, however, to secure an efficient binocular and direct-vision prism. The magnifying power of the binocular should be sufficient to show the coronal structure clearly and distinctly. The instrument, with prism in place, can be tested by the aid of an alcohol or Bunsen flame, colored with lithium or strontium chloride, and partially screened by a piece of cardboard in which openings are cut having the same angular magnitude as the coronal rays.

It would be interesting to examine with such an instrument the green coronal image in the immediate vicinity of a prominence. An objective prism or grating, or a small direct-vision prism, used in conjunction with a telescope of three or four inches aperture, would be more suitable for this purpose, however, on account of the larger scale of the image.

9. POSITION OF THE GREEN CORONAL LINE.

It has been recently shown by Lockyer, Campbell, and others that the green coronal line photographed at the Indian eclipse of 1898 did not correspond in position, as it had previously been supposed to do, with the line falling at 1474 on Kirchhoff's map of the solar spectrum, Undoubtedly the best way to accurately determine the wave-length of the green coronal line at the coming eclipse is by photography, but direct visual comparisons of the chromospheric and coronal lines will also be of value. Any spectroscope that easily separates the D lines will serve for the purpose, but a dispersion of two or three prisms would be advantageous. The spectroscope should be attached to a telescope of from four to six inches aperture, provided with good slow motions and driving-clock. The slit should be made radial at the computed point of second contact, and set in the focus of the telescope corresponding to λ 5317. The micrometer of the spectroscope should be provided with a rather coarse wire, extending only half way across the field, and fined down to a sharp point. At the beginning of totality this wire may be set so as to occult the bright chromospheric line at λ 5317 (1474 K). A few seconds later the green coronal line should become visible, and it may be seen at once whether it coincides in position with the wire. If time permits, micrometer settings may be made to determine the wave-length of the coronal line. Or the same instrument may be employed in an attempt to trace the green line across the coronal rifts.

10. PHOTOGRAPHS OF THE SPECTRUM OF THE CHROMOSPHERE.

The importance of securing a complete record of the spectrum of the base of the chromosphere is so great that no pains should be spared to surpass the admirable results recently obtained in India. So far as the writer knows, the numerous lines of the green and yellow flutings of carbon vapor, which can be seen at the Sun's limb on any good day with the spectroscope attached to the 40-inch Yerkes telescope, have not yet been observed or photographed during eclipses. This indicates that the spectrum of the "flash" is probably far more complicated than even the best photographs show it to be, and thus emphasizes the fact that too much attention cannot be devoted to this field of eclipse research. The brief duration of the flash is the principal obstacle to success. For this reason Mr. Evershed's suggestion that stations lying only a few miles within the north and south boundaries of the shadow path be selected for this work is an excellent one. At such points the duration of totality may be only one third that on the central line, but during this entire time the spectrum of the chromosphere would be visible. Thus photographs taken at second and third contacts would give the combined spectra of the lower and upper strata, while exposures made at mid-eclipse would record only the higher layers. Observers who wish to give special attention to the smaller prominences and the lower corona could also work to advantage at such stations, but all other observations should be made on or near the central line.

There can be little doubt that of all forms of spectroscopes suitable for photographing the spectrum of the flash the objective prism is the one most likely to give good results. As compared with a slit spectrograph it has certain disadvantages, notably on account of the absence of a slit, which renders the use of a comparison spectrum practically impossible. This defect is rendered less serious by the fact that a sufficient number of well-known lines to serve as standards can be found in the chromospheric spectrum itself. Thus the wave-lengths of the unknown lines can be determined with a considerable degree of accuracy, especially if Hartmann's valuable interpolation formula is used, and the reductions made by the method of least squares. Again, the necessary exposure times are less than with a slit spectrograph of equal resolving power, and the danger of complete failure is very small.

A slit spectrograph, if it is to be comparable in working efficiency with an objective prism, should be of large aperture, while the camera objective should be a triple lens or some other combination capable of giving good definition over a fairly large field. If a tangential slit is to be used the solar image should be as large as possible, and special care should be taken to provide reliable slow motions for use in placing the slit tangent to the Sun's limb. A train of prisms is undoubtedly superior to a grating in an instrument of this kind, unless one is fortunate enough to possess a grating which concentrates most of the light in a single spectrum. The time of exposure may be reduced to a minimum by using a long collimator (of correspondingly large aperture) and a comparatively short camera. The focal length of the camera objective will of course depend on the angular dispersion of the prism train and the linear dispersion desired on the photograph. In general, when it is necessary to reduce the time of exposure to a minimum, it is not advisable to attempt to realize the full theoretical resolving power of the prism train. This could be done only by the use of a very long camera, which would require a great increase in the exposure time.

Summing up, it may be said that the objective prism has a decided advantage in requiring less care in manipulation, and in showing a long arc of the chromosphere with a comparatively short exposure. It is therefore likely to be used in the majority of cases. Slit spectrographs should be employed only by experienced observers, who must take pains to secure the highest possible degree of efficiency in the design. The chances of photographing the spectrum of an active region in the chromosphere will be much increased if a slit having the curvature of the image of the Moon's limb is substituted for a straight slit. This presupposes that the slit is to be used tangentially, the position which demands the greatest skill on the part of the observer, but the one which may ultimately give the best spectrum of the lowest stratum of the chromosphere. Although a large solar image is needed, brightness should not be sacrificed for size through the use of an objective of very small angular aperture.

Reflecting jaws would facilitate setting the image on the slit. If a radial slit is used much less care is necessary in adjusting the position of the solar image, which may also be smaller in diameter. In this case the plan used by Campbell at the Indian eclipse, of moving the photographic plate by clockwork during the exposure parallel to the spectral lines, should prove effective in giving the spectrum of the various levels of the chromosphere on a single plate. The same method may be adapted to the requirements of a tangential slit or to those of an objective prism by limiting the length of the spectral lines by means of a slit parallel to the length of the spectrum, placed immediately in front of the photographic plate.

A third method of using the spectrograph is to set the slit so that it makes a small angle with the tangent to the Moon's limb at the point of contact. With a fairly large image of the Sun the spectrum obtained in this way on a fixed plate is quite wide enough to differentiate the spectra of the various strata. In observations of the faintest lines in the chromospheric spectrum with the 40-inch telescope this manner of placing the slit is found to give excellent results.

It is to be hoped that someone will use a quartz spectrograph for work in the ultra-violet. For this and other purposes the valuable combination of polar heliostat and spectrograph used by Newall in India should prove useful.[1]

Little need be said regarding the design of the objective prism spectroscope, unless it be to emphasize the importance of employing a lens corrected for the wave-lengths comprised by the photograph and the advantage of using several prisms with a short focus objective rather than a single prism with an objective of long focus. The dark line spectrum of the cusps should be photographed for use in connection with the reductions.

A direct concave grating spectroscope, similar to that used in 1899 by Mitchell at the Yerkes Observatory and described by him in the June number of this JOURNAL, should give good results in eclipse work. Newall describes in the paper referred to above an objective grating with which he successfully observed the distribution of "coronium" about the Sun.

In all cases it will be advantageous to employ multiple coated and backed plates, and to determine the proper moment to expose for the spectrum of the flash by the aid of a solar spectroscope used visually. A suitable photographic shutter should be provided, and a device for rapidly bringing fresh plates into position would prove of great service.

II. PHOTOGRAPHS OF THE SPECTRUM OF THE CORONA.

As already remarked, the eclipse will be of so short duration that it will be inadvisable to attempt any exhaustive study of the spectrum of the corona. Nevertheless, in view of the importance of definitely determining its wave-length, the green coronal line should be photographed with the highest dispersion it is safe to employ—probably three prisms, with a long collimator and a comparatively short camera. If possible, the chromospheric line at λ 5317 and the solar spectrum should be photographed on the same plate for purposes of comparison. From such a plate an accurate determination of the wave-length of the green coronal line may easily be obtained.

[1] See *Proc. Roy. Soc.*, **64**, 55, 1898.

Further attempts to measure the rotation of the corona will probably be put off until the Sumatra eclipse, but if any work is done it would appear from Campbell's results that the green line should be chosen in preference to all others. In any event the H and K lines should not be used, as the objective prism has shown that they do not belong to the spectrum of the corona.

12. HEAT RADIATION OF THE CORONA.

Direct measurements of the heat radiation of the corona, although attempted at two previous eclipses, have hitherto yielded no satisfactory results. As Professor Very has pointed out in the October 1899 number of this JOURNAL, the question is one of great intrinsic importance, and it has an additional interest because of its bearing on the possibility of mapping the corona without an eclipse. If the corona radiates sufficient heat to produce easily measurable deflections with a bolometer, radiometer, or other sensitive heat-measuring instrument, and if the intensity of heat radiation from the rifts and streamers is sensibly different, there is a chance that it may ultimately become feasible to map the outline of the corona in full sunlight. Discussion of the method would be out of place here;[1] suffice it to say that the principle on which it is based has been proved by laboratory experiments to be sound. Two sets of measures are particularly desirable just at present:

a. Measures of the heat radiation of a streamer at various distances from the limb, to determine the law of decrease with distance.

b. Measures of the relative heat radiation of rifts and streamers.

Of the four heat-measuring instruments available for this work the observer must endeavor to select that which is best adapted for his purpose. The radiometer and radiomicrometer are not affected by magnetic disturbances, and have other important advantages. The bolometer and thermopile require the

[1] "On a New Method of Mapping the Solar Corona without an Eclipse." This JOURNAL, 1, 318.

coöperation of an exceedingly sensitive galvanometer, but they are small and light, and can be used in any position. The thermopile needs no battery, and if made in Ruben's new form, as described in the last volume of the *Zeitschrift für Instrumentenkunde*, it ought to be well adapted for eclipse work. Each observer must, however, base his selection upon experience in the use of the various instruments. Whichever is chosen, means must be provided for instantly varying the sensitiveness through a large range, as with our present ignorance of its intensity it would be unsafe to expose a very delicate instrument to the full radiation of the corona. With a bolometer or thermopile a good balancing bridge is essential, and for the former it is necessary to have a battery giving a very uniform electromotive force. Every precaution must be taken to shield all junctions (which should be of copper throughout) from convection or radiation, and to protect all parts of the apparatus from the wind and other sources of disturbance. If possible, the measures should be differential, one strip, vane, or junction being exposed to the radiation from the Moon, the other to that of the corona. An observer with a single instrument should not attempt to measure the heat radiation at more than one or two points, using the lowest sensitiveness of the instrument that will give reliable readings. On account of the difficulty of the work, and the danger of a mishap at the critical moment, it is hoped that several observers with independent instruments may take part in it. The writer will be glad to discuss details of the apparatus (including heliostat, device for rotating coronal image, differential radiometer, radiomicrometer, bolometer or thermopile, galvanometer, balancing bridge, etc.) with anyone who is prepared to undertake the measurements.

It might be profitable to consider many other questions relating to the eclipse, particularly those connected with photometric and polariscopic observations. But, as stated at the outset, this article is intended to be merely suggestive in character, and no attempt has been made to cover the whole field. It will be well worth while to undertake photometric observations of the corona, if photographic methods are employed in conjunction with some such instrument as Hartmann's new photometer. Work with the polariscope is less important at this time. Arrangements should always be made, if possible, to accurately determine the latitude and longitude of eclipse stations. The contacts should of course be recorded with all possible accuracy.[1]

It should perhaps be said in conclusion that the above suggestions do not necessarily represent the views of the Eclipse Committee, as the writer, except in a single instance, is alone responsible for them. The committee desires to secure for publication all possible information regarding the plans of eclipse parties, and communications may be addressed to the secretary at the Yerkes Observatory.

[1] Special attention is called to Professor Campbell's article on the observation of contacts in the *Astronomical Journal*, No. 474, which has appeared since the present paper was put in type.