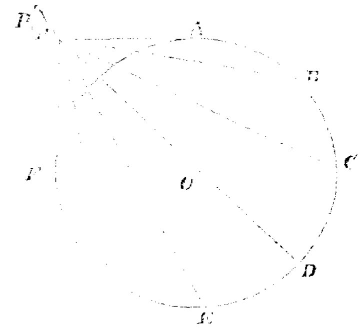
NOTE.

Let the circle A C E F represent the disk of the sun; let P be a point in the corona at the intersection of two lines, P F, P A, tangent to the circumference at points F, A, 90° from each other, and let P be illuminated only by light from O, at the center of the disk. This light will be polarized by reflection in the plane whose trace is P D, and which (like the planes whose traces are P A, P B, P F, and so forth) passes through the eye of the observer. If an infinite number of points, illuminated only from O, as in this hypothesis, formed the corona, the appearance would be that due to strictly radial polarization.



But if P be illuminated from all points of the solar sphere which can send it light, that light will be polarized in the tangent planes P A, P F, and an infinite number between. More light may be received polarized in the plane of P D than in that of P C, and more in P C than in P B, yet it seems evident that reflected light, due to vibrations in an infinite number of planes at all azimuths, must be sensibly depolarized, at least so far as to make it much more difficult to determine the plane of maximum polarization at P than if there were but one, and that one radial. If P were at a distance, P O, in comparison with which the sun's dimension could be neglected, the polarization would again be wholly in the plane of P D. For all points, then, exterior to P the evidence of radial polarization will grow more marked; for all points nearer to O, less so.

Since similar considerations apply to every point in the corona, if its polarization be in a general sense radial, or such as would be due to directly reflected sunlight, we cannot, under the most favorable circumstances, expect evidence of it in the polariscope, from the parts very near the moon, during a total eclipse. Experience as well as theory shows that no such evidence can be found, and no conclusion against the presumption that the inner corona shines by reflected light should be drawn from its absence.

Such conclusions have been drawn, as it seems to me, erroneously, and it is therefore not superfluous to call attention to their apparent fallacy.

It is well also to remark, that if the above considerations are of any value, we are led to attach more importance to the independent evidence of the polariscope as to the extent of the corona, since evidence of polarization such as exists can only be drawn (as it here appears) from a region *outside* that to which some have believed the corona to extend.

REPORT OF OBSERVATIONS OF THE TOTAL ECLIPSE OF THE SUN OF DECEMBER 22, 1870, BY PROFESSOR EDWARD C. PICKERING, ASSISTED BY MR. WALDO O. ROSS.

BOSTON, *June* 19, 1871.

DEAR SIR: In preparing the following report on the polarization of the light of the eclipse of December 22, 1870, I have first compared some of the previous observations, then given the results of the measurement of the delicacy of different instruments, next shown what kind of polarization we should expect from theoretical considerations, then described the instruments used and the observations made with them, and finally given the conclusions to be derived and recommendations for future observations.

PREVIOUS OBSERVATIONS.

The following table shows some of the principal polariscopic observations previously made, which I have discussed more at length elsewhere, (Journal Franklin Institute, January, 1871.) The first column gives the name of the observer; the second the point of observation; the third the date; the fourth the kind of polariscope used, and the fifth the conclusion as to the intensity or existence of polarization.

Observer.	Location.	Date.	Instrument.	Polarization.
Arago	Perpignan	1842	Arago	Doubtful.
Mauvais	Perpignan	1842	Savart	Probable.
Abbadie	Fredericksweerk	1851	Nicol & quartz	Strong.
Carrington	Lilla Ider	1851	Nicol	None.
Liais	Paranagna	1858	Savart	Feeble.
Secchi	Mount Michel	1860	Arago	Marked.
Prazmowski	Briviesca	1860	Biquartz	Very strong.
Campbell	Jamcandi	1868	Arago Savart	Strong.
Winter	Masulipatam	1868	Savart	Very strong.
Smith	Eden Ridge	1869	Arago	None.
Pickering	Mount Pleasant	1869	Arago	None.

Prazmowski's conclusions do not agree with his observations, as a radial polarization would have required that the two upper and two lower quadrants should have had the same instead of the complementary tints he describes.

The last column of this table shows how much these observations differ. The Savart in most cases gave a strong polarization, the single observation with the Nicol prism showed none, while only various results were obtained with the Arago. Some again found the polarization most marked near the sun, others at a distance from it. The results also differ regarding the sky around the sun, and the nature of the light received from the moon's disk. So great a diversity therefore showed the necessity of careful preparation for the present eclipse.

DELICACY OF DIFFERENT INSTRUMENTS.

A number of experiments were made by Mr. Ross and myself with a modification of the polarimeter, with two plates of glass. An unpolarized object was viewed through this instrument, and the plates turned until the polarization became perceptible with the polariscope to be tested. The results were then reduced to percentages by Fresnel's formula. To eliminate index-error, readings were taken on each side of the zero, and the mean used. It was found that the sensibility varied with the size of the object and the intensity of its light. The following series must therefore be regarded as showing comparative rather than absolute delicacy :

Limit of visibility of Savart's bands, 1 per cent.

Limit of visibility of color in Savart's bands, 2½ per cent.

Color first perceptible in a small Arago polariscope with selenite giving red and green images, 5 per cent.

Same with large Arago with quartz giving blue and yellow, 15 per cent.

Nicol prism, variation in light, (or rotating,) becomes perceptible with 10 per cent.

These are the means of series of observations by Mr. Ross and myself.

Another series of experiments were made with a common polarimeter, replacing the Savart by a Nicol prism and the crystal to be tried. The plates were turned until the bands were distinctly visible, equally so with all the crystals. The results were as follows:

Savart's plates	4. 2
Calcite 1^{mm} thick cross	17. 2
Calcite 1^{mm} thick rings	9. 6
Hemitrope 3^{mm} thick	15. 1
Doppelspath 3^{mm} thick	13. 0
Doppelspath 5^{mm} thick	14. 7
Aragonite irregular	15. 7

A similar series was made some months later using fainter bands.

Savart I	2.0
Savart II, wider bands	2.5
Spar Hemitrope, black cross	7.6
Spar Hemitrope, white cross	6.2
Crystal saltpeter	8.7
Babinet's wedges	2.0

These results agree very well with the others, and show that Savart's bands give the best results, and that other crystals require from three to four times as strong a polarization to render it visible. The wedges of Babinet described below, however, appear to equal Savart's bands in delicacy. Some allowance should be made for the fact that my eyes are more accustomed to the bands, and therefore perhaps detect them more readily.

Another method was used to compare the biquartz of Prazmowski with Babinet's wedges. The plane of polarization of a beam was measured twenty times with each, and the probable error computed; this would be proportioned to their relative delicacy. The degree of polarization of the beam was first measured by the polarimeter.

	5 per cent.	25 per cent.
Prazmowski yellow	1°.45	0°.42
Prazmowski violet	1°.06	0°.29
Babinet	1°.14	0°.39

From this we infer that the wedges are less delicate than the sensitive tint of the quartz, but more delicate than its complementary yellow color.

From their nature all these observations are necessarily somewhat indefinite and depend in a great measure on the eye of the observer, but they give a general idea of the comparative value of the various instruments.

We next wanted to produce an artificial corona polarized radially, to try our instruments on, and to know what appearance to expect in the solar corona, if its light is of this nature. With the aid of Professor Langley and other members of the party we arranged the apparatus represented in Fig. I.

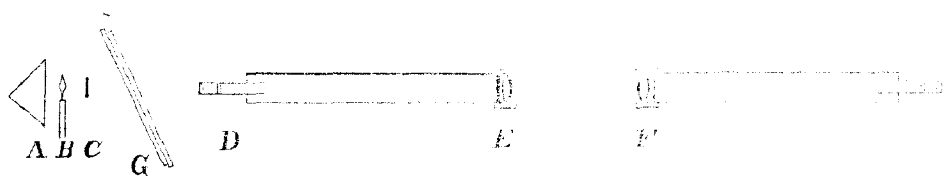


Fig. 1

(See also Plate No. 28.) A tin cone, A, was procured and lined with black unglazed cambric, as this substance was found to give the best results. White paper or cloth, while reflecting no more light specularly, added a large amount by diffuse reflection, which being unpolarized marked the effect of the other. A candle, B, was placed in front of the cone and the eye protected from its light by a circular disk, C, representing the moon. On placing the eye in the axis of the cone, light was received and reflected by the cloth in planes passing through the axis, and hence polarized radially. If now one or more plates of glass, G, were inserted in front of the candle we could superimpose a uniform polarization of all the light, and thus imitate all the effects of sky polarization.

As the diameter of the base of the cone was about one foot, it should be placed at a distance of 20 or 30 feet to give it its proper angular dimensions, or, when viewed with a telescope magnifying 30 or 40 diameters, at a distance of three or four hundred yards. As it was necessary to use a darkened room this was impossible, and the common method of using a collimator was impracticable on account of the size of the object. I therefore devised a plan by which we can view any object, large or small, near or distant, with a telescope adjusted for parallel rays, and vary its apparent angular diameter at will. This device is shown in Fig. I, in which, instead of a collimator, an ordinary telescope is used, with eye-pieces attached. The latter D forms a very minute object of A when this is placed a few feet off, and this image is then removed to a distance by F, which acts as a collimator. By slightly altering the focus of D E we render the rays from any object, near or distant, parallel. By changing the eye-piece D or altering the distance of A we readily give it any magnitude we desire. We were thus enabled to test all our polariscopes, whether attached to telescopes or not, on the same object.

We found as a result that when using the Savart it was a matter of extreme difficulty to recognize with certainty the radial nature of the polarization, although the presence of polarized light was shown in a very marked manner, the trouble being to tell on so small an object whether the bands were dark or light-centered. With the Arago, on the other hand, the presence of polarized light was more difficult to detect, but once seen its radial nature was obvious, the top and bottom being of one color, and the sides of a complementary tint. We also found that very good results were obtained with a Nicol prism, especially when it was rotated as a dark band crossing the corona, then turned with it. It should be remembered, however, that in this case the polarization was very considerable and the light feeble, conditions in which the Nicol prism is most valuable. In preparing for the observation of future eclipses I would strongly recommend the use of this imitation corona, and that all the polarizers should be tried on it, as it affords an excellent means of testing their efficiency.

THEORETICAL CONSIDERATIONS.

Two theories have been proposed for the polarization of the sky adjacent to the corona and of the dark disk of the moon: first, that they were polarized radially by reflection from the corona, as when the sun is not eclipsed; and secondly, that being illuminated by reflection from objects beyond the limits of the shadow, they are polarized throughout in a vertical plane, or by refraction horizontally. In the former case, however, the large size of the corona would render the polarization of objects adjacent to it feeble, as may be seen from the discussion given below of the polarization of the corona itself; but even supposing the latter concentrated at a single point, the angle of incidence for the adjacent sky would be so great as to render the polarization very slight. Even at a distance of 2° it would only amount to .03 of 1 per cent., while on the moon's disk, since the angle of incidence would everywhere exceed 89° 52½′, the polarization would be only one two-thousandths of one per cent. As our most delicate polariscopes scarcely show 1 per cent., it would evidently be impossible to detect such feeble polarization. Moreover, radial polarization cannot be observed so near the sun when not eclipsed, although it should then be, if anything, greater than during totality. Of course, this discussion applies only to the sky very near the sun; that at a distance may be polarized radially.

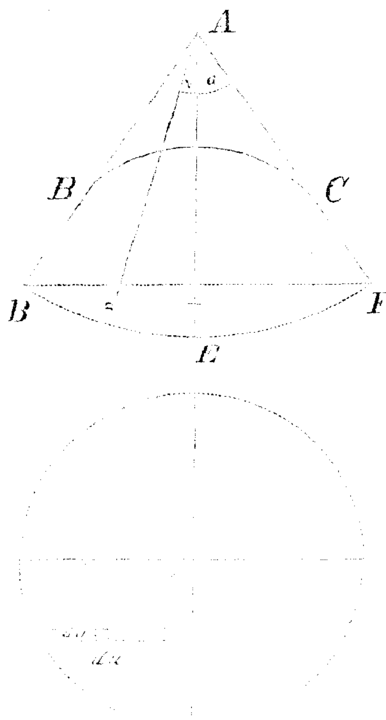


Fig. II

While crossing the Atlantic last November, I obtained a most unexpected verification of the second theory. One morning the sun was barely visible through the fog, and on examining it with the polariscope I found the fog polarized vertically even while near the sun, probably by reflection of the light from the water. Presently the fog cleared a little, and the usual radial polarization appeared; then, becoming thicker, its plane became vertical, so that at one time I could almost trace it to the sun's limb. Of course, there was no change above or below the sun, as there the plane was vertical throughout, but on each side it was sometimes horizontal, sometimes vertical, and at an angle of 45° the bands of a Savart would disappear in one case while they attained their maximum of distinctness in the other. Thus, when clear, the bands, if held vertically, disappeared, and as the sky cleared, the plane of polarization could be seen to swing around to its usual position. The conditions were here the same as during an eclipse, the fog replacing the moon; my own observation of the eclipse of 1869 agrees perfectly with this theory.

The next point to be considered is what amount of polarization we should expect to find in different parts of the corona. Any point as A, Fig. II, receives light equally from all points within the cone, B A C, (neglecting the absorption of the solar atmosphere,) since for the more distant parts the larger area compensates for the increased distance and obliquity. The effect is, therefore, the same as if we had a spherical surface, D E F, with center at A, radiating light to it. Dividing this surface up by two series of planes passing through A, and making angles u and v, with A F, and we have the elements $du\,dv$. The amount of light reflected by A from any such element consists of two parts, one polarized in the plane of incidence, the other in a plane at right angles to it. The magnitude of these beams is given by Fresnel's formula—

$$I = \tfrac{1}{2}(A + B)$$

in which the beam polarized in the plane of incidence—

$$A = \frac{\sin^2(i - r)}{\sin^2(i + r)}$$

and the other beam—

$$B = \frac{\tan^2(i - r)}{\tan^2(i + r)}$$

In the present case we must regard the index of refraction very nearly unity, or $1 + dr$, and hence A is proportional to $\frac{1}{\sin 2i}$ and B to $\frac{1}{\tan 2i}$. These may be again decomposed into two, one polarized horizontally—

$$d^2 H = (A \sin v + B \cos v)\, du\, dv$$

and the second vertically—

$$d^2 V = (A \cos v + B \sin v)\, du\, dv$$

Substituting, since $u = 90° - 2i$,

$$d^2 H = \frac{\sin v}{\cos u}\, du\, dv + \cos v \tan u\, du\, dv$$

$$d^2 V = \frac{\cos v}{\cos u}\, du\, dv + \sin v \tan u\, du\, dv$$

As a first approximation, let us consider only the light received from points in the plane of the plates in the upper part of Fig. II; for these—

$$u = 0;\ u' = 45°$$

hence the light is totally polarized in the plane of incidence and—

$$B = 0$$

Hence—

$$d H = \sin v\, dv;\ d V = \cos v\, dv$$

Integrating between $v = 0$ and $v = a$, and doubling for the two sides of the vertical, we have,

$$H = 2(1 - \cos a)$$

and—

$$V = 2 \sin a$$

The former is evidently always the smallest, hence the light is polarized in a vertical plane, (more strictly radially,) the degree of polarization being—

$$\frac{V - H}{V + H} = \frac{\sin a + \cos a - 1}{\sin a - \cos a + 1}$$

In the following table—

a	m	H	V	$\frac{V-H}{V+H}$
0°	∞	.0	.0	100.0
15°	43.0	.062	.518	78.6
30°	15.0	.268	1.000	57.7
45°	6.2	.584	1.414	41.4
60°	2.3	1.000	1.732	26.8
75°	0.5	1.482	1.938	13.3
90°	0.0	2.000	2.000	0.0

the first column gives a, the second the distance from the sun's limb in minutes of arc, the third H, the fourth V, the fifth the degree of polarization in percentages. We see from this that at 6′ the polarization would be only 40 per cent., while at 30″ it would be only 13 per cent. This approximation is the more accurate, since, although the points not in the plane of the paper have a less value of v, and hence diminish H relatively, yet this effect is partially compensated by the fact that their polarization being only partial, B is present, by which H is increased.

Returning now to the general case, we have to obtain H and V, from the equations given above, by double integration. Integrating with regard to v we have—

$$d\,\mathrm{H} = -\frac{\cos v}{\cos u}\,du + \sin v \,\mathrm{tang}\, u\, du$$

$$d\,\mathrm{V} = \frac{\sin v}{\cos u}\,du - \cos u + \mathrm{tang}\, u\, du$$

Since for any point on the exterior of the cone B A C we have—

$$\cos a = \cos u \cos v$$

or—

$$v = \cos^{-1}\frac{\cos a}{\cos u}$$

our integral must be taken between $v = 0$ and $v = \cos^{-1}\frac{\cos a}{\cos u}$; hence:

$$d\,\mathrm{H} = -\frac{\cos a}{\cos^2 u}\,du + \frac{\sqrt{\cos^2 u - \cos^2 a}}{\cos^2 u}\sin u\, du + \frac{du}{\cos u} = d\mathrm{M} + d\mathrm{N} + d\mathrm{O}.$$

$$d\,\mathrm{V} = \frac{\sqrt{\cos^2 u - \cos^2 a}}{\cos^2 u}\,du - \frac{\cos a \sin u}{\cos^2 u}\,du + \frac{\sin u}{\cos u}\,du = d\mathrm{P} + d\mathrm{Q} + d\mathrm{R}$$

We have thus six terms to integrate, which give—

$$\mathrm{M} = -\int\frac{\cos a}{\cos^2 u}\,du = -\cos a \,\mathrm{tang}\, u$$

$$\mathrm{N} = \int\frac{\sqrt{\cos^2 u - \cos^2 a}}{\cos^2 u}\sin u\, du$$

making $\cos a = a$, $\cos u = x$,

$$\mathrm{N} = \int -\frac{\sqrt{x^2 - a^2}}{x^2}\,dx = +\left(\frac{\sqrt{x^2-a^2}}{x}\right) - l.(x + \sqrt{x^2 - a^2})$$

$$= +\frac{\sqrt{\cos^2 u - \cos^2 a}}{\cos u} - l.\left(\cos u + \frac{\sqrt{\cos^2 u - \cos^2 a}}{\cos u}\right)$$

$$\mathrm{O} = \int\frac{du}{\cos u} = l.\,\mathrm{tang}\left(\frac{\pi}{4} + \frac{u}{2}\right)$$

Hence we have the complete integral—

$$H = -\cos \alpha \,\text{tang}\, u + \frac{\sqrt{\cos^2 u - \cos^2 \alpha}}{\cos u} - l.\left(\cos u + \frac{\sqrt{\cos^2 u - \cos^2 \alpha}}{\cos u}\right) + l.\,\text{tang}\left(\frac{\pi}{4} + \frac{u}{2}\right)$$

Treating V in the same way, we have—

$$Q = \int \frac{-\cos \alpha \sin u}{\cos^2 u} du = -\frac{\cos \alpha}{\cos u}$$

$$R = \int \frac{\sin u}{\cos u} du = -\, l. \cos u$$

On attempting to integrate the last term,

$$P = \int \frac{\sqrt{\cos^2 u - \cos^2 \alpha}}{\cos^2 u} du$$

we find that it is an elliptic integral, whose value can, therefore, only be obtained approximately. A development by the binomial theorem gives—

$$dP = \frac{\sin \alpha}{\cos^2 u} du - \frac{\sin^2 u \, du}{\sin \alpha \cos^2 u} - \frac{\sin^4 u \, du}{8 \sin^3 \alpha \cos^2 \alpha} + \&c.$$

$$P = \sin \alpha \,\text{tang}\, u - \frac{\text{tang}\, u - u}{\sin \alpha} - \frac{1}{8 \sin^3 \alpha} \int \frac{\sin^4 u \, du}{\cos^2 u} - \&c.$$

Hence—

$$V = -\frac{\cos \alpha}{\cos u} - l. \cos u + \sin \alpha \,\text{tang}\, u - \frac{\text{tang}\, u - u}{\sin \alpha} - \frac{1}{8 \sin^3 \alpha} \int \frac{\sin^4 u \, d\, u}{\cos^2 u} \Big\} - \&c.$$

of which the other terms are best integrated by series. Having performed this integration and taken proper limits, we should get H and V for a certain point of the corona. We should then strictly consider all other points in the same straight line with the observer, and take the sum of their effects. The approximation given above, however, shows the general result, which is, that if the polarization is produced by reflection according to Fresnel's theory, it should be most marked at a distance, diminishing to nothing close to the sun's limb.

INSTRUMENTS.

The telescope I used was the finder of the 15-inch equatorial at Cambridge. Its aperture was 3 inches, focal length 48 inches, and its mounting equatorial. I had attached to it the eye-piece represented in Figure III, made by Zentmayer, of Philadelphia.

A B is a common positive eye-piece containing a Nicol prism C. At its focus is a slide D, with three holes, into which different polarizing plates can be placed and changed instantly. A B can also be drawn out and a higher or lower power substituted. The whole was arranged so that it could revolve and the angle be measured by a graduated circle E, and index F. One of the apertures in D was left vacant, so that the Nicol prism alone could be used; it would perhaps be better to fill it with a thick piece of plate glass, that the focus might be the same as when the other apertures were used. The second place contained a biquartz, or two plates side by side, one turning the ray to the right the other to the left. When this line of junction is parallel to the plane of polarization, both assume the same color, which is a peculiar violet tint, known as the transition or sensitive tint. Turning it 90° the color of both becomes complementary or dull yellow; in other positions, one is red, the other green. In the third aperture, at the suggestion of

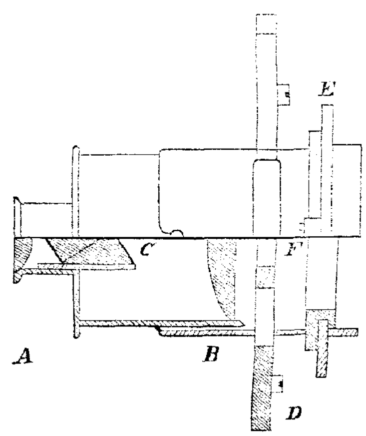


Fig. III

Professor Stokes, I placed the quartz wedges used by Babinet, which show bands like those of a Savart polariscope, only reversed, that is strongest when inclined 45° to the plane of polarization, and disappearing when parallel or perpendicular to it. I at first intended to use a Savart in this position, but this requires diverging rays and cannot be used with a parallel beam. I also had a cheap 3-inch telescope, by Newton, for a collimator in testing the polariscopes and for determining contacts and general observations. It was suggested by Professor Young that one cause of my not seeing any polarization in 1869 may have been the small size of the corona. He, therefore, proposed that it should be enlarged by placing an Arago in front of the telescope. I accordingly strapped a small French telescope as a finder to my larger one, and slipped a cap on the objective with a double image prism and quartz plate. This arrangement has also the much more important advantage of eliminating the sky polarization; for while the two images of the corona are so far separated that one only is visible, the second image of the sky, distant two or three degrees, overlaps the first, so that all disturbing effect of it is removed, and we have the corona polarization alone.

To measure the degree of polarization a modification of Arago's polarimeter was used, consisting of four plates of glass free to turn and carrying an index and graduated circle which shows the amount of the rotation. The object to be tested is viewed through them with a Savart polariscope, the bands being placed parallel to the axis of rotation. The whole instrument is turned until the bands are perpendicular to the plane of polarization, when they will be white centered, and the plates are then turned until they disappear. From the angle we can tell the amount of polarization present, since it is then just equal to that produced by the plates. We also carried two Arago's polariscopes, one consisting of a double image prism and *quartz* plate placed at opposite ends of a tube of such a length as to give two images of the quartz in contact, but not overlapping. The second Arago consisted of a double image prism and plate of selenite placed close together, and attached to the end of a tube, the further end of which was closed by a cap with a square hole in it.

One other instrument remains to be described, namely, that prepared for measuring the amount of light remaining during totality.

Previous observations of this quantity are extremely vague, and we, therefore, attempted some more accurate measure. A darkened box, A B, Figure IV, was prepared about six feet long.

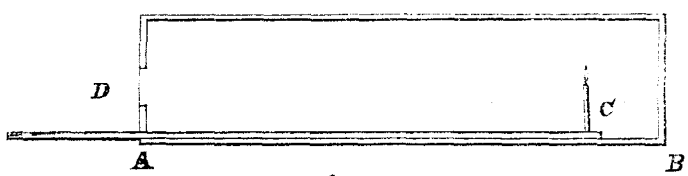


Fig. IV

In this was placed a candle, C, on a slider, by which it could be placed at any distance from the aperture D. This slider carried a graduated scale, so that the distance C D was given directly in tenths of an inch. D was closed by a disk of paper with a circle oiled in the center as in the Bunsen photometer. The first difficulty encountered arose from the fact that the light of a candle is so different in color from that of daylight that in no position would the spot disappear. We then inserted a piece of blue tissue-paper between it and the candle, which, cutting off the red rays of the latter, rendered its color more nearly that of daylight. A more convenient method was to use a piece of glazed paper, blue on one side, which gave a spot which disappeared almost perfectly. By this arrangement we can at any time darken a room so that the obscurity shall be the same as that of totality or compare the latter with twilight.

OBSERVATIONS.

The point selected for our observations in Jerez was the top of the house of Señor Rivero, who kindly placed it at our disposal. It was distant about half a mile from the station of the other members of the party and commanded an excellent view of the surrounding country, especially in the direction where the shadow passed off. The day was cloudy and rainy, but we obtained a tolerable view of first contact and were able to watch the gradual progress of the eclipse. Mr. Ross took charge of the photometer and the larger Arago polariscope, but a few minutes before totality it was so cloudy that I laid down my instruments, thinking that nothing could be seen with them, and that it would be better to devote our entire attention to the photometer. Fortunately, however, at the moment of totality, the clouds, although still covering the sun, became sufficiently thin to enable us to carry out our original plan, and to obtain quite a good view of the corona. Mr. Ross's observations were made by making the spot disappear, then drawing a line with a pencil across the scale of the photometer, setting the instrument again, drawing a second line, and so on, moving the scale each time. He thus obtained a permanent record of his readings, which were as follows:

No.	Scale.	Intensity.	No.	Scale.	Intensity.
1	21.0	.23	5	20.9	.23
2	19.8	.25	6	18.4	.30
3	17.5	.33	7	14.4	.48
4	19.6	.26	8	16.6	.36

The considerable variation in these results is doubtless due to the continual change in the clouds drifting over the sun, and probably also to the change in position of the moon. They afford, however, almost the first quantitative measure of the actual intensity of the light during totality, and the ready means of comparing it with twilight or a cloudy day.

He also made an observation with the larger Arago polariscope, holding it so that when looking at a horizontal plate of glass, (that is, when the plane of polarization was vertical,) the right-hand image was yellow, the left-hand one blue. On looking at the corona, the appearance represented in Fig. V, Plate No. 28, was seen, in which horizontal lines represent yellow and vertical blue. He says: "The appearance of the corona was perfectly white, that of the sky around it the opposite of that obtained with a horizontal plate; that is, the blue was on the right. The inference to be drawn from this would be, that the plane of polarization of the sky surrounding the corona was horizontal. The colors were faint but unmistakable. I did not note the appearance of any color on the surface of the moon. The color of the sky in the right-hand image was a dull bluish-purple, the other a dull yellow."

My own observations were, however, quite at variance with this. I first used the smaller Arago with a plate of selenite, which gave red and green images, but since it is impossible to grind selenite to as true a surface as quartz or glass, objects seen through it are a little indistinct, as when seen through mica or uneven window-glass. I found, however, the two images of the corona distinctly colored, the right-hand one red above and below, and green on each side; the other with these colors reversed, showing a radial polarization; the sky polarization was comparatively faint. I next pulled the prism and selenite, which were fastened together, out of the tube, and repeated the observation; the sky polarization was thus eliminated, as two images distant 3° were superimposed. The same result was obtained as before, showing that the effect could not but be due to sky polarization. I then returned to my telescope, in which I had adjusted my bi-quartz and the low power eye-piece. With this I got less conclusive results. The image was dimmed by the clouds, though not sufficiently to prevent the colors from being distinctly visible. On attempting to record them, however, they seemed to be continually changing, and this was probably in reality the case, as we know that a clear sky is strongly polarized, while, when cloudy, no signs of this phenomenon can be detected. Hence, every cloud crossing the moon's disk would change the colors. I then attempted to see if at any time I could detect the colors due to radial polarization, that is, green above and red below, and am very confident that at one time these colors were present. The colors were distinctly, though faintly, visible over the moon's disk and uniform on each side of the line of junction of the quartz, showing that the moon's disk was polarized not radially, but in the same plane throughout. These observations took some time, and when completed I looked at the corona with a Savart not attached to a telescope. This showed bands on the sky which were much stronger on the corona, and when turned so as to disappear on the former, still remained visible on the latter; thus showing the independent polarization of the latter. Totality being now nearly over, I watched for the passage off of the shadow. I failed to see it, however; probably owing to the presence of the clouds, which rendered it difficult to tell when totality ceased.

I noticed in a very marked manner the chill often described during totality, which surprised me, as I expected that the clouds would prevent much radiation. Although the thermometer stood at 62° at first contact, during totality the cold rendered my hands numb and caused my eyes to water. After totality the clouds became so thick that no further observations were possible.

The only observation of importance during the partial phase was that, shortly before totality, I examined the sky close to the sun and found no traces of polarization, which agrees with all the other observations in supporting the second theory of sky polarization described above. I also noticed that just before totality the upper point of the sun's crescent was cut off by a mountain in the moon.

CONCLUSIONS.

The polariscope is an instrument so sensitive to the presence of clouds that it does not seem safe to draw any decided conclusions from these observations. The principal point to be discussed is the want of agreement with the two Arago polariscopes used. The instruments are so easily used and the effects are so striking, it seems scarcely possible that any mistake in observing could be made with them. I used the larger one in 1869 and obtained the same result then that, Mr. Ross did, in the last eclipse. My recollection of it is so distinct and so utterly unlike what I saw with the small Arago this year that I am confident it cannot be a mere error of observation. The next question was whether it might be due to a defect in the instrument. But it was tested and found to be in good order beforee ach eclipse, and has been frequently used for the last two years, always giving good results. Moreover, while showing no polarization in the corona it rendered that of the sky very preceptible, which proves that there is no defect in the instrument. Though less delicate than the other Arago, it surely ought to have shown the marked polarization evinced by the smaller instrument. The only other possible explanation seems to be some peculiarity in the condition of the light which would affect some instruments and not others. The colors in the two instruments are produced in entirely different ways. In the larger, which contains a plate of quartz, it is due to the unequal rotation of the plane of polarization of the rays of different colors. In the smaller Arago, on the other hand, the colors are produced by a plate of selenite, in which the different rays having different wave length are cut off unequally.

A theory presented itself which at first seemed quite plausible. The spectroscope shows that the light of the corona is in a great measure at least monochromatic. Now the polarization of such light can be detected by a Savart or other instrument showing variation of intensity, but not by an Arago or instrument showing color. To prove this I produced an image of a soda flame by reflection, which was strongly polarized. Viewing this with a Savart the bands were strongly marked; the light varied with a Nicol prism, but no effect was produced on viewing it with an Arago. The polarized light of the corona, however, is doubtless that part which is not monochromatic, and for various other reasons this theory fails. There still remains, therefore, an unexplained disagreement in the observations with different Arago polariscopes, and it is to be hoped that in future eclipses a variety of these instruments may be used, some with quartz, others with selenite. I have only one other suggestion to make in future observations, namely, placing at the diaphragm of a large portrait camera a double image prism and strapping it to a telescope mounted equatorially; we should thus obtain a permanent record of two images of the corona, one polarized horizontally, the other vertically; if they were polarized radially the former would be comparatively faint above and below, the other on the sides. Since the two images would be in other respects precisely alike, we should have an excellent means of permanently recording any polarization of the corona while that of the sky, for reasons given above, would be neutralized.

Respectfully submitted.

EDWARD C. PICKERING.

Professor BENJAMIN PEIRCE,
Superintendent United States Coast Survey.