Columbus, Ohio.—No halo was observed at this station and we find no report of it in the file of the local papers.—*J. Warren Smith, Professor of Meteorology.*

[In reply to a circular letter sent by Prof. Smith to the Weather Bureau coöperative observers in Ohio, reports were received of the appearance of solar or lunar halos, for the most part inconspicuous, on or about the dates in question at a number of places in the eastern half of the State.]

Fort Smith, Ark.—Mr. L. J. Guthrie, Local Forecaster, sends a drawing of a halo seen on October 31, consisting of the circumzenithal arc and the two parhelia of 46°.

THE DIFFERENT FORMS OF HALOS AND THEIR OBSERVATION.[1]

By LOUIS BESSON, Observatoire de Montsouris.

[Translated by Cleveland Abbe, jr., May-June, 1914.]

INTRODUCTION.

Halos are optical meteors produced by the light of the sun or of the moon, in clouds composed of ice crystals. They consist of curves or of luminous foci, either white or tinted with prismatic colors. The remarkable brilliancy they may attain, the extreme variety of their forms, and the somewhat fantastic character of their appearance, make their observance and study most interesting. For these reasons numbers of astronomers and physicists have paid particular attention to them at different times. We owe memorable descriptions of halos to Hevelius. Tycho Brahe observed them carefully at Uraniaborg for 16 years. Among the chief we may mention Huyghens, Mariotte, Fraunhofer, Young, Venturi, Galle, as having studied this class of phenomena and labored more or less successfully to establish a theory of them. The theory was, however, still quite imperfect when Bravais took it up toward the middle of the last century. In a masterly memoir he so far perfected and completed the theory that he seemed to have indeed succeeded in quite satisfactorily explaining all the known forms of halos.

In fact, even today the theory cannot be regarded as other than a more or less probable hypothesis for a very large number of the forms, because existing observations are generally far too few and too inexact to furnish a satisfactory check on the results of computation. This is why the Austrian physicist Pernter, in his recent treatise on meteorological optics, could plausibly reject the Bravais theory relating to three kinds of tangent arcs of the 46°-halo, and substitute another theory which gives them quite different forms.

On the other hand, there is a whole class of extremely rare halos which have been observed but once or twice and remain wholly enigmatical. Not only is their explanation still imperfect, but it will be a long time before we shall have a complete list of their forms. We still have rather frequent reports of combinations and forms that have never been reported during the centuries that have past, and it may be supposed that many unknown forms still await observation.

Halos will, therefore, long offer a fertile field of investigation. Observers should be made aware of this fact in order that a larger number of persons may turn to this field of study. In fact our knowledge of halos can not advance at all rapidly unless numerous persons located at many points on the globe shall observe them. No individual observer, however vigilant throughout his life, can see more than a fraction of the total possible forms of halos. The well-known French meteorologist Renou watched ceaselessly for halos during more than half a century, nevertheless he never saw the oblique arcs of the anthelion, nor the halo of Hevelius, nor the paranthelia of 90°, not to mention many another rarer phenomenon.

From time to time every assiduous observer will find his pains rewarded by his being the first to make some angular measurement or some important discovery; but he will never be able to elucidate more than a portion of the subject by means of his own unaided observations. On the other hand, if there are numerous observers in each country paying intelligent heed to the halos occurring, there can be no doubt that in a few years many uncertainties and gaps will disappear from the theory of these phenomena. Indeed many of their forms, though extremely rare at any given place, probably occur often enough at one place or another upon the earth. * * *

As a matter of fact, the observations on halos published in scientific works are quite inadequate, both as regards quantity and quality. The majority of them are quite devoid of interest since they pertain to phenomena which the observer thought extraordinary, but were really nothing other than more or less brilliant manifestations of known phenomena. Sometimes there are among the described forms, curves whose form is not yet well defined or that appear to be new ones. Unfortunately the descriptions of those portions of the phenomenon whose identity is undoubted almost always reveal such inaccuracies that they greatly weaken our confidence in the observer's other descriptions.

In most cases the observer is a man of science. Often, indeed, he is skilled in the most delicate measurements of physics or of astronomy. If his observation is bad or has not the value that should attach to it, the reason is that he was not familiar with this very special class of phenomena. One observes but poorly that with which one is unacquainted.

Here as in everything else, if one is to do useful work in studying halos it is indispensable that one shall be well acquainted with them and practiced in observing them. Unless one may profit by lessons from an experienced observer for some little time, it is not easy to acquire this practical knowledge. True, various works on meteorology or on general physics present more or less complete lists of halo forms, and a more or less detailed exposition of their theory. None of these sources, however, offer the beginner that practical guidance which would help him to seize in transit, so to speak, these generally fugitive phenomena, and to recognize their often incomplete or indistinct forms. * * *

Having pointed out the insufficiency of halo observations and the advantage of multiplying and improving them, it is now in order that I should facilitate the task of persons disposed to undertake observations and should indicate to those already engaged points to which they should particularly direct their attention.

What are halos?

We shall now pass in review the various known forms of halos, beginning with those of most frequent occurrence and the easiest to perceive.

[1] **Besson, Louis,** Les différentes formes de halos et leur observation. *Extrait du* Bulletin de la Société astronomique de France (mars, avril et mai 1911). Also published separately Paris. [1911?] 22 p., 20 figs. 8°.

In the first place, it is necessary to clearly distinguish between halos and the diffraction coronas that are frequently seen about the moon. The latter may be recognized by the fact that they are in direct contact with the luminary while in the case of a halo the colored ring is separated from the luminary by a relatively dark space whose radius is very rarely less than 22°.

ORDINARY HALO OF 22°.

The halo of 22° is the commonest of all forms (*a*, Fig. 1). At Paris this halo may be seen about the sun on an average of 130 days per annum, to which must be added at least 40 lunar halos of the same class. When the luminary is high in the sky the halo is often perfect,

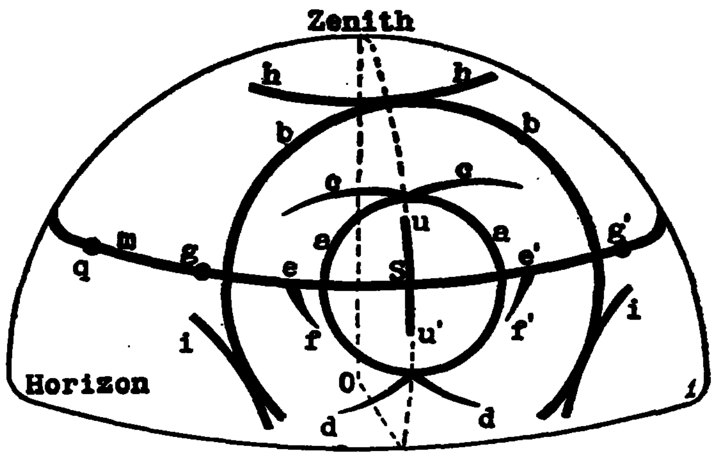


FIG. 1.—Perspective view of the sky, showing the sun (S); ordinary halo of 22° (a); great halo of 46° (b); upper tangent arc of the halo of 22° (c); lower tangent arc of the halo of 22° (d); ordinary parhelia of 22° (e, e'); Lowitz arcs (f, f'); parhelia of 46° (g, g'); circumzenithal arc (h); infralateral tangent arcs of the halo of 46° (i); the parhelic circle (m); a paranthelion of 90° (q); *plane of the horizon; the observer* (O).

but generally it appears as more or less extensive fragments of varying distinctness.

In spite of its frequency an inexperienced observer may find some difficulty in seeing it for the first time. The most favorable moments are those when the sky is covered with a transparent cirro-stratus veil. The observer, supplied with smoked glasses, places himself so that the sun and its immediate vicinity is hidden by a corner of a roof or some other screening object. Thus shielded from the blinding light, he examines the sky at a distance of 22° from the sun. He is quite likely to perceive there a circle, or rather a luminous ring having the luminary at its center. This ring is colored like the rainbow, but the colors are much less pure. At the inner margin, the only one that is sharply defined, one may distinguish the red, to which succeed outward orange, yellow, sometimes green, and finally a slightly violet-white tint which may extend out several degrees from the inner margin gradually fading away. When the phenomenon is less brilliant one sees scarcely more than a whitish ring with a reddish tinge along its inner margin. This is almost always the case with the lunar halos. Within the ring the sky is relatively dark.

The halo of 22° presents little of interest in optics, but its observation forms the best of preparation for that of the other forms of halos. The observer should practice observing it even when it is only present in its most rudimentary forms. When he has grown familiar with the phenomenon he will find that most of the detached cirri which pass at a favorable distance from the sun, form more or less distinct fragments of this halo.

This halo furnishes material for interesting statistics. First with reference to the annual variation in its frequency. The latter presents a marked maximum in spring in France, England, Scandinavia, Germany, Russia, Siberia, Japan, New York, and over the North Atlantic Ocean. On the other hand at Melbourne the largest number of halos is observed in November and December. It would be desirable to extend this research to other portions of the globe, particularly to the Southern Hemisphere and the Equatorial regions.

Equal interest attaches to the study of the annual variation in the relation of halo frequency to the frequency of cirrus or cirro-stratus, a relation that would measure the aptitude of these clouds to produce the halo. So far this relation has been determined for Paris (2) only,

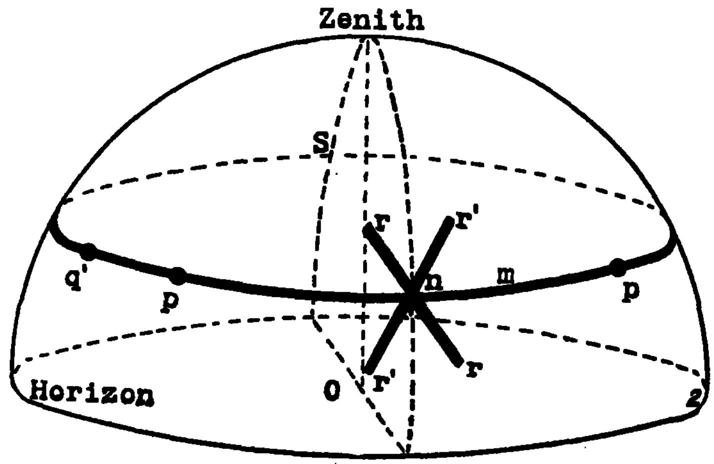


FIG. 2.—Perspective view of the sky, showing the observer (O); his horizon, and his meridian (O S zenith, n); the parhelic circle (m); ordinary paranthelia of 120° (p); the paranthelion of 90° (q'); the oblique arcs of the anthelion (r, r'); and the anthelion (n).

where there is a very pronounced maximum [0.48] in April and a much weaker one [0.32] in October.

Finally it may be pointed out that in certain regions of the globe, the annual number of days with halo seems to show a variation that is either parallel with or inversely as the variation in sun spots. In other regions no relation has been found between the two phenomena (3). It is unfortunate that existing series of good observations on halos are too few and too short to permit us to verify or to determine as precisely as is desirable this interesting result.

ORDINARY PARHELIA OF 22°.

Parhelia are luminous spots appearing to the right and left of the sun and at the same altitude as the latter. (Fig. 1, *e*, *e'*, *g*, *g'*.) When they are produced by the moon they are called *paraselenæ*. Their distance from the luminary, measured along an arc of a great circle, is 22° when on the horizon and increases steadily with the altitude of the source of light. Consequently if the ordinary halo of 22° is also visible the parhelia are located on its circumference when the sun rises or sets, and they stand farther and farther without the halo as the sun approaches the zenith. The halo and the parhelia are distinctly separated, however, only after the sun has reached an altitude of 25° or 30°. (See fig. 1, *e* and *e'*.)

The colors of parhelia are more distinct and purer than are those of halos. They are arranged in the same order as in the latter. The blue is often very pronounced; in fine parhelia it is followed by a violet-tinged white, then by a pure white forming a horizontal band which may attain a length of 20°. This latter is the *tail of the parhelion* (see fig. 17).

When the parhelia are less brilliant they generally assume the appearance of rounded spots somewhat larger than the sun, whitish in color with a more or less reddish tinge on the side toward the sun and greenish on the opposite side.

When near the horizon the parhelia are frequently elongated vertically. When thus distorted they have some times been compared to fragments of a rainbow. One may then be uncertain whether he has to do with a parhelion or with a limited arc of the halo of 22°. To ascertain this it is necessary to observe whether the luminous arc shifts with the cloud which causes it, so as to form successively different portions of the halo, or whether it remains fixed at the altitude of the sun. In the latter case only, must the phenomenon be classed as a parhelion.

When the sun is high the parhelia sometimes take on a hooked form, the parhelion on the right then has a shape perfectly comparable with that of the acute accent (') and the left-hand one is like the grave accent. The appearance of the *arcs of Lowitz* (see below) should then be watched for. (See fig. 1, *f* and *f'*.)

Theoretically the brilliancy of the parhelia should diminish, other things being equal, as the sun's altitude increases, and becomes wholly zero when the latter amounts to 60°. As a matter of fact, the parhelia disappear some time before this, when the solar altitude is 50° or 51°. The observer should not fail, upon occasion, to determine as accurately as possible the altitude at which the parhelia disappear.

With regard to the solar distance of the parhelia, theoretical requirements seem to be wholly verified by observational determinations at any rate for altitudes of the sun below 40°. Above that altitude we have but few determinations, and they are in poor agreement with the calculated distances. Thus measurements for solar altitudes over 40° would have a very real interest.

At Paris the average annual frequency of parhelia is 35 days. They are generally of shorter duration than the halos. Generally they flare up momentarily, as does a fire into which one throws a quantity of some inflammable substance. They are not always accompanied by the ordinary halo. Frequently but one of them is seen, or they may appear only in succession.

They are less frequently formed by a continuous, homogeneous cirro-stratus veil than by isolated tufts or milky patches of cirrus. Sometimes they momentarily reveal small clouds, invisible before they reached the position of the parhelion and again become invisible as soon as they move away from it. The ice-formed portions of the cumulo-nimbus, known as "false cirrus," are very favorable for the production of parhelia.

Oblique arcs of Lowitz.—The oblique arcs of Lowitz is the name given to luminous arcs which arise at the parhelia and are directed obliquely downward toward the halo of 22° (fig. 1, *f* and *f'*). Barely two observations of this phenomenon are known, and it must be very carefully described if one should observe it. Note carefully the direction of curvature and the exact position of the point of contact with the halo.

Tangent arcs of the halo of 22°.

The halo of 22° may be touched at its highest and its lowest points by luminous curves called, respectively, *the upper tangent arc* and *the lower tangent arc of the halo of 22°* (fig. 1, *c* and *d*).

The form of these tangent arcs varies greatly, according to the altitude of the sun. When the sun has reached 40° or 42°, the two arcs, previously distinct, fuse into a closed curve that is called *the circumscribed halo* or *the elliptic halo* (figs. 9, 10, 18, 20). This curve departs greatly from an ellipse at first, but approaches it more and more closely as the sun's altitude increases. Simultaneously, the interval separating it from the ordinary halo progressively shrinks, and the two curves finally merge into one.

The successive forms assumed by these tangent arcs are presented in figures 3 to 10, which are for solar altitudes ranging from 5° to 55°.

Of course the lower tangent arc is not observable when the sun is lower than 22° unless indeed one is observing from a mountain peak or a balloon whence the eye looks into ice-clouds lying below the horizon.

The formation of a tangent arc is preceded by an increased brilliancy of the ordinary halo at its upper and lower points. At the same time the upper portion of the halo assumes a flattened aspect. Then it is time to look for the appearance of the tangent arc, which is not clearly detached from the halo for some distance from the point of tangency because of the width of the two curves.

Sometimes a small colored arc appears at a point 22° above (fig. 17) or below the sun. It is too short to have an appreciable curvature and may even appear as a simple luminous spot. It is an incipient form of the tangent arc. It is to be recorded as *the upper* or *the lower vertical parhelion of 22°* or as *the upper* or *the lower summit of the halo of 22°*.

When the ordinary and the circumscribed halos are simultaneously visible in their entirety, as shown in figures 10 and 20 (*c* and *d*), the observer sometimes ascribes the circular form to the circumscribed halo while describing the ordinary halo as a vertically elongated ellipse. At other times one believes there are two circles intersecting above and below, as in the sketches forming figures 18 and 20. To be warned of these *illusions* is sufficient to avoid them.

When, in addition to the ordinary halo, or the parhelia, there is yet another phenomenon at or about 22° from the sun, the first thought will be of an ordinary tangent arc. If one compares the observed phenomenon with that one of the forms shown in figures 3 to 10 that corresponds most nearly to the appropriate solar altitude, the agreement will almost always be found to be satisfactory. In spite of the complexity of their changing forms these tangent arcs of the halo of 22° are among the phenomena for which theory is the most certain. Angular measurements, however, may reveal some anomalies due to accessory causes; for example, to oscillations of the ice crystals. It may also happen that other rarer phenomena occur in combination with the usual forms. (See *Extraordinary tangential arcs.*)

In the Temperate Zone the frequency of occurrence of the tangent arcs of the halo of 22° shows a maximum in the Spring and a second less pronounced maximum in the Autumn. At Paris the best opportunity for observing them is at solar altitudes between 30° and 40°, where their average frequency of occurrence is 10 days per annum.

HALO OF 46°.

The halo of 46° is a colored circle having the sun at its center, and resembles the ordinary halo except that it has almost double the radius and is of lesser brilliancy. (Fig. 1, *b*, *b*).

In two-thirds of the cases only the superior portion is visible. Its average frequency at Paris is 8 days per annum. When the 22° halo attains a lively brilliancy there is approximately one chance in three that the halo of 46° will also appear.

Theoretically, the radius of this great halo is 45° 44′ for the yellow-green color. Measurements carried out at Montsouris Observatory give a slightly different mean radius; but the observed values always show differences among themselves, so that the question arises whether the magnitude measured is truly invariable or whether one is not here dealing with two phenomena of slightly different radii. This is a question demanding further investigation.

CIRCUMZENITHAL ARC.

Sometimes one sees a colored arc above the sun and 46°, or a little more, distant from it. This arc may attain a lively brilliancy and it then presents all the spectrum colors in great purity. This arc is horizontal, that is to say, it forms part of a circumference whose center would be the zenith (fig. 1, *h;* fig. 11, *h*); but one rarely sees more than a fourth or at the most a third of the circle.

Usually the circumzenithal arc does not long remain visible, five minutes on the average. Thus there is little chance of seeing it unless attentively searched for when the circumstances are favorable. It appears only when the sun's altitude is less than 31°, and especially when the sun is near 20°. Out of 10 circumzenithal arcs 6 were observed during solar altitudes between 15° and 25°.

There is an intimate relation between this phenomenon and that of the parhelia. When a cloud that has produced a parhelion, afterwards passes to 46° above the sun the circumzenithal arc rarely fails to appear, of course, provided the solar altitude is favorable. This arc is often formed, as are parhelia, in dense cirrus or in detached tufts of false cirrus. It also frequently appears in the cirriform front or rear margin of cumulo-nimbus. On account of its great altitude above the horizon it is sometimes seen in the icy alto-stratus whose opacity does not permit one to ascertain the position of the sun itself.

According to Bravais's theory the angular solar distance of this arc varies with the altitude of the luminary. When the sun stands at 22° 08′ the solar distance equals the radius of the great halo (45° 44′), and it departs from this value by less than 1° so long as the sun's altitude lies between 17° and 27°; but when the sun is above 27° or below 17° the solar distance of the circumzenithal arc increases rapidly. It amounts to 57° 48′ when the sun is at the horizon or at 32° 12′ and can not form when the sun stands higher than the latter position.

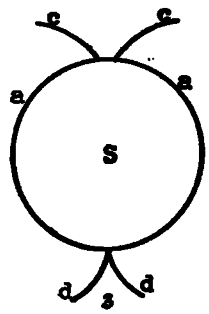


FIG. 3.—Tangent arcs of 22°-halo (a) for solar altitude 5°.

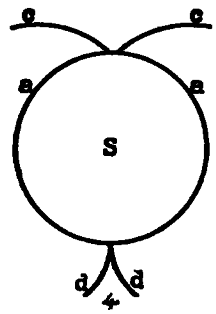


FIG. 4.—Tangent arcs (c, d) of 22°-halo (a) for solar altitude 11°.

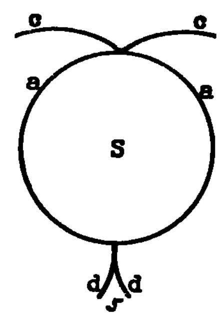


FIG. 5.—Tangent arcs (c, d) of 22°-halo (a) for solar altitude 15°.

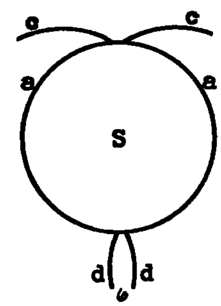


FIG. 6.—Tangent arcs (c, d) of 22°-halo (a) for solar altitude 20°.

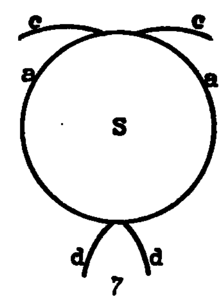


FIG. 7.—Tangent arcs (c, d of 22°-halo (a) for solar altitude 25°.

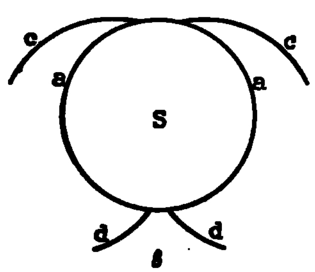


FIG. 8.—Tangent arcs (c, d) of 22°-halo (a) for solar altitude 29°.

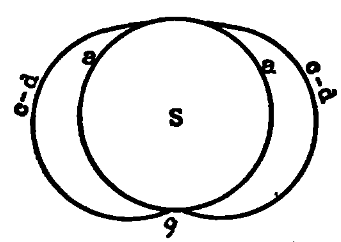


FIG. 9.—Circumscribed halo (c-d) of the 22°-halo (a) for solar altitude 40°.

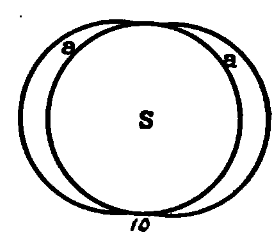


FIG. 10—Circumscribed halo of the 22°-halo (a) for solar altitude 55°.

Numerous recent published observations seem to definitely establish this theory, contrary to the opinion of Pernter, who, in his "Meteorologische Optik," rejected the same on *a priori* grounds.

It is, however, desirable to multiply the number of verifications of the theory, especially for solar altitudes exceeding 27°, where we have very few observations of this arc.

It is rare that the halo of 46° and the circumzenithal arc appear simultaneously; when this does occur it is always at solar altitudes approximating 22°. At this time the two curves are tangent to each other, therefore the circumzenithal arc is also called the *upper tangent arc of the 46°-halo*. But it is not impossible that on some day the arc and the halo should appear simultaneously for a solar altitude such that they shall be distinctly separated. Such an observation would be extremely interesting [and was actually made by the author on

December 21, 1910, at Paris when he succeeded in photographing the whole phenomenon (**3a**)].

When one observes an arc at about 46° above the sun, one should at once note the direction of its convexity, whether toward the zenith or toward the sun. Only when the arc is convex toward the sun may it be recorded as the circumzenithal arc.

If the arc is too short or too diffuse to show an appreciable curvature one will record it as the *summit of the halo of 46°* or as the *vertical parhelion of 46°*. When the arc is distinctly concave toward the sun it is generally considered, ipso facto, as belonging to the halo of 46°. There are cases, however, where the arc might be the upper bitangent arc. (See *Upper bitangent arc*, p. 441.)

Kern's arc.—"Kern's arc" is the name given to an arc (fig. 11, *h'*) situated on the same celestial parallel as the circumzenithal arc (fig. 11, *h*), but on the opposite side of the zenith (fig. 11, *Z*). But one observation of this arc is known, viz, that by H. F. A. Kern (**4**) at Lenon, Netherlands, in 1895.

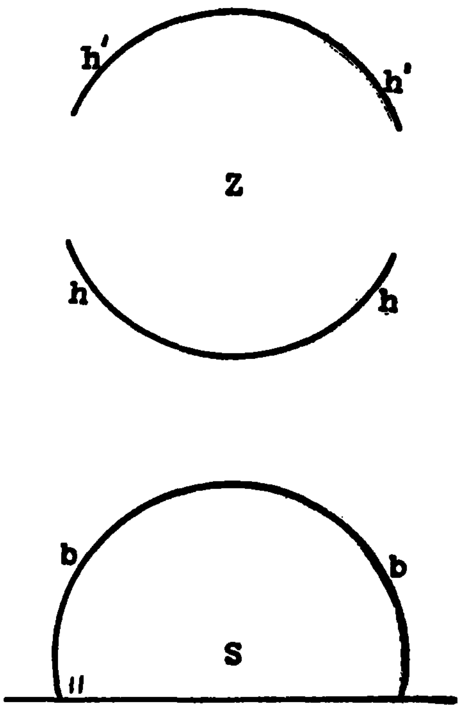


FIG. 11.—Halo of 46° (b), with the circumzenithal arc (h) and Kern's arc (h') about the zenith (Z).

It is here convenient to mention certain observations of abnormal circumzenithal arcs that formed a complete circle about the zenith.

CIRCUMHORIZONTAL ARC.

The circumhorizontal arc is a colored arc which like the circumzenithal arc is parallel to the horizon at a solar distance of 46° or a little more, but it lies below the sun instead of above it. It is also called the *lower tangent arc of the halo of 46°*. Theoretically this arc can be formed only for solar altitudes exceeding 58°. Consequently it may not be observed at Paris except between May 11 and August 1, but at latitudes within 8° of the Equator it is possible to see it on any day toward noon.

So far only three or four observations of this arc are known. It is desired to bring this phenomenon to the attention of observers in low latitudes as they are the most favorably situated for its observation. The atmospheric conditions favoring the formation of the circumhorizontal arc are theoretically the same as those for the circumzenithal arc and the parhelia, but in the actual case the latter can not serve as precursory signs because they are impossible at the great solar altitudes needed to show the circumhorizontal arc.

Very probably the theory for this arc as proposed by Bravais is exactly correct, but so far it has not been verified. The best verification would be to measure the solar distance of the arc under different altitudes of the sun. Theoretically this interval is not exactly equal to the radius of the great halo except for the solar altitude of 68°. If the sun departs in either direction from this altitude then the solar distance of the circumhorizontal arc increases, at first slowly so that it is less than 1° at altitudes between 68° and 63° or 73°, then more and more rapidly as the sun approaches altitudes of 58° or the zenith.

Sometimes one observes a luminous spot or a short arc of insensible curvature at about 46° below the sun. At such times it is generally impossible to definitely assign this appearance to either the great halo, the circumhorizontal arc, or the lower bitangent arc (see *infralateral tangent arcs*), it should then be recorded as the *lower summit of the halo of 46°* or the *lower vertical parhelion of 46°*.

INFRALATERAL TANGENT ARCS OF THE HALO OF 46°.

Colored arcs situated symmetrically either side of and 46° distant from the sun toward which they are convex, are called *infralateral tangent arcs of the halo of 46°* (fig. 1, *i*). They rest upon the horizon as though portions of rainbows. When the halo of 46° is simultaneously visible they are tangent to it (fig. 20, i). The following small table shows the position of the point of tangency according to Bravais's theory, which is also the point of maximum brilliancy. This position may be defined by the central angle α, measured on the circle of 46°, between the lowest point of the circle and the point of tangency of the one or the other of the infralateral arcs (fig. 12).

Positions of points of tangency of infralateral arcs of the halo of 46°.

	°	°	°	°	°	°	°
Solar altitude	0	10	20	30	40	50	60
α	90	86	81	76	70	61	45

Recently Pernter has put forward a new explanation for these arcs, that seems to be inadmissible, while Bravais's theory takes into account the observed characteristics. In order to decide the question with certitude it would be necessary to measure, for various solar altitudes, both the altitude of the point of tangency to the 46°-halo and also as accurately as possible the azimuth of that point or of the brightest point of the arc when the halo is absent. The resulting values should be compared with those given in the above table. Pernter's theory of these infralateral tangent arcs would lead to quite different values for α.

If a theodolite is available and one has sufficient time, he should measure the coordinates of several points on the infralateral arc, thus securing a yet more complete verification. At present we have but one angular measurement (**5**) relating to these arcs and that measurement conforms to Bravais's theory.

The best chances for observing the infralateral tangent arcs of the halo of 46° occur when there is a brilliant display of the tangent arcs of the halo of 22°. The two phenomena are closely related, but the former is much rarer than the latter.

Lower bitangent arc.—Theory says that when the sun has reached an altitude of 60° the two infralateral arcs unite to form a single curve which Bravais calls the *lower bitangent arc.* As the sun ascends above 60° this curve

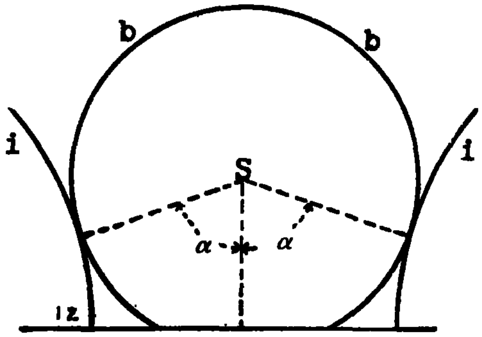


FIG. 12.—Halo of 46° (b) and the infralateral tangent arcs (i) of that halo; showing the angular position (α) of the point of tangency on "b."

steadily approaches the halo of 46° and when the altitude of 68° has been attained it becomes sensibly identical with the lower third of the halo. As the sun mounts yet higher this curve separates exteriorly from the great halo as an arc of a concentric circle tangent to the circumhorizontal arc.

This lower bitangent arc has never been observed. It could be observed only from points below latitude 53° and the best chances for observing and verifying it would be in the equatorial regions; an interesting theoretical prediction.

UPPER BITANGENT ARC.

His theory led Bravais further to foresee the possibility of another luminous curve, also doubly tangent to the halo of 46° but on its upper side. This curve is the *upper*

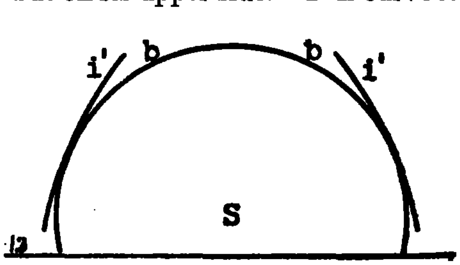
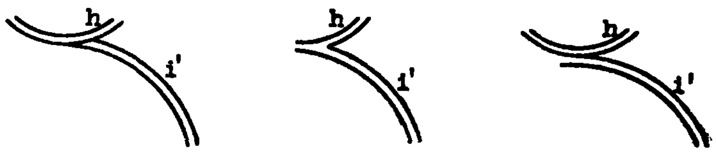


FIG. 13.—Supralateral tangent arcs (i') of the 46°-halo (b).

bitangent arc. It is very difficult to distinguish this from the halo of 46°, from which it is but slightly separated. It had not been reported by any observer until September 26, 1910, but on that date was manifested at Paris in so characteristic a manner (6) that its actual existence seems to be incontestibly established.

When the sun is low the summit of this arc is normally too faintly luminous to be perceptible; it then consists of two symmetrical arcs laterally tangent to the halo of 46°. (See fig. 13.) Bravais calls them the *supralateral tangent arcs.* If the sun's altitude increases the two points of tangency approach the summit of the great halo and the union of the two arcs becomes increasingly evident. When the sun reaches an altitude of 22° the point of tangency is exactly in the sun's vertical and the arc becomes sensibly identical with the upper portion of the halo. When the sun ascends from 22° to 32°, the latter altitude being the upper limit for the phenomenon to form, the arc gradually separates from the halo while preserving the form of an arc concentric with it.

Theoretically, if the generating ice crystals continue in perfect equilibrium the bitangent arc ought to be tangent at its culminant point to the circumzenithal arc supposed to be simultaneously visible. In reality, however, the ice crystals are always in oscillation which results in displacing the two curves so that they no longer remain exactly tangent but may mutually intersect. Figures 14, 15, and 16 show such forms observed September 26, 1910.



FIGS. 14, 15, 16.—Forms of the upper bitangent arc (i'₁) of the 46°-halo, in combinations with the circumzenithal arc (h).

Figure 14 shows much analogy with an old observation by Beckerstedt in 1763 (see fig. 17) and cited by Bravais in support of his theory. The halo of 46° would not be able to produce such forms as these figures show; they are characteristic of the upper bitangent arc but seem to be of very rare occurrence.

Sometimes when the sun is low, one may see *simultaneously with the tangent arc of the 22° halo,* an arc having approximately the form of a fragment of the 46°-circle. The colors of this arc are purer than those of the halo and

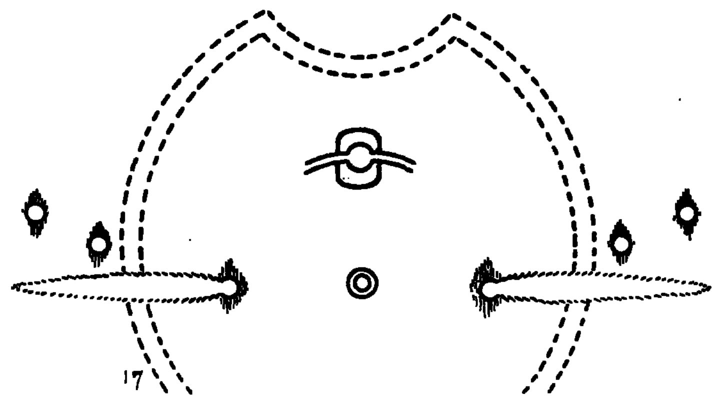


FIG. 17.—Halo observed by Beckerstedt in 1763.

the maximum brilliancy is not at the summit but at a certain distance to the right or the left. Probably this is a supralateral arc occurring either alone or superposed upon the halo of 46°. One should determine whether the point of maximum brilliancy is at the theoretical point of tangency for the two curves. It would be still better to measure, if possible, the solar distance of the inferior extremity of the luminous curve. If the phenomenon is indeed a supralateral arc and of sufficient length, the solar distance ought to prove noticeably more than 46°.

On the other hand, when the sun is higher than 22°, and *always simultaneously with the tangent arcs of 22°,* it sometimes happens that at about 46° above the luminary one may see an arc having the pure colors of the circumzenithal arc but with descending branches. Probably this also is the upper bitangent arc. To prove it with certainty one should, as in the preceding case, measure the solar distance of the arc which in this case is readily done by simply measuring its altitude in the sun's vertical. If the sun is at least 28° high even a rather rough determination ought to show a solar distance clearly greater than 46°.

PARHELIA OF 46°.

There have been a number of observations of colored parhelia analogous to the ordinary parhelia of 22° but

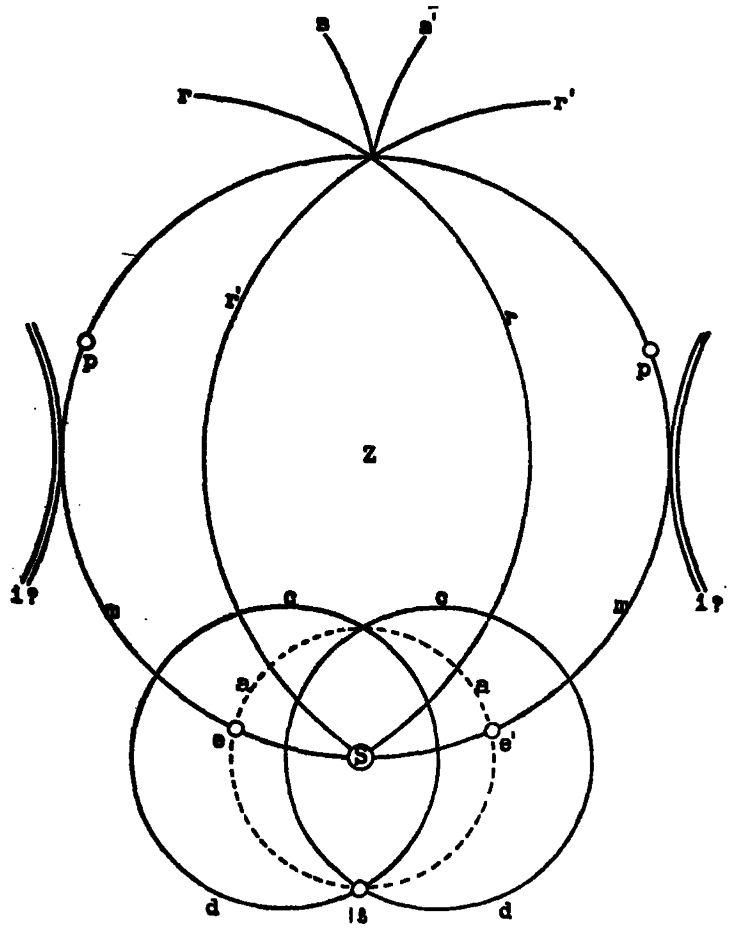


FIG. 18.—Halo observed by Schult, showing halo of 22° (a), its circumscribed halo (c-d), the ordinary parhelia (e, e'), the parhelic circle (m), the ordinary paranthelia of 120° (p), two pairs of the oblique arcs of the anthelion (s, s'; r, r'), and what are perhaps the infralateral tangent arcs of the 46°-halo (1?).

located on the halo of 46° or, in its absence, at a solar distance approximately equal to the radius of that halo and at the same altitude as the luminary. (Fig. 1, *g g'*.) This is one of the rarest of phenomena. Two explanations of it have been offered leading to quite different consequent solar distances and limiting altitudes at which it can take place. The limiting solar altitude, *H*, in the one case (*a*) is 32° 12′, and in the other case (*b*) 60° 45′. As for the solar distance, *D*, of the parhelion measured on an arc of a great circle, it varies with the altitude, *H*, of the luminary according to the one hypothesis or the other as shown by the following table:

Solar distances of the parhelion of 46°.

H.	0°		10°		20°		30°		40°		50°	
	°	′	°	′	°	′	°	′	°	′	°	′
D_a.....	45	44	46	00	50	38	61	52	.....		.....	
D_b.....	43	40	43	54	46	00	49	12	53	56	60	24

So far we have but one measurement (7) of the solar distance of the parhelion of 46°, which was made at the solar altitude of 3°. This measurement is much more favorable to hypothesis (*a*) than to hypothesis (*b*).

PARHELIC CIRCLE.

The parhelic circle is a white circle passing through the sun and parallel to the horizon. (See fig. 1, *m*; fig. 18, *m*.) Its appearance is often preceeded and announced by the formation of the white parhelic tails. (See fig. 17.) These tails lengthen, finally, in such a manner as to make a more or less complete circuit of the sky. As they themselves may attain a length of 20° there is no occasion to record the occurrence of a parhelic circle unless the white train starting at the parhelion exceeds this limit. *But*, however short the white train may be *if it extends toward the sun* it can not be other than the parhelic circle. Further, the circle may develop without accompanying parhelia, since the latter do not appear for solar altitudes above 51°, while the luminous intensity of the parhelic circle increases with the altitude.

The white band that forms the parhelic circle sometimes has a reddish border that should be recorded if it is observed.

The parhelic circle often develops very suddenly, and its circumference may show knots of white light, though they are sometimes of very brief duration. They must be carefully watched for, as these diffuse images of the sun sometimes present the anthelion and the paranthelia. (See figs. 2 and 18.) When the moon is the luminary, these phenomena are called the paraselenic circle, [paraselenæ], antiselene, and parantiselenæ, respectively.

Anthelion and the oblique arcs of the anthelion.

The *anthelion* is a rounded luminous spot situated at 180° from the sun, usually pure white, but it may be iridescent or surrounded by colored rings. (See fig. 2, *n*.)

It should not be confounded with the antisolar corona or glory of the aeronaut, often observed from mountain summits or a balloon, located precisely opposite to and in the prolongation of a straight line from the luminary through the eye of the observer.

Furthermore, the name "anthelion" should not be applied to twilight-like glows appearing at a point on the horizon opposite the point of sunrise or sunset.

The term *anthelion* should be reserved for those *luminous images that form at the point opposite the sun and at the same altitude*.

Oblique arcs of the anthelion.—The anthelion may appear when the parhelic circle is absent. Sometimes the anthelion is traversed by ascending white intersecting arcs called *the oblique arcs of the anthelion*. (See fig. 2, *r, r'*.) This is a very rare phenomenon and its theory is still quite uncertain. These arcs may apparently be classified according to their inclination, into two different kinds both of which may occur simultaneously, as in Schult's observation, reproduced in figure 18. Sometimes these arcs are prolonged until they recross in the sun itself, as occurred on that same occasion. (See fig. 18, *r* and *r'*.)

When these arcs are observed one should measure, or estimate if there is no instrument available, their angular inclination. Their course on the celestial sphere should also be determined as exactly as possible, as should be their second point of intersection if they have one. Observe their width, whether it is uniform or increases with the distance from the anthelion.

The oblique arcs may appear without a simultaneous anthelion strictly so-called, i. e., a rounded image of the sun at their point of intersection. They have sometimes shown iridescence also.

Paranthelia.

The so-called ordinary paranthelia of 120° appear at an azimuth of 120° on either side the sun. They are mutually 120° apart and 60° from the anthelion. They have always appeared as wholly white. (See fig. 18, *p*.)

Sometimes paranthelia, also white, appear at points located at practically right angles to the sun. (Fig. 2, *q'*.) Is their azimuthal distance from the sun exactly 90°? Is this distance slightly different from 90° but constant for all solar altitudes, or does it vary with the latter? Lack of precise measurements does not permit of exact answers to these questions.

Still other paranthelia may appear at different and equally uncertain points on the horizontal small circle passing through the sun. A notable location is at about 40° from the anthelion.

LIGHT PILLARS AND CROSSES.

A light pillar is a train of light extending vertically above the sun or moon, and it may also be prolonged beneath the luminary. In width these pillars differ but little from the diameter of the luminary; their length is very variable, sometimes being less than a degree and again amounting to 30 or 40 degrees. (See fig. 1, *u*, *u'*.)

The *light pillar* must not be confused with the luminous rays that sometimes seem to escape from the edges of the lower clouds when these hide the sun. Such rays diverge from the sun in all directions and are vertical but by accident, while the light pillar is and remains always vertical. It is also not to be confused with the rosy twilight bands that radiate from the setting sun and sometimes traverse the whole sky, apparently reconverging at the opposite horizon. Almost always there are several such bands at the same time, and they also are vertical only by accident.

Bravais distinguishes *light pillars of the first class* or those that rise above the horizon after sunset; and *light pillars of the second class* or those that appear above or beneath the luminary while it is above the horizon.

Crosses.—Solar or lunar crosses consist of two trains of light, the one vertical and the other horizontal, intersecting at the sun or moon respectively. The horizontal arm is usually interpreted as a fragment of the parhelic [or paraselenic] circle. (Compare fig. 1, *u*, *u'*, and *m*.)

Pseudhelia and mock suns.

The *pseudhelion* is a white image of the sun symmetrically located with reference to the luminary and the plane of the horizon. The phenomenon is visible only to an observer in a balloon or on a mountain. Bottlinger (8) has seen it surrounded by a small elliptical ring.

Other *mock suns*, to which the term should be restricted, appear toward sunset or sunrise in contact with the true sun and located in its vertical. This phenomenon is usually accompanied by a light pillar and very probably is genetically related to the halos, but it has not yet been satisfactorily explained.

HALOS OF ABNORMAL RADIUS.

On various occasions there have been observed circular solar or lunar halos analogous to those of 22° and 46° but having a different radius. In the majority of cases there has been no direct measurement of the radius of the abnormal halo; it has been estimated in terms of the ordinary halo that is almost always simultaneously visible. Under such circumstances the error may easily amount to 2°; besides, it is often impossible to decide in the case of two observations of this kind, whether the observations refer to the same halo or to two halos of

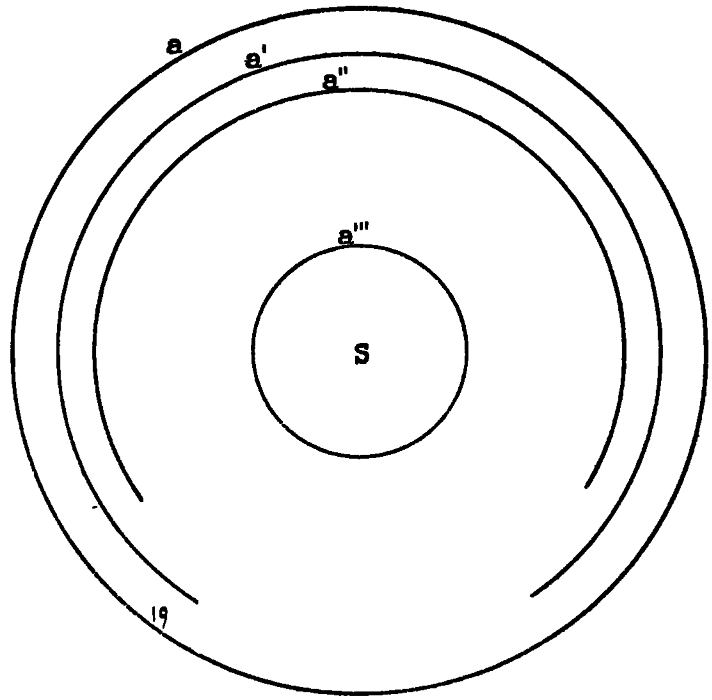


FIG. 19—Extraordinary halos of 19.5° (a'), of 17.5° (a''), and of 7.5° (a'''), together with the ordinary 22°-halo (a). Hissink has observed a' and a'' occurring simultaneously.

actually unequal radii. Precise measurements are especially desirable here.

A halo of 4°–6° radius was seen by Hall in 1796 (9).

A halo of 7°–8° radius was seen by Arctowski (10) in 1898 and by Hissink (11) in 1899.

A halo of 9°–10° radius was seen by Van Buijsen (12) in 1892 and afterwards by Hissink (13) and Russell (14).

A halo of measured radius 14° was seen by Heiden in 1839 and a halo of measured radius 16° by the same at the same time.

A halo of about 17° was seen by Besson and Dutheil (15) in 1900.

A halo of measured radius 17° 55′ was seen by Hissink (16) in 1899 and 1905, and afterwards by Krčmar (17).

A halo of measured radius 19° 25′ was seen by Burney in 1831, and afterwards on three occasions by Hissink (18).

The two halos last mentioned were certainly different circles, as they have been observed simultaneously by Hissink (see fig. 19).

A halo of 26°–29° was seen by Scheiner in 1629, and afterwards by Greshow and by Whiston.

A halo of 34°–38° was seen by Feuillée, by Parry, and by the members of the Charcot expedition in 1904 (19).

A halo of about 90° was seen by Hevelius in 1661, afterwards by Erman, Sabine, and others. In contrast to the preceding halos which are colored like the 22° halo, the halo of Hevelius has always appeared as a white circle. The exact determination of its radius would be of special interest.

We would add that sometimes confusion has arisen by applying the name "white rainbow" to a phenomenon almost identical in magnitude and appearance but quite different in its nature from the degenerating form of the true rainbow which forms the true white rainbow. This *false white rainbow* is still of problematic character, but it should be due to ice crystals, as are the halos. It would seem to be a halo of about 140° radius.

EXTRAORDINARY UPPER AND LOWER TANGENT ARCS OF THE 22°-HALO.

In exceptional cases there may be arcs other than the ordinary tangent arcs, touching the halo of 22° either at

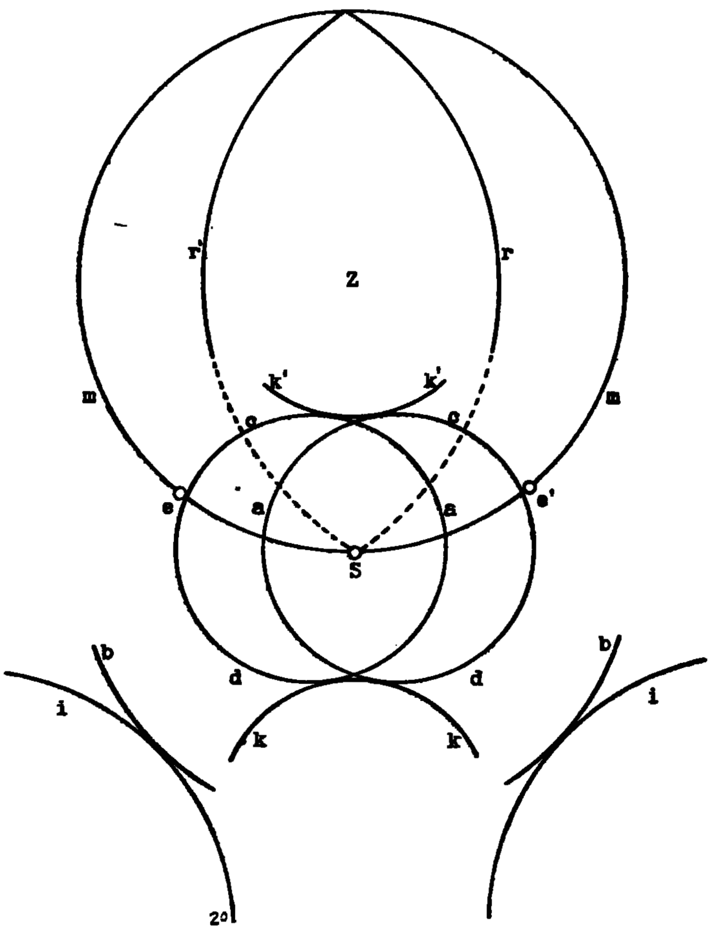


FIG. 20.—Halo observed by Rear Admiral A. von Kalmar, at Pola, on March 26, 1896, embracing: Halo of 22° (a), circumscribed halo of 22° (c-d), ordinary parhelia (e, e'), extraordinary tangent arcs of the halo of 22° (k, k'), infralateral tangent arcs (i, i') accompanying fragments of the 46°-halo (b, b), the parhelic circle (m), the oblique arcs of the anthelion (r, r'). S, the sun; Z, the zenith.

its summit or its base. Such are the arcs shown at *k'* and *k* of figure 20, which were observed by Vice Admiral Kalmar (**20**). Two kinds of such arcs have been observed, viz:

1. *Arcs parallel to the horizon.*—The arcs parallel to the horizon are, according to Bravais, "secondary" parhelic circles engendered by the very brilliant vertical parhelion situated at the point of tangency with the halo, and which plays the part of the luminous source.

2. *Arcs not parallel to the horizon.*—Bravais has proposed a theory of the arcs not parallel to the horizon that does not accord well with the observations. Exact determinations of their curvature are needed.

Infralateral and supralateral arcs of the 22°-halo.

Enigmatical arcs that touch the upper or the lower side of the 22° halo are called the supralateral or the infralateral arcs, respectively, of the 22°-halo. The dextral supralateral arc was first observed by Az. de Ruijter (**21**) in 1898. Manois (**22**) observed the two infralateral arcs in 1901. In 1904 the dextral supralateral (*j'*) and infralateral (*j*) arcs as shown in figure 21 were observed in Holland (**23**).

In the existing state of our knowledge of ice crystals it is very difficult to explain these arcs.

OBLIQUE PARHELIC CURVES.

There have been several observations of bands of white light passing through the luminary in the manner

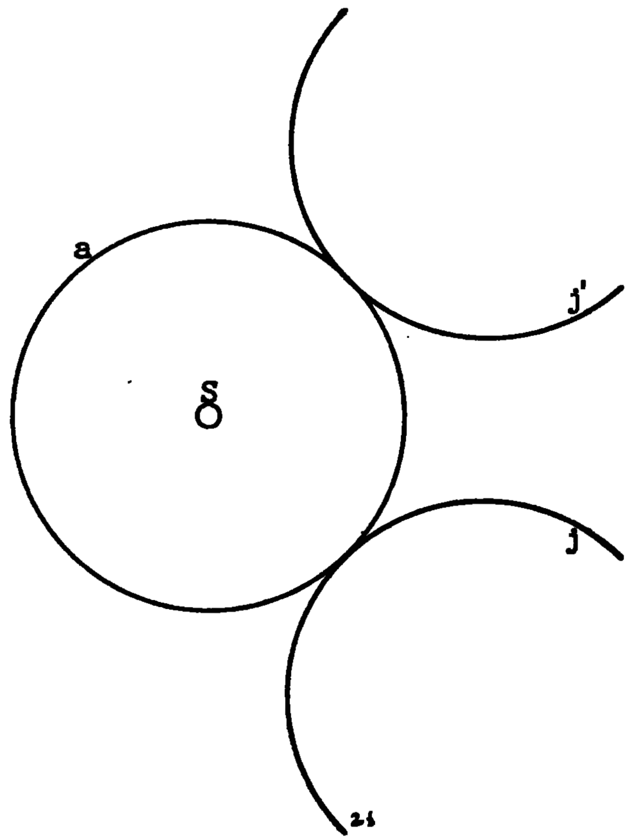


FIG. 21.—Halo of 22° (a) with the dextral infralateral (j) and supralateral (j') arcs S, the sun.

of the parhelic circle, but departing noticeably from a horizontal position. The theory of these *oblique parhelic curves* is very uncertain. In 1904 Mellema (**24**) saw two parhelia on a curve of this class.

EXTRAORDINARY CIRCUMZENITHAL ARCS.

Horizontal or approximately horizontal arcs appearing above or below the sun, but differing from the upper and lower tangent arcs of the 22°- and 46°-halos, are called *extraordinary circumzenithal arcs*. They have been observed particularly at about 18°, 26°, 33°, and 54° above the luminary.

A general theory of these arcs has been outlined by Bravais, who finds that their horizontality is never other than an approximate one. He does not explain the horizontal closed circles that have been observed on numerous occasions.

SECONDARY HALO PHENOMENA.

It is a recognized fact that if a parhelion or any other luminous focus is sufficiently brilliant it may "secondarily" engender halo phenomena such as parhelia, a 22°-halo, a parhelic circle. As we have seen (p. 444) this seems to be the origin of certain extraordinary tangent arcs. Pernter (25) observed a circle of 22° and two parhelia that were evidently secondary phenomena about an ordinary lower tangent arc of the 22°-halo which appeared as a luminous oval of the form shown in figure 4.

SINGULAR PHENOMENA.

In closing I would direct attention to some phenomena that have been seen but once, and in every way deserve the designation *singular:*

1. *A small elliptical helio-centric halo;* its major axis placed vertically and 21° in length, its minor axis being 15° long. It was observed and measured by Hissink (26) in 1901. A somewhat analogous phenomenon is shown on a sketch by Wagner dated 1733.
2. *An elliptical seleno-centric lunar halo* tangent to the 22°-halo at either end of the horizontal major axis, and having a minor axis of 20° or 22°. It was observed in 1904 by the Charcot expedition (27).
3. *Two white arcs seen* in 1898 *by Arctowski* (28) simultaneously with a (false?) white rainbow, placed at 90° on either side of and at the same altitude as the rainbow.
4. *An arc obliquely intersecting the upper left-hand part of the 22°-halo.* This arc was observed by Barrett (29) in 1905.
5. *Colored parhelia* seen by Aveline in 1798, located on the parhelic circle *about 44° from the sun* and with their more brilliant portions turned *away from* the luminary.

PRACTICAL DIRECTIONS FOR OBSERVING HALOS.

Record the successive phases of the phenomenon, stating the exact time of occurrence of each phase together with the corresponding variations in the appearance of the sky.

State the time used, whether mean local or the mean time of some definite meridian.

When the visible curves or luminous spots are recognized *designate them by their proper names;* record their peculiarities and endeavor to carry out the checks or measurements which are given above as desirable.

If an unknown phenomenon appears, first examine its form, its position with reference to the sun and to the other luminous phenomena, its colors and their arrangement, and record the exact time of the observation.

If paper and pencil are at hand, at once *make a sketch of the phenomenon.* Later carry out angular measurements if possible. The use of photography is always to be recommended, but should never be substituted for the observations according to the directions just given.

Never combine in one drawing phenomena observed at different times.

The method of projection exemplified in figures 18 and 20 is a convenient one for representing appearance of a phenomenon that occupies a large portion of the heavens, but the form and proportions of the curves are necessarily altered. The interesting portions of the phenomenon should be drawn separately and true to nature.

Angular measurements.—Angular measurements may refer to three elements—altitude above the horizon, the azimuth, and the mutual distance of two phenomena or of the luminary and the phenomenon.

A theodolite gives both altitude and azimuth at one setting.

Altitude alone may be determined by a clinometer or by a mercury level conveniently graduated (30).

Azimuth may be determined by the aid of a compass and a plumb line, provided the altitude of the point measured does not exceed 30°.

The radius of a halo or the solar distance of a notable luminous point may be readily measured with sufficient exactness by the aid of a sextant or reflecting circle.

The lenses of the telescope on the sextant or the theodolite should be removed for this work, as the phenomena can not be perceived through them.

When the colors are diffuse one will be able to sight only on the center of the phenomenon. But it is desirable that one should *point on a definite color* so far as this may be possible, or better yet sight in succession on several colors, e. g., on the red, the green, and the violet.

Record the exact time of each angular measurement. If one has this exact time of the measurement, the corresponding measurements of solar altitude and azimuth may be omitted because they can be calculated at leisure. Nevertheless it is always well to make one or two settings on the luminary for purposes of control.

Is there *no instrument at hand,* the position in the sky of a point on the halo may be marked by bringing it in line with some known fixed object, such as the point of a lightning rod, the corner of a roof, the apex of a tree, etc. Or the azimuth of the luminous point with reference to distant terrestrial objects may be determined with the aid of an improvised plumb line. In this connection the observer will carefully mark his own position at the time of observation in order that he can accurately replace himself there when returning with a measuring instrument.

In describing a phenomenon it is necessary to carefully specify whether the recorded intervals are in azimuth or on arcs of great circles.

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Besson, Louis. Sur la théorie des halos. Annales de l'Observatoire de Montsouris, 1908 and 1909.

REFERENCES AND NOTES.

(2) **Besson, L.** La théorie des halos. Annales de l'Observatoire de Montsouris, 1908, p. 358.

On page 359 of this work Besson gives the following numerical results of some of his observations at Paris:

Monthly ratios of the number of cases of 22°-halos to the number of cases of cirrus clouds at Paris.

January	0.22	June	0.39	November	0.25
February	0.30	July	0.29	December	0.27
March	0.36	August	0.25		
April	0.48	September	0.30	Year	0.32
May	0.43	October	0.32		

(3) Annuaire de la Société météorologique de France, 1906, p. 115.

(3a) **Besson, L.** Un arc tangent qui n'est pas tangent. La Nature, Paris, 1911, **39**, 1er sem., p. 247–248, illus.

(4) Koninklijk nederlandsch meteorologisch Instituut. Onweders, optische verschijn., enz., in Nederland, 1895, p. 66.

See also Maanblad voor Natuurwetenschappen, 1896, No. 5.

(5) Annales de l'Observatoire de Montsouris, 1909, p. 183.

(6) Comptes rendus, **151**: 693.
(7) Annuaire de la Société météorologique de France, novembre, 1900, p. 7.
(8) Meteorologische Zeitschrift, 1910, **27.** Jhrg., p. 74.
(9) This and all other observations for which no bibliographic references are given, are from Bravais, Mémoire sur les halos.
(10) Résultats du voyage du S. Y. *Belgica*: Arctowski, Phénomènes optiques, p. 32.
(11) Onweders, optische verschijn., enz., 1899, p. 57.
(12) Onweders, enz., 1892, p. 60.
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(15) Annuaire de la Société météorologique de France, novembre 9, 1900, p. 7.
(16) Onweders, enz., 1899, p. 57; and ditto, 1905, p. 81.
(17) Meteorologische Zeitschrift, 1907, **24.** Jhrg., p. 87.
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(19) Not published.
(20) Meteorologische Zeitschrift, 1896, **13.** Jhrg., p. 183.
(21) Onweders, enz., 1898, p. 50.
(22) Annales de l'Observatoire de Montsouris, 1901, p. 304.
(23) Onweders, enz., 1904, p. 71.
(24) Onweders, enz., 1904, p. 70.
(25) Meteorologische Zeitschrift, 1888, **5.** Jhrg., p. 201.
(26) Onweders, enz., 1901, p. 65.
(27) Unpublished.
(28) Résultats du voyage du S. Y. *Belgica*: Arctowski, Phénomènes optiques, p. 40.
(29) Greenwich magnetic and meteorological observations, 1905.
(30) This instrument is described in Comptes Rendus, Paris, 1905, **140**: 960.

HALOS AND THEIR RELATION TO THE WEATHER.

By Andrew H. Palmer, Assistant Observer.

[Dated Weather Bureau, San Francisco, Cal., July 15, 1914.]

When rays of light from the sun or the moon pass through a cloud sheet, various subjective phenomena are caused by the moisture particles which make up the cloud mass. When the sun is observed through haze or attenuated fog it appears as a disk with sharply defined edges. When a moderately dense cloud sheet occurs at a low or intermediate level, the sun's disk, when visible, is irregularly defined, is sometimes too bright to be observed directly with the naked eye, and is frequently surrounded by concentric rings of light called coronas. These rings, which vary in number from time to time, are ordinarily 1° to 5° in radius, and show the various colors of the spectrum, always with the red on the *outside*. They are produced through diffraction and interference of the light rays by the water spherules and ice crystals encountered. Because of the brightness of the sun many solar coronas pass unobserved, as they usually may be seen only by reflected light. Incomplete coronal arcs are often seen in the thin margins of broken clouds like strato-cumulus and alto-cumulus. With the highest cloud sheet, the cirro-stratus, refraction and reflection of the rays by the ice crystals produce rings in which the colors, when visible, are always arranged with the red on the *inside*. These are halos proper or greater halos, and may be defined as somewhat complicated arrangements of arcs and circles of light surrounding the sun or the moon, accompanied by others tangent to or intersecting them, with spots of special brightness called parhelia appearing at the points of tangency and intersection. Parhelia are most often observed about sunrise or sunset, frequently when the intersecting arcs are themselves invisible, except at the points where the two causes combine to reflect a double portion of the sun's rays. In the order of their frequency, halos average about 22°, 46°, or 90° in radius, but on rare occasions various other sizes have been observed. In the following discussion halos proper are alone considered.

There is a very intimate relation between halos and cirro-stratus clouds, a halo usually being formed whenever this kind of cloud is penetrated by the rays of the sun or the moon. Based upon the observations made at Blue Hill Observatory during 1896–97, the mean height of cirro-stratus clouds is 10,099 meters during April to September, inclusive, and is 8,893 meters during October to March, inclusive (1). The mean for the year is 9,496 meters, an average higher than that of any other form of cloud. The maximum height at which they have been observed is 13,601 meters, while an instance of cirro-stratus cloud at 4,036 meters is also on record. However, it is sufficient to say that they are high clouds, so high in

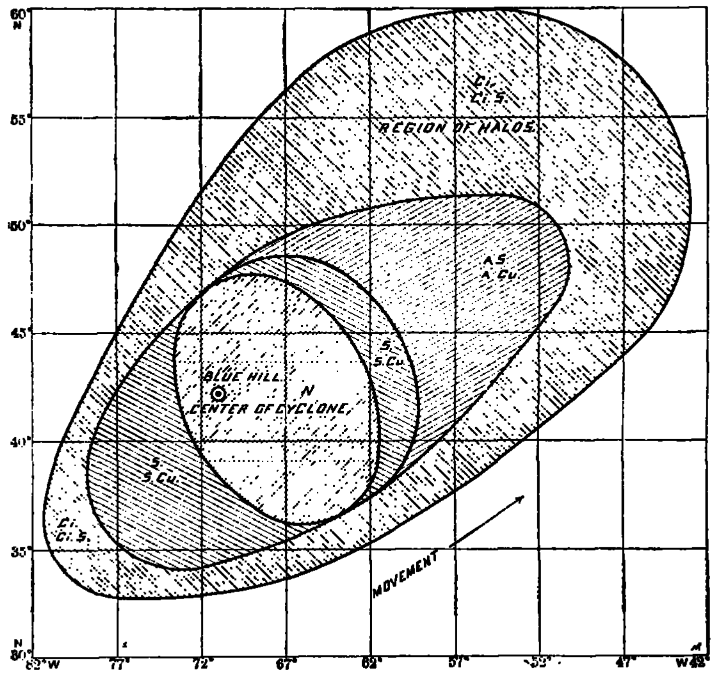

Fig. 1.—Cloud regions and cloud classes about a typical Northern Hemisphere cyclone central over Blue Hill Observatory. (International cloud notation.)

fact that the water particles making up the cloud are known always to be in the form of hexagonal prisms of ice. Though it is unnecessary to consider the physics of halo formation here, it should be stated that the form and the arrangement of these ice spicules or needles are important considerations in the refraction and the reflection of the light rays (2). The size of the halo, whether it be approximately at 22°, 46°, 90°, or one of the rarer types, is determined by the amount of reflection and refraction suffered by the rays, and is therefore closely dependent upon the density, the thickness, and the height of the cirro-stratus sheet. While most halos are approximately circular, a few are elliptical, the latter form being explained sometimes by inequalities in distance between the observer and the moisture particles, and sometimes by the distortion resulting from heterogeneous conditions of temperature, and hence of density in the lower atmosphere. The light of some arcs is polarized, while that of others is not (3). From a study of halos observed in Russia, Dr. Ernst Leyst concluded that there was no relation between halos and sunspots (4).

At Blue Hill Observatory, which is located upon the summit of a high hill 10 miles south of Boston, Mass., record is kept of the occurrence of halos among the other miscellaneous phenomena. The kind of halo, whether solar or lunar, and the duration of its existence, is re-