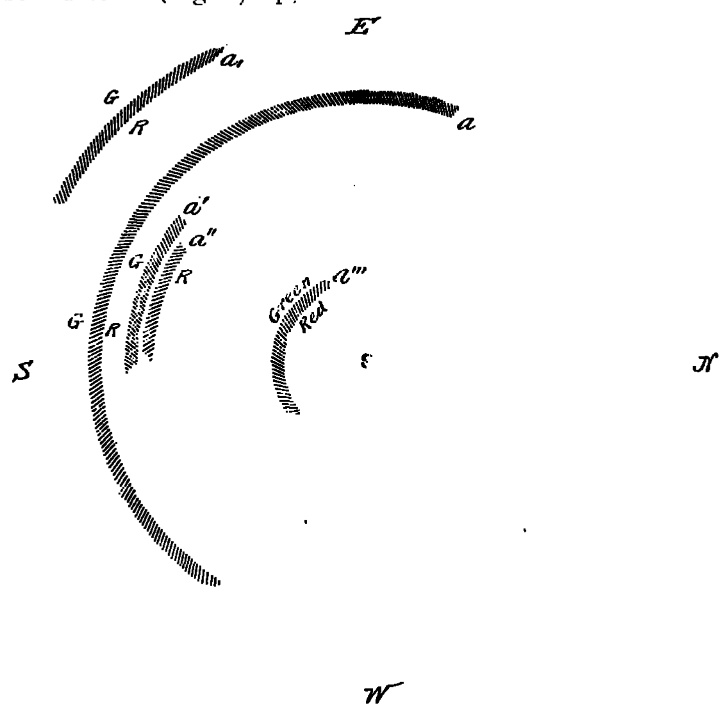
The first suggestion of a halo was manifest at 2:20 p. m. when a short arc of 22° radius appeared between the zenith and the sun. Five minutes later, while viewing the developing halo, I became faintly aware of other curves within the ordinary halo. All doubts were removed at 2:35 p. m., when the inner curves assumed faint but definite colors and the arcs increased in length. I immediately measured them and sketched an outline of the general features. This sketch corresponded with the sketch made later (at 3:00 p. m.; see fig. 1), except that the curve at 28°–29° was not yet visible. As a check, the ordinary halo was measured; the result was 22° 50′, a trifle too large. The radii of the inner ones were not established at this time. During the next 15 minutes the distinctness of the whole phenomenon fluctuated to a considerable extent and at times portions became nearly lost to the eye. At this time glimpses were had of a colored curve lying outside of the 22° arc. This curve was clearly seen later. (Fig. 1, a_1.)



a, halo of 22°; a_1, halo of 28°–29°; *a′*, halo of 18°–19°; *a″*, halo of 17°–18°; *a‴*, halo of 8°–9°

FIG. 1.—Sketch of halos of abnormal radius observed at Sand Key, Fla., on May 11, 1915, at 3:00 p. m., 90th merid. time, by C. G. Andrus, Assistant Observer, Weather Bureau. The brightness varied inversely as the depth of the shading.

Conditions became exceptionally favorable at 3 p. m. The entire spectacle was then at its best. Then it was that the five concentric curves were clearly visible simultaneously. The unusual radius was more striking in each case than was the brightness or attractiveness of the display. The 8°–9° arc could not be definitely seen beside the unshaded sun, and but for the fact that its red color was on its inner circumference, it might have been mistaken for a corona of large radius. A sketch, drawn from the rough original, of the aspect of the phenomena at 3:00 p. m. is reproduced in figure 1. This sketch, however, fails to indicate that the two arcs of about 18° radius do not merge but are separated by a space of about ½ degree in width.

The angular measurements of the radii of the halos were made with the aid of three pins, A, B, and C, stuck in a pad of paper. Pins A and C were thrust in permanently and in such a way that when A is nearer the sun the pin's shadow is quite long and always falls upon C or on the line connecting C and A. While keeping A thus accurately pointed toward the sun, the observer having his eye at C, the third pin, B, is inserted so that it is in line with the halo to be measured and with the eye at C. Thus is obtained a graphic representation of the angle ACB (sun–eye–halo) which is resolved by the use of right triangles and the trigonometric ratios. This method was used for the measurement of all but the innermost and outermost arcs. The innermost one was too near the dazzling sun and the outermost was fast fading when its measure was about to be taken. This latter one was estimated to have a radius about one and one-third times that of the 22° halo.

At 3:09 p. m. all arcs but the 22°-halo had faded; but a careful watch was kept and at 4:25 p. m. a sun-dog began to brighten to the left of the sun and at his altitude, on the outer edge of the 22° halo. At 4:30 p. m. the arc of the circumzenithal circle was observed and measurements and a sketch were at once made (4:33 p. m.). The sun's altitude was gaged to be slightly less than 18° and the solar distance to the nearest portion of the circumzenithal arc as slightly less than 45°. At 4:52 p. m. the distance of the arc from the sun was measured as 53°. There is a possibility that this is slightly too large, but the error should not be more than 1½°. The arc had faded at 5:00 p. m., but the parhelion remained until 5:05 p. m., and the halo continued visible until shortly before sunset.

In regard to the arrangement of the colors of the arcs, it was especially noted that in the case of all five halo-curves, the parhelion, and the circumzenithal arc, the red of the spectrum was on the side nearer the sun. Thus, in the halo-curves and the parhelion the red was on the inner circumference, but in the circumzenithal arc the red was on the outer circumference of the curve.

SOLAR HALO OF MAY 20, 1915, AT PHILADELPHIA.

On May 20, 1915, there was a brilliant solar halo visible from about 10 a. m. (75th meridian time) to after noon, at many points in Pennsylvania, Delaware, New Jersey, New York, and Connecticut. This area of visibility corresponded very closely to the area covered by a lunar halo on April 26, 1898, described in this REVIEW, April, 1898, **26**: 168. The phenomenon of the present month caused widespread comment, and quite a little alarm among those ignorant of its true nature and significance; Weather Bureau offices and private observatories were everywhere busy for several hours "answering the questions of the curious and allaying the fears of the superstitious." The nature of many of the questions offers an interesting index of the present unusual mental state of many of our people.

On another page we print Prof. C. S. Hastings's explanation of the halo and interesting features that have been discovered by the aid of photography. George S. Bliss, Section Director in charge of the Weather Bureau station at Philadelphia, sends the following description of the phenomenon as seen at his station:

> On May 20, 1915, there was visible at this station, and for some distance around, the most brilliant solar halo I have ever seen. The phenomenon lasted, with little or no change in appearance, from 10 a. m. until 12:30 p. m., when the clouds changed to cirro-cumulus and it disappeared quite abruptly. The inner circle [halo of 22°?] was as bright as any rainbow, while the segment of the outer circle [46°-halo?] was almost as bright, but was limited in extent to an arc of about 60° or 70°. The small secondary circle [parhelic circle] was complete, was very bright, and perfectly white with no yellowish cast.

Toward Zenith.

FIG. 1.—Full-size photograph of the solar halo (Oval of Venturi) seen at New Haven Conn., Thursday, May 20, 1915, at 11:45 a. m. The vertical is to the horizontal diameter, as 1 : 1.07.

This report by Mr. Bliss was of interest in confirming the presence and the length of the inferior segment of the 46°-halo also reported by Prof. Hastings in his article following. Other reports on these halos may reveal further interesting features, but it is particularly to be regretted that Mr. Bliss did not measure or photograph his phenomenon, for, as pointed out below, it is probable that the supposed 22°-halo was really the circumscribed halo of 22° sometimes called the Oval of Venturi (see this REVIEW, July, 1914, **42**:439 and fig. 10). Our observations still emphasize the great need in this country for more accurate observations and measurements of halos. Mr. Andrus's observations (p. 214) deserve special commendation on this account. Other observations of the halo of May 20 reveal the fact that the anthelion and the oblique arcs of the anthelion were certainly observable at Reading, Pa., and at Atlantic City, N. J.; but as pointed out elsewhere (MONTHLY WEATHER REVIEW, July, 1914, pp. 434–435) the mere observation is of relatively small value, and our reports from those stations do not tell us the angle between the arcs of the anthelion nor their precise angular length.—C. A., jr.

HALO OF MAY 20, 1915, AT NEW HAVEN, CONN.

By Prof. C. S. HASTINGS.

[Dated: Sloane Laboratory, Yale University, May 21, 1915.]

A remarkably vivid solar halo was observed at New Haven, as at many places in the eastern portion of our country, on May 20, 1915. There were some features of peculiar interest which may have been overlooked and which are important as bearing upon the theoretical explanations of phenomena, often of extraordinary complexity, and always of great popular interest. With a view of interesting meteorologists in a theory which has been quite completely worked out and published[1] many years ago, I venture to send you an account of observations made by myself and companions together with certain theoretical conclusions. All significant observations were made between 11:30 a.m. and noon, while the sun was at an altitude of 68° or more.

The most surprising features of the halo at first glance were the extreme liveliness of the colors and the impressive darkness of the space inside the apparent circle, a contrast far surpassing any previous cases observed by us. The ring appeared notably more brilliant above and below than east and west of the sun. A careful search for appendages to the ring was without fruit until my attention was directed to an arc—perhaps 60° in extent—vertically below the sun and bisected by the vertical circle through the sun. This was relatively faint, but of purer colors than those of the smaller ring. There could be no doubt that this was a portion of the well-known 46°-halo and was attributable to refraction by means of crystal faces at right angles to each other, such as are found at the bases of hexagonal ice crystals.

It will be observed that the whole phenomenon was no more surprising for its brightness than for its simplicity, and it is just this latter feature which renders it particularly important from the standpoint of the theorist.

The feature which first impressed itself upon the mind of the writer as an indication that we did not have here the familiar 22°-circle was the relative darkness of the sky within the ring. It was inconceivable that fortuitously arranged crystals of ice could yield so intensely colored a circle with so little diffused light that the sky within its area was a blue sky, far indeed from being milky, which it became a few minutes later. If not explicable by fortuitously arranged crystals it was not the 22°-circle at all, but the "Oval of Venturi," which the upper and lower tangent arcs of the 22°-halo form by uniting when the altitude of the sun is sufficiently great. If this were the true type the horizontal diameter of the ring should be slightly greater than the vertical and the upper and lower portions of the ring should be brighter than the eastern and western portions. The first condition I thought I established by rough measurements immediately after the question as to the nature of the phenomenon entered my mind, while the second condition was manifest to any observer whose attention was directed to it.

Very fortunately there is independent and perfect evidence for the correctness of my conclusions. Mr. Charles N. York, of this city [New Haven, Conn.], had the happy thought of photographing the ring and secured an excellent negative on an 8 by 10 plate.[2] (See fig. 1, opposite.) This shows perfectly that the ring had a horizontal diameter about 7 or 8 per cent greater than the vertical, and that the upper and lower portions were much brighter than the lateral portions, the distribution of light being symmetrical with respect to a vertical circle through the sun. Naturally, the angular extent of field was far too small to show the fragment of the 46°-circle; as a matter of fact the angular value of the plate was only just adequate for taking the whole of the ring. Exactly what instant the exposure was made is unknown to me,[2] but it was after the first moments when my companions and I observed it wholly without cirrus clouds within the ring.

To summarize the observations we may say that this halo was a magnificently developed one of extreme simplicity, having only two elements, namely, the Oval of Venturi and a fragment of the 46°-circle. The theoretical explanation is also simple. We conclude that only a single kind of ice crystals was present, namely, elongated hexagonal prisms with bases at right angles to their axes: that these prisms were falling with their axes horizontal and, in general, rotating about their axes. The ring, or oval, was produced by refraction through two alternate faces of the prism whenever a crystal at about 22° from the sun happened to present itself in a favorable position—that is, whenever the light thus refracted should be deviated by an angle little different from the minimum of 22°.

The fragment of the 46°-circle was due to those crystals which happened to be at this angular distance from the sun and so placed that light from the sun could enter at a basal face—vertical in position—and emerge at a prismatic face which happened to be in such a position that the deviation should be very near the minimum of 46°. The high degree of saturation of the colors is due to the obviously narrow range of possible departure from this minimum. A simple calculation, or geometric construction, shows that for minimum deviation in a 90° angle of ice the light should enter one face at an angle of 22° from it (an "angle of incidence" of 68°) and emerge at the other at the same angle; but this is just the angle at which sunlight would fall on vertical surfaces at the time of the observations, the zenith distance of the sun being very nearly 22° during the whole. Here we have a case

[1] Hastings, C. S. Light. Chas. Scribner's Sons, New York, 1901.

[2] The accompanying beautiful large-scale photograph of the solar halo of May 20, 1915, we owe to the enthusiasm and generosity of Charles N. York, of New Haven, Conn. For the benefit of those who may wish to attempt halo-photography in the open, Mr. York sends the following information:

The photograph reproduced here, was made at 11:45 a. m. (75th mer. time), using a Goerz "Dagor" lens of 9½ inches focal length, and stop 32. The plate was an 8 × 10 Stanley "Commercial", exposed behind a "15-time" ray filter for $\frac{1}{10}$ second. A "pyro" developer was used.