in the reversed position of its luminous portion, decreasing in brightness as the horizon is approached.

One need but to observe the sky a little before the rising of the sun, or a few minutes after it has set, to recognize the phenomenon or meteor [4] with which we are concerned. It is very plain, and probably as old as the earth itself; and there is every reason for astonishment that it does not receive more attention in both the modern and ancient works on physics or astronomy. I know of but one work where it is expressly mentioned, and that is a work entitled "On the Colors of the Sky." [5] M. Cramer—who had indeed well observed the anti-crepuscule and had even made some optical studies on it—was as surprised as I at the silence of writers in this respect. A number of years ago he wrote to me on the subject, and I communicated to him what I knew thereof together with the note on the work by Funccius. No doubt other occupations prevented him from carrying his researches farther, as well as from publishing them. Happy would I be might I still consult on this, and all other subjects, a friend at once so faithful, so wise, so enlightened and whose loss I shall eternally regret. * * *

On the evening of a fine day, then, one will observe at sunset or a few minutes after, in that portion of the sky opposite the sun and immediately on the horizon, a kind of band or *dark segment* of bluish and purple color surmounted by a *luminous* and colored *arch* which is whitish, orange, and finally on its upper border of a rose color sometimes verging on fire color. For these colors, or rather these shades of true colors are never well, clearly, or sharply defined here. Also, it is only under more or less favorable circumstances, according as the air is more or less free from vapors, exhalations, and clouds, that the anticrepuscule of one day or of one climate differs from that of another. Otherwise there is nothing more uniformly constant than this phenomenon, which is a purely optical one; therein quite different from the aurora borealis which belongs to physics but is variable and accidental. * * *

Now as the sun sinks below the horizon, the twilight or crepuscule sinks, and the [anti-twilight or] anticrepuscule rises by a corresponding amount; those solar rays that had been striking the vault at or near the zenith no longer reach so far, they are reflected from points nearer the sun, and the anti-twilight continues to rise; its luminous, colored arch detaches itself from the bluish, purple segment which soon shows nothing but a gray or ash shade, it [the colored arch?] mounts steadily and finally comes to the zenith where it is still visible when the air is there clear; for after having attained a certain elevation it grows weaker and weaker, until at last it totally disappears. I have observed the anti-twilight innumerable times in the more southern portions of France, at Paris, and in its environs.

The bluish and purple band at the horizon becomes gray and ash-colored when the anti-twilight or anticrepuscular arch [6] detaches itself therefrom, because the red rays from the sun and from the more brilliant portion of the twilight (crépuscule) no longer are reflected so far downward.

[The author also remarks that while the secondary rainbow is frequently observed, he is not aware that a secondary anti-twilight arch has ever been seen.—C. A., jr.]

[4] *I. e.*, "Any phenomenon or appearance in the atmosphere," the first significance of the word.—*Transl.*

[5] It is interesting to note here that Mairan uses the name "anti-twilight arch" not less than 4 times in this Eclaircissement.—*Transl.*

EXPLANATIONS OF THE WESTERN PURPLE LIGHT AND THE EASTERN AFTERGLOW (NACHGLÜHEN).[1]

By ALBERT HEIM.

[Translated for the MONTHLY WEATHER REVIEW by C. Abbe, Jr.]

All observations of the phenomenon point to the conclusion that the western purple light (Westpurpur) is the condition necessary for the afterglow (Nachglühen). If the western purple light does not appear, then the afterglow in the east is always absent; and if the western purple light is very weak, then one sees hardly a weak suspicion of the afterglow.

Wolf, who was the first to study the alpenglow with exactness, reached the conclusion—which is confirmed by Maurer—that the evening glow of the western sky, which we see projected into the high air layers as the western purple, was reflected at a sharp angle from the mirroring undersurfaces of high air layers. Mirror reflection does not essentially change the color of the light falling upon the mirror, but the width of the effective surface and the breadth of the bundle of rays prevents the production of sharp shadows. Therefore, a portion of the evening red (Abendrot) is reflected downward once more into the blue earth shadow. If this is the manner in which the afterglow originates, then the name "reflex glow" (Spiegelglühen) is justified.

If the afterglow (Nachglühen) is a reflex glow, then we may compute the altitude of the mirroring air layers. The results give altitudes of only 20 to 35 km. for the afterglow at a solar depression of 1½° to 6°, and of 70 to 80 km. for a depression of 9°. The different phases of the afterglow correspond to mirroring layers at different heights.

It seems to me that the following explanation of the afterglow is also a possible one:

The upper air layers receive almost solely yellow-red, they are directly illuminated by the yellow-red. The air reflects diffusely not simply blue *alone*, but all colors, as is shown by the whitish appearance along the horizon; however, it reflects more of blue than of the other components of white light. If it receives yellow-red almost exclusively, then it must also reflect diffusely the yellow-red, of course weakened. Thus there originates throughout the whole zone of air standing in the earth's shadow *a diffuse evening red* (Abendrot) *below the directly illumined evening red*. This is at one and the same time the purple light in the west and the afterglow in the east. In the purple light we see nothing other than the higher air layers illumined by the evening red from the sun. Yellow-red illumination of the air appears as purple-red. And the afterglow in the east is the reflection (*Widerschein*, Reflex, Abglanz) of the western purple.

Finally, there is support for the probability that diffraction affects the light rays shining down to us from the higher and still directly illumined air layers at the time of the purple light and the afterglow. Kiesling, Pernter, and Riggenbach, particularly have assumed that diffraction was the cause of the western purple light. According to Riggenbach's observations after the eruption of Krakatoa it was very clear that the purple light resulted from the widening of Bishop's Ring, which latter certainly owed its copper-red-brown to the light's diffraction by dust particles. It seems to me that mirror-reflection and diffuse reflection send the light down to us

[1] *Heim, Albert.* Luft-Farben. Hofer & Co. A.-G. Zürich, 1912. 8 cm. pp. 70-74. [Notable illustrations in color!]

from the higher illuminated air masses and that diffraction can influence only the color of the light.

The color and the time of occurrence of the western purple light and of the afterglow are in agreement with all three classes of explanations. The relative rarity of the afterglow and its varying intensity with the position of the sun speak in favor of the idea of mirror reflection. It seems to me, however, that if the cause were mirror reflection from the sunset zone the light would appear somewhat less scattered and would give more light and shade effect in the mountains. As a matter of fact I have often wondered, as I stood in the mountains in the afterglow itself, at the shadowless or very weakly shadowing character of this peculiar flesh-red light; and how it often appears not merely as the western purple and the eastern afterglow but fills the whole intervening space with its all-pervading, mysterious, gloomy yellow-red. The breadth of the light-giving surface and of the mirror together are after all an inadequate explanation, it seems to me, for this diffuse behavior of the afterglow. Just as the sky is blue and the mountains and valleys are filled with blue haze during the day, so now the sky is purple, copper-colored, or reddish yellow and the mountains and valleys are filled with these colors. If reflection throws the western purple light into our eyes and upon the eastern mountains, then there must be a much stronger polarization of the purple.

If the sky's blue were a true fluorescence of the air, then the western purple light and the afterglow would be blue instead of red. I conclude, from their colors, that the sky's blue is merely a pseudo-fluorescence.

The peculiar form of a "salmon-colored spot" in which the western purple light often begins, has not yet been explained, while the arched form of the western purple seems to be a matter of course. Evidently we have not yet the last word in explanation of the western purple light and of the afterglow. In the case of the afterglow we may have to do with the combined effects of several factors. Nature is, indeed, always more complicated than we like to assume in thought. One thing is quite certain, *the afterglow on the eastern mountains and the eastern sky is* not a direct evening red, but *an indirect evening red which is brought down into the earth's shadow by mirroring or diffuse reflection and diffraction.* Put more simply: The afterglow in the east is the reflected splendor of the western purple light. We may therefore describe the afterglow also as an indirect alpenglow. Here also is repeated a relation similar to that of the first alpenglow: The west furnishes light and color, the east is illuminated thereby. Thus it comes about that light and color are stronger in the west than they are simultaneously in the east. If one stands on the eastern mountains and wholly in the afterglow, there appears no repetition of sunset in the west; one sees only a great surface of purple light spread over almost the whole western sky.

Here and there a sheaf of divergent rays [crepuscular rays] from a mountain or a cloud in the western sky, reaches high up into the recently empurpled heavens. (See Heim's fig. 18.) The shadow rays [or crepuscular rays] appear blue-green in the purple. Hence one may conclude that the air that appears to be already in the western purple, as we stand down below it, still receives direct rays from the sun at high levels above us. The western purple light therefore arises first from direct illumination of the upper air layers. Diffuse reflection and diffraction are but the processes that conduct the splendor down to our eyes in the earth's shadow or across to the mountains.

This does not enable one to decide, however, whether the purple light originates in the west behind the cloud or only on our side of the latter. If the former, then the clouds intercept the purple-colored solar rays; if the latter, then the purple does not develop where the cloud's shadow falls. The former appears to me much the more probable case.

The western purple light, then, seems to be the evening glow of the higher air directly illumined by the setting sun, reflected down into the earth's shadow to our eyes. The eastern afterglow shows us mountains and air indirectly illuminated by the reflection of this lofty evening glow.

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TWILIGHT PHENOMENA IN ARIZONA, SEPTEMBER TO DECEMBER, 1916.

By Prof. ANDREW ELLICOTT DOUGLASS.

[Dated: Department of Physics and Astronomy, University of Arizona, Tucson, Dec. 2, 1916.]

[In his letter transmitting this paper Professor Douglass corrects his statement, quoted by me in the REVIEW for August, 1916, 44:434, to the effect that red sunsets were not observed by him after the middle of September, 1916. His accompanying description of twilight colors is closely in accord with the classical description by von Bezold, which, together with Exner's classification of the twilight phenomenon will be found translated on pages 620 to 623 of this number of the REVIEW. Therefore, with the consent of Professor Douglass, I have inserted in brackets in his text the designation given by Exner to the phase of the twilight described. Thus, [(c) First twilight arch] is to be interpreted as meaning that the phase of twilight under consideration will be found under (c) of Exner's classification to have the designation here given.—*H. H. Kimball.*]

From September 16, 1916, to the present time the writer has watched every evening after sunset for the occurrence of bright twilight and afterglow colors, and shadow phenomena. The clearness of our atmosphere permits all these phenomena to be seen with greatest ease down to our horizon of mountains, which averages about one degree in elevation in all directions. From west-northwest to west-southwest the average height is about 1.8°, while in the northwest the apparent horizon descends a very slight amount below the true horizon. In the east the mountains rise from 1° to 2° above the true horizon.

On account of the clearness of the air the sun is never under any circumstances faint enough to be looked at directly by the naked eye. Clouds are rare and two levels of clouds still more rare, so that it becomes possible to estimate cloud heights by the time when direct sunlight ceases to illuminate them. It thus becomes possible here to use means of investigation that would seem incredible to an observer accustomed only to Atlantic coast conditions.

Out of 80 nights, clouds have interferred to a serious extent on only 6 nights. Slight cloudiness has prevailed on over 50 per cent of the nights. In fact, it is a condition of a few thin, scattered cirrus clouds that is most favorable to the beautiful ray phenomena so often noticed. [See Abbe's translations of Heim's and Bezold's descriptions of these crepuscular rays; this REVIEW, p. 622 and p. 625.]

As soon as the disk of the sun is behind the western mountain, a heavy bronze area [(b) Twilight glow] is apparent extending to a distance of 4° or 5° in all directions from the sun itself. At first this bronze is of a rather yellowish color, which soon changes to a reddish tone, lasting some 20 minutes after the disappearance of the sun.

After the sun has really set the clear western sky in that general vicinity shows a structure which seems likely to be due to a high layer of haze in the atmosphere. This structure usually appears as a faint, soft etching of large numbers of parallel lines. In general