Citation:

Visser, S.W., On the diffraction of the light in the formation of halos. II. A research of the colours observed in halo-phenomena, in:
KNAW, Proceedings, 21 I, 1919, Amsterdam, 1919, pp. 119-124

Meteorology. — *"On the diffraction of the light in the formation of halos. II. A research of the colours observed in halo-phenomena".* By Dr. S. W. VISSER. (Communicated by Dr. J. P. VAN DER STOK).

(Communicated in the meeting of June 29, 1918).

In the first paper on the diffraction of the light in the formation of halos [1]) a survey of colours observed has been given on pag. 1175 taken from "Thunderstorms, optical phenomena etc. in Holland".

Prof. Dr. E. VAN EVERDINGEN however informed me, that these records are altogether insufficient because only a small number of colour observations are dealt with in "Thunderstorms". On his suggestion I have studied a number of records sent in to the "Koninklijk Nederlandsch Meteorologisch Instituut". In the first place I hope to have set right a neglect against the sincere voluntary observers of the Institute; in the second place this research gave valuable materials for the answer to the question how far and in what manner the diffraction works in the formation of halos.

In this paper a survey of the research is given; the results will be discussed and it will appear, that indeed the diffraction has an important influence on the refraction of light in ice crystals.

I started with all the colour records in the years 1913, '14 and '15. Then the research was extended to the years 1911, '12 and '13. In the first part I soon found, that great prudence was necessary. As an example I take the observations of "rainbow-colours". In the three years 1913—'15 I find "rainbow-colours" 12 times recorded by 9 observers. There are however 7 who have never sent in another record during all this time. They were evidently led by suggestion and fancy more than by observation power. The personal character also comes to the front. Therefore it was resolved to make a very careful selection and only to use records of those observers known to the Institute as wholly reliable. In this manner the notes are studied of eleven observers, who are mentioned in this paper with the numbers I tot XI.

[1]) These Proceedings Vol. XIX.

Omitted were all incomplete observations and those about the moon. 550 Observations were at my disposal, divided over the six years as follows:

	1910	1911	1912	1913	1914	1915	Total
colour-records	125 (6)	107 (7)	114 (7)	81 (8)	66 (8)	57 (7)	550
total	473	480	399	283	325	377	2337
%	26	22	29	29	20	15	24

In parenthesis is mentioned the number of observers.

The row "total" gives the total number of records taken from "Thunderstorms".

The fourth part of all the notes gives reliable records.

31 Colours and colour-groups are mentioned, among which three very anomalous ones: blue IX; violet, red VIII; red, violet, green V. In the first communication are mentioned[1]) golden brown (red), yellow, green, violet (3 times by two observers); yellow, violet; golden brown, clear white, blue.

All the colour observations (divided over the two circles, the tangential arcs and the circumzenithic arc) are contained in the table I. (See table following page).

In the table the personal character comes out strongly.

144 observations of red by 10 observers (among which 115 of VII and IX), and 133 orange by 5 (among which 130 of V and X) where in most cases the same colour is meant, this clearly points to the personal estimation of this colour. The same is evident in the groups red-white and orange-white.

The table II also gives an idea of this individual opinion. (See table II page 122).

All the colour records of each observer, separately for the ordinary circle, the parhelion and the tangential arcs have been collected without further observations in this table. From this it appears, that the records of V, VII and X are limited to green (V has one observation of violet on a total number of 158). III also mentions blue, but never violet; VIII notes neither green nor blue, but in 22 records 12 times violet.

This phenomenon however interesting from a physiological point of view, greatly diminishes the value of the records, but without doubt green and blue colour shades often occur, as is further evident in the percentages of the separate colours in the following table (in which parhelion and tangential arc are taken together).

[1]) l.c. p. 1330 seq.

TABLE I.

	circle 22	parhelion	tang. arc.	circle 46	circ. zen. arc.	total
white	51 (8)	7 (3)	1 (1)	—	—	59 (8)
red (brown)	119 (10)	14 (3)	9 (4)	2 (2)	—	114 (10) [1]
orange	123 (4)	7 (2)	3 (1)	—	—	133 (5)
yellow	15 (6)	4 (3)	1 (1)	—	—	20 (6)
blue	—	—	—	1 (1)	—	1 (1)
red, white (brown, white)	20 (6)	8 (1)	1 (1)	—	—	29 (6) [2]
orange, white	27 (1)	1 (1)	1 (1)	—	—	29 (2)
yellow, white	5 (2)	—	—	—	—	5 (2)
red, orange	4 (1)	—	—	—	—	4 (1)
red, yellow (brown, yellow)	10 (4)	2 (1)	1 (1)	—	—	13 (6) [3]
red, green	22 (3)	9 (5)	5 (2)	—	2 (2)	38 (5)
red, blue	10 (3)	2 (1)	2 (2)	1 (1)	—	15 (4)
red, violet	7 (1)	2 (2)	1 (1)	1 (1)	—	11 (2)
orange, yellow	1 (1)	—	—	—	—	1 (1)
orange, green	1 (1)	—	—	—	—	1 (1)
orange, violet	—	1 (1)	—	—	—	1 (1)
violet, red	1 (1)	—	—	—	—	1 (1) [4]
red, orange, white	—	1 (1)	—	—	—	1 (1)
red, yellow, white	1 (1)	1 (1)	1 (1)	—	—	3 (2)
red, green, white	1 (1)	—	—	—	—	1 (1)
red, orange, green	1 (1)	—	—	—	—	1 (1)
red, orange, violet	—	1 (1)	—	—	—	1 (1)
red, yellow, green	4 (3)	2 (2)	1 (1)	—	4 (1)	11 (3) [5]
red, yellow, blue	8 (3)	—	1 (1)	—	—	9 (4)
red, yellow, violet	1 (1)	1 (1)	—	—	—	2 (2)
red, green, blue	3 (2)	—	3 (2)	—	—	6 (2)
red, blue, violet	—	—	1 (1)	—	—	1 (1)
red, violet, green	—	1 (1)	—	—	—	1 (1)
red, yellow, green, blue	—	—	2 (2)	—	—	2 (2)
red, green, blue, violet	—	—	1 (1)	—	—	1 (1)
rd., or., yl., gr., bl., vi.	1 (1)	1 (1)	1 (1)	—	2 (1)	5 (3) [6]
	436	65	36	5	8	550

[1]) Among which brown 10 (2).
[2]) „ „ brown, white 11 (3).
[3]) „ „ brown, yellow 3 (1).
[4]) 1911, April 12: "on the outside reddish, inside violet". VIII. — April 23 VIII records: "on the outside common red".
[5]) An observation of an arc of Lowitz by HISSINK 1910, Sept. 7 at Zutphen was neglected.
[6]) Colours mentioned 2 times.
"All colours" once
"rainbow-colours" twice.

TABLE II.

	Circle of 22°							Parhelion							Tangential arc						
	w	*r*	*o*	*y*	*g*	*b*	*v*	*w*	*r*	*o*	*y*	*g*	*b*	*v*	*w*	*r*	*o*	*y*	*g*	*b*	*v*
I	1	3	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
II	—	4	—	1	—	—	—	—	1	—	—	1	—	—	—	3	—	—	—	4	—
III	2	21	—	5	2	15	—	—	—	—	—	—	—	—	—	3	—	1	3	1	—
IV	—	1	—	—	—	—	—	-	5	1	3	1	1	1	—	1	—	—	—	—	1
V	61	44	82	13	23	—	—	—	6	—	—	6	—	1	2	5	1	—	4	—	—
VI	1	6	1	4	1	4	2	—	—	—	—	—	—	—	—	1	—	—	—	—	—
VII	23	60	1	8	4	—	—	—	5	—	2	2	—	—	—	5	—	1	2	—	—
VIII	2	13	1	2	—	—	8	1	3	3	1	—	—	3	—	1	—	—	—	-	1
IX	11	50	—	7	1	—	—	14	23	2	4	1	2	2	2	6	—	3	—	1	—
X	3	4	73	2	1	—	—	2	1	6	1	1	—	—	—	—	3	1	—	—	—
XI	1	7	—	—	1	2	—	1	1	—	—	1	—	—	—	5	1	2	4	5	2
	105	213	158	46	33	22	10	18	45	12	11	13	3	7	4	30	5	8	13	11	4

	white	red	orange	yellow	green	blue	violet
circle 22°	17.9	36.3	26.9	7.8	5.6	3.8	1.7
parhelion, tang. arc	11.9	40.8	9.2	10.3	14.1	7.6	6.1

Surely the figures for violet are strongly flattered (21 observations of violet among which 12 of VIII). Without the records of VIII the percentages for violet are respectively about 0.3 and 3.8.

Evident is the great variety of colour of parhelion and tangential arc [1]).

By adding red and orange, green, blue, and violet the personal influences may be destroyed to some extent. Then I find

	white	red orange	yellow	green blue violet
circle 22°	17.9	63.2	7.8	11.1
parh. tang. arc.	11.9	50.0	10.3	27.8

Against a decrease of white and red we see an increase of the other colours. In more than $^1/_4$ of all cases colours are recorded approaching green and blue for the parhelion and the tangential arcs. This also happens with one in nine ordinary circles, where colours are made mention of.

1) Without doubt in the first communication I have slightly misunderstood PERNTER: the predomination of fixed crystal positions must at all events be very important.

Some colours and groups occur relatively often.

yellow; yellow, white	25 times;	6	observers
red, yellow; red, yellow, white	16 „	6	„
red, green; red, blue; red, violet	64 „	8	„
red, yellow, green; red, yellow, blue; red, yellow, violet	22 „	7	„
red, green, blue	6 „	2	„
Spectrum colours	5 „	3	„

Green, blue and violet, to escape from personal influences, are again added.

The yellow takes a peculiar place. Yellow circles seem to occur. It is clear, that the yellow is often missing between the red and the green, but on the other hand it is often met with.

As regards the rainbow colours; 5 observations of 3 observers remain in six years.

Separate mention deserve the estimations of breadth by HEMMES at Arnheim in the ordinary circle and the tangential arc.

1911 Dec. 29	red $\frac{1}{2}°$ yellow $\frac{1}{2}°$ blue $1°$
1912 Feb. 18 / March 3 / May 10	„ $\frac{1}{4}°$ „ $\frac{1}{4}°$ „ $\frac{1}{4}°$
March 8	„ $\frac{1}{2}°$ „ $\frac{1}{2}°$ especially at the top also blue.
1912 Jan. 6 / 1913 June 14	red $\frac{1}{4}°$, green $\frac{1}{4}°$ blue $\frac{1}{4}°$
1911 Dec. 3	red $\frac{1}{4}°$ yellow $\frac{1}{4}°$ green $\frac{1}{4}°$ blue $\frac{1}{4}°$.

The fact that the breadth strongly varies also appears from the detailed tables on the circumzenithic arc by BESSON [1]): 17 times on 91 arcs BESSON measured the colours. The distance from red to violet varied from $1\frac{1}{2}°$ to $3°$ ($1\frac{1}{2}°$: 3 times; $2°$: 6 times; $2\frac{1}{2}°$ twice; $3°$: 3 times). Three times blue and violet are wanting; among these is one arc, with which the breadth of the inside red to the green is $5°$. BESSON notes: "très large, très brillant".

These variations of breadth are very important for the theory of diffraction.

Summing up I find as the results of the research after eliminating the individual influences:

1. the pretty large wealth of colours,
2. the variation of colours,
3. the variation of breadth.

[1]) Sur la Théorie des Halo's. Paris 1909. p. 62.

These results are not expected by the simple theory of refraction; they demonstrate the action of diffraction. It is these very properties which, for the rainbow, made the ordinary refraction-theory insufficient.

Evidently the conditions for the development of these phenomena of diffraction are present rather frequently. With great certainty this research has established the conclusions drawn in the first paper. The observations however difficult by the small power of the colours, which generally are to be taken as mixed colours, the records, however often delusive by personal influences sufficiently show, that in the formation of halos the diffraction plays an important part.