A DOUBLE TANGENT ARC ABOVE THE SUN

By G. P. Können
FOM-Instituut voor Atoom- en Molecuulfysica, Amsterdam

On 29 October 1972 a remarkable optical phenomenon was observed in Bussum, Netherlands. At 1645 MET there were two parhelia visible in the horizon clouds, together with a sun pillar. At 1655 a reddish, double arc appeared in a strongly iridescent cirrus cloud directly above the red, setting sun, lasting for about five minutes. In the meantime, the sun and the parhelia disappeared behind the horizon clouds. A picture was obtained of this halo display, taken with an Asahi Pentax S1a camera, fitted with a 17 mm fish-eye lens. This picture is reproduced as a drawing in Fig. 1. The bottom of the arcs has been drawn. For the distance of the bottom of arc A with respect to the lower limb of the sun we measured 21·5° ± 0·1°. The distance between A and B was 1·7° ± 0·1°, and the width of arc B was 0·5°. The calculated sun elevation at the moment the photograph was taken was 2·3°.

Arc A can be identified as the common upper tangent arc of the 22° halo. This arc is formed in hexagonal ice crystals with horizontally oriented refraction edges. The angle of refraction is 60°. Because this kind of arc is formed in the minimum deviation of the crystal, the angles of the light rays with the refracting faces are equal (Fig. 2). The theoretical distance of this arc from the sun is 21·6° for red light (Tricker 1970). For arc B there are two possible explanations. It may be either the upper tangent arc of the 24½° halo, which is generated by horizontally oriented refraction edges of 64·8° (Visser and Alkemade 1956), or the upper Parry arc of the second order, referred to as Parry arc II by Goldie and Heighes (1968). This arc is formed in hexagonal ice crystals with two horizontally oriented faces, by light entering one of the inclined faces and emerging through the other one. This arc is thus not formed in the minimum deviation of the crystal so that the angles of the light rays with the refracting faces are not equal (Fig. 2). The formation of this arc is similar to that of the lower Parry arc of the first order (Jayaweera and Wendler 1972). A second order Parry arc can only be visible at solar elevations less than 17° and will only appear as a relatively bright arc for very low solar elevations.

To distinguish between these two possibilities we plotted for red light ($n = 1{\cdot}307$) the distance between the second order Parry arc and the 22° halo as a function of the elevation of the sun above the horizon. This graph is given in Fig. 3 and is similar to the graph given by Goldie (1971). Also the relative position of the tangent arc of 24½° halo has been indicated. The measured distance of 1·7° ± 0·1° agrees with the calculated distance of the second order Parry arc at a solar elevation of 2·4° ± 0·5°, indicating that arc B is indeed the upper Parry arc of the second order, and not the tangent arc of the 24½° halo.

Analysing the double arc observed by Alkemade on 8 November 1944, Visser and Alkemade (1956) did not consider the possibility that the upper arc may have been a second order Parry arc. They identified it as the upper tangent arc of the 24½° halo. Their observation of the double arc was made without adequate instruments, so that no exact measurements are available. We estimate their solar elevation to be about 2° at the middle of their observation, which is about the same as for us.

We have plotted in Fig. 4 the upper tangent arc of the 22° halo (A), the second order Parry arc (B) and the upper tangent arc of the 24½° halo (B′), calculated according to Tricker (1970) for red light at a solar elevation of 2·3°.

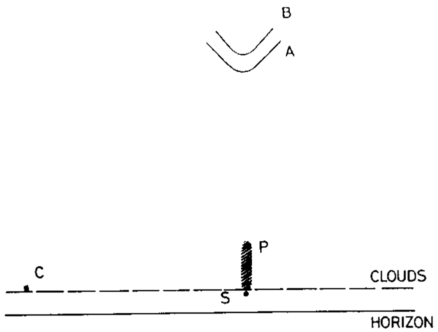

Fig. 1. A drawing of the halo display. S is the sun, P the sun pillar, C a trace of the left parhelion, A and B the double tangent arc

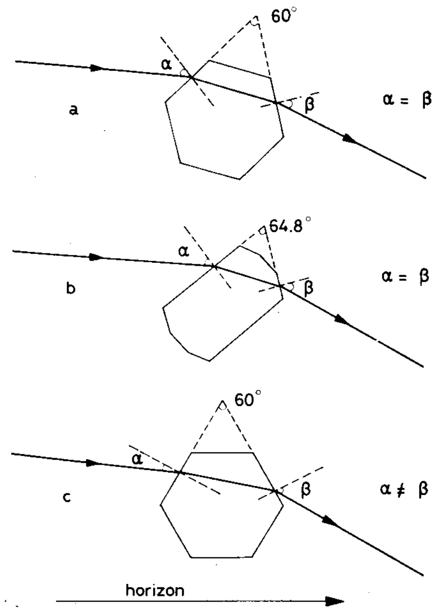

Fig. 2. (a) The formation of the tangent arc of the 22° halo; (b) Formation of the tangent arc of the 24½° halo; (c) Formation of the upper Parry arc of the second order

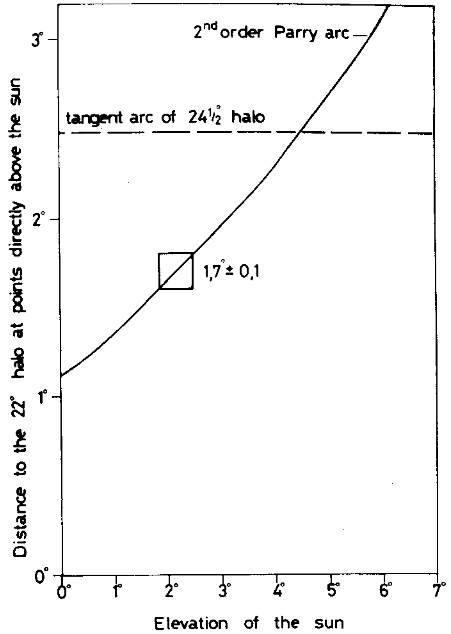

Fig. 3. The distance of the second order Parry arc and of the upper tangent arc of the 24½° halo with respect to the tangent arc of the 22° halo as a function of the solar elevation for red light ($n = 1{\cdot}307$). The value observed by us of 1·7° ± 0·1° is given in the graph

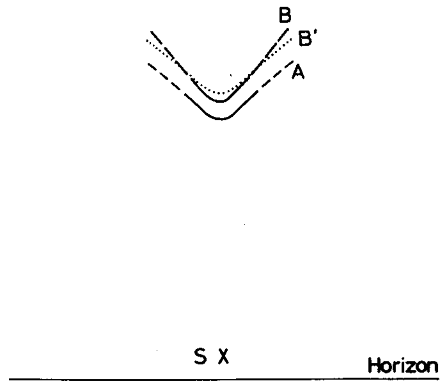

Fig. 4. Theoretical plot of the upper tangent arc of the 22° halo (A), the second order Parry arc (B) and the upper tangent arc of the 24½° halo (B′) for red light at an elevation of the sun of 2·3°

The solid lines represent the arcs we observed. Comparing the shape of the arcs observed by Alkemade with the theoretical arcs plotted in Fig. 4, we have the impression that a second order Parry arc is in better agreement with their observation than an upper tangent arc of the $24\frac{1}{2}°$ halo.

We thank Professor Dr J. Kistemaker for discussions.

REFERENCES

GOLDIE, E. C. W.	1971	A graphical guide to haloes. *Weather*, **26**, pp. 391-393
GOLDIE, E. C. W. and HEIGHES, J. M.	1968	The Berkshire halo display of 11 May 1965. *Ibid*, **23**, pp. 61-65
JAYAWEERA, K. O. L. F. and WENDLER, G.	1972	Lower Parry arc of the sun. *Ibid*, **27**, pp. 50-53
TRICKER, R. A. R.	1970	*Introduction to meteorological optics*. Mills and Boon, London
VISSER, S. W. and ALKEMADE, C. T. J.	1956	A tangent arc of the halo of $24\frac{1}{2}°$. *Quart. J. R. Met. Soc.*, **82**, pp. 92-96