POLARISATION OF HALOES AND DOUBLE REFRACTION

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IN contradistinction to rainbows, little attention is paid to the polarisation of haloes. A main reason for this is probably that their degree of polarisation is commonly very low. Most haloes are caused by refraction; simple calculation yields a degree of polarisation of 16 per cent for the 46° halo and of only 4 per cent for the common 22° halo. Even for haloes formed by reflection on the faces of ice crystals the polarisation is generally low, since total reflection frequently contributes. For instance the parhelic circle hardly shows polarisation for this reason, except possibly at low solar elevations. Only in a few cases have observations of these polarisation effects been made. A recent study of parhelion polarisation is given by McDowell (1974).

There remains, however, another mechanism to generate polarisation in haloes, which has received even less attention. Ice crystals are birefringent (doubly refracting) (Hobbs 1974) and an incoming beam of sunlight is thus split into two beams, both of which are totally polarised with directions perpendicular to each other. Both beams can give rise to the formation of a 100 per cent polarised halo and their distances with respect to the sun are slightly different. The splitting of the beams is most pronounced for a light path perpendicular to the optical axis of the ice crystal (Fig. 1), as in the formation of the 22° halo, the parhelia and similar haloes. In these cases the

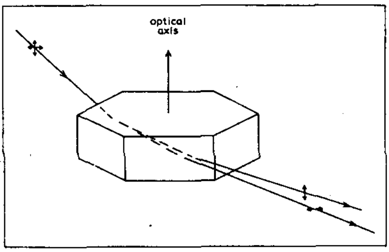

Fig. 1. The splitting of unpolarised light into two polarised beams by double refraction in ice crystals. The splitting is greatest for a light-path perpendicular with respect to the optical axis of the crystal

two polarised haloes are shifted by about 0·11°, which is about one quarter of the angle subtended by the moon.

From our experience, this effect can be seen especially clearly in the parhelia. These phenomena are generally bright and their red boundaries (towards the sun) are commonly well defined. By rotating a polarised filter before the naked eye it can easily be observed that such a boundary is about 0·1° closer to the sun for polarised light for which the $\vec{E}$ vector is radial with respect to the sun. The same holds for the other colours, although this is somewhat more difficult to observe. Moreover one gets the impression that the colours are more brilliant with the filter.

It can be concluded that parhelia consist of a superposition of two entirely polarised elements, which are slightly shifted with respect to each other. Therefore their red boundaries are completely polarised, but further away from the sun the polarisation disappears, because of mixing with the other component, whose polarisation is perpendicular. Since the mixing occurs with a somewhat different colour, one observes at these places a shift of colours with a filter.

Of course, other refractive haloes should show the same effect; we have also observed it clearly, for instance, in bright upper tangent arcs of 22° at various solar elevations. For many types of halo however, the effect is less pronounced, since they are not very bright and their boundaries are less clearly defined. It is nevertheless interesting to realise that for the 46° haloes, like the circumzenithal arc, the polarisation direction of the red border should be tangential instead of radial as for the 22° phenomena. Unfortunately it turned out to be very difficult to observe the effect in this halo.

To our knowledge, observations of this kind have never been published. The only report of polarisation of haloes by double refraction which has come to our attention is that of Cornu (1889), but he studied the effect only in artificial haloes of $NaNO_3$ crystals and not in atmospheric ones. The aim of our article is to give attention to this effect in atmospheric optics, which is so easy to observe in nature and seems to be so little known.

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