Brewster's dark patch: a neglected optical phenomenon in the landscape

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Introduction

In his invited lecture at the 1967 annual meeting of the Optical Society of America, Minnaert (1968) talked about what he called 'neglected optical phenomena' – a term that certainly applies to what is now known as 'Brewster's dark patch' (Takács *et al.*, 2017). This refers to a phenomenon that can easily be observed on any clear day without the use of any special equipment, but which has been discussed in the literature[1] only since 1980, and even then only very rarely (Können, 1985; Pye, 2001; Takács *et al.*, 2017). If Brewster's dark patch had been noticed a few decades earlier, its description would certainly have been given a place in Minnaert's (1954) classic *The Nature of Light and Colour in the Open Air*.

Observing Brewster's dark patch

Brewster's dark patch is best seen when the Sun is low. Just wait for a clear sky. Walk to a ditch or lake and position yourself so that the water's surface is just in front of you. Look at the water and observe the glare at its surface – which is the mirror image of the blue sky; its presence prevents you from looking into the water. Raise both of your arms and adjust the orientation of your body so that one arm points directly at the Sun. If you now look down at an angle of about 50°, you should see a dark patch on the water in front of you. This is Brewster's dark patch. Looking into the patch allows you to see fish and, in case of shallow water, objects at the bottom – something fishing birds may make use of when looking for prey (Pye, 2001). On gently rippled water the patch seems more visible than on still water, but under an overcast sky Brewster's dark patch is absent (Figure 1).

Explanation of the patch

Brewster's dark patch is a manifestation of the polarisation of the blue sky. As this polarisation is a necessary condition for its appearance, the patch does not appear when the light of the sky is unpolarised, as is the case in overcast situations.

Figure 2 schematically depicts the formation of Brewster's dark patch. The polarisation of a blue sky is strongest along a band

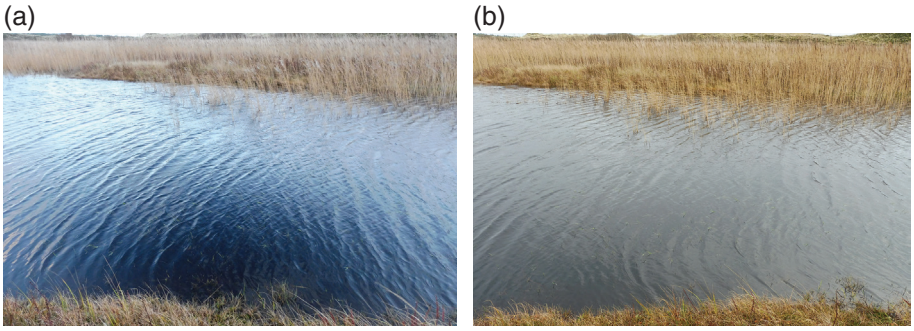

Figure 1. (a) Brewster's dark patch in a ditch, photographed shorly before sunset. The azimuth (compass direction) in which the patch appears is perpendicular to the azimuth of the Sun. (b) In overcast situations Brewster's dark patch is absent. The slightly darker area at the bottom left of the photograph is not a polarisation effect, but is a result of the dependency of the reflectivity of water on the angle of reflection of light. (The photograph in (a) was taken in Terschelling, Netherlands, at 53°24′2″N, 5°16′57″E, on 26 November 2017 at 1515 UTC, under clear sky conditions with a Sun elevation of 1.1°. Photograph (b) shows the same place on the following day, under an overcast sky. The horizontal field of view is 72° for both images.)

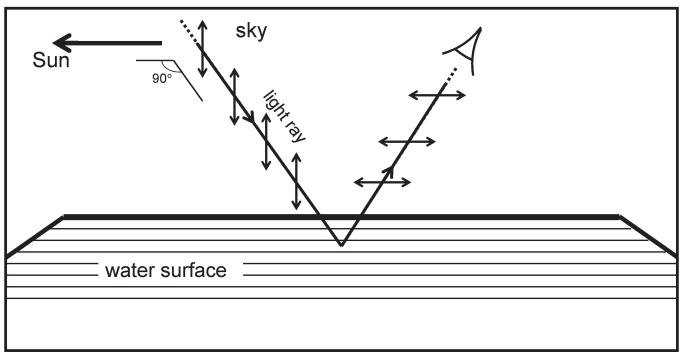

Figure 2. Around sunset, the light coming from parts of the blue sky with azimuths that differ by +90° or -90° from the azimuth of the Sun consists mainly of vertically polarised light. Water surfaces are poor reflectors of vertically polarised light, particularly around the Brewster angle of incidence (53°). Thus, the process of reflection by a water surface removes the dominant vertical polarisation of sky light. This manifests itself as 'Brewster's dark patch', a weakening of the glare on the surface of a body of water in a compass direction of 90° relative to that of the Sun.

[1]Around 1969 I noticed the phenomenon, and in 1970 I described and explained the observation in a Dutch popular science journal called *De Jonge Onderzoeker (The Young Scientist)*, and 5 years later in the Dutch journal *Zenit*, illustrating them with a black-and-white photograph (Können, 1970; 1975). The effect seemed to me so obvious that I assumed it had been described many times before. I was surprised that I could not find any earlier description in the literature. This provided me with an initial stimulus that led to my writing the book *Polarized Light in Nature* (Können, 1985).

in the sky at 90° angular distance from the Sun. When the Sun sets in the west, the band runs from the northern horizon through the zenith to the southern horizon; the direction of polarisation of the band is vertical with respect to the horizon. The vertically polarised component of the light from the band can be seven times stronger than the horizontally polarised component. However, a horizontal (water) surface reflects vertically polarised light less effectively than horizontally polarised light. Thus, the surface acts as a natural polarisation filter which is most effective at Brewster's angle of incidence (53°). The combined effect of the gradient in sky light polarisation and the gradient in the reflection coefficient of water for vertically polarised light results in a striking dark patch centred at Brewster's angle at an azimuth that differs by 90° from that of the Sun. You can't miss it.

Figure 3. Le Passeur (The Ferryman), a painting by Édouard Vuillard, 1897. The dark patch between the oars is Brewster's dark patch. (Source: Musée D'Orsay, Paris.)

Depiction of the patch in works of art

As mentioned above, descriptions of Brewster's dark patch are absent in pre-1980 monographs on the subject of natural phenomena in the open air. That is surprising; apparently the patch has escaped observation. However, as illustrated by Minnaert (1954; 1968) in his descriptions of the so-called 'contrast triangle', it seems that the keen and unbiased eyes of some artists are able to observe and document 'impossible' phenomena. Indeed, several painters have depicted Brewster's dark patch in their work. The earliest known example (D. Pye, pers. comm.) is Albrecht Dürer's aquarelle *Weiher im Walde* (1495); another, very beautiful, example is the 1897 painting *Le Passeur* by Edouard Vuillard (D. Pye (pers. comm.); Takács *et al.* (2017)), shown in Figure 3.

Nowadays Brewster's patch appears more often in paintings. It can be seen, for instance, in the work of Darko Topalski; an example is given in Figure 4. The reason is – as confirmed to me by D. Topalski himself (pers. comm.) as well as by other painters – that many current painters work out their object from a photograph rather than from an initial sketch. In a photograph, of course, Brewster's dark patch can no longer escape observation.

Figure 4. Dawn of the River, an oil painting by Darko Topalski, 2012. Brewster's dark patch is depicted in the bottom right corner of the painting.

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