Speculations on the possible causes of the Whymper apparition

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During the first ascent of the Matterhorn, a remarkable optical effect comprising three crosses surrounded by a great arch was observed by Edward Whymper, the British mountaineer. The authors review previous published explanations of the apparition. There are no photographs, only a woodcut and sketch, so the size of the apparition is not known, and it is not possible to make a definitive conclusion about what caused it. A fogbow and ice crystal arcs could have produced a circle and crosses in a direction consistent with the apparition. Some simulations are presented; one has a form approximating Whymper's sketch. However, while this simulation used a crystal type that can occur, it required an unusual alignment that would be very rare.

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1. Introduction

The Matterhorn lies on the Swiss–Italian border above Zermatt, Switzerland. It has a spectacular pyramidal form rising 1000 m from its base. Its first ascent was accomplished by a party of seven that included Edward Whymper on 14 July 1865. High on the NE (Hornli) ridge is a rocky shoulder that is the hardest part of the climb. It was here, during the descent that the least experienced member of the team slipped. His companions on the rope were dragged with him. Whymper and his two Swiss guides, the Taugwalders, were at the rear of the party. They momentarily held the fall but the section of rope attaching them to the front four climbers broke under the strain and Whymper and the guides watched helplessly as their four companions fell to their deaths down the precipitous north face. The survivors continued their descent, and soon after the disaster they saw an apparition in the form of a huge bow and crosses in the sky. It was included as the frontispiece of Whymper's classic "Scrambles amongst the Alps"[1] and is shown in Fig. 1. In this paper, we review the description of the apparition, its veracity, and previous explanations found in the literature, and we discuss features of more recent simulations.

2. Description

Whymper described the apparition as follows: "*When, lo! a mighty arch appeared, rising above the Lyskamm, high into the sky. Pale, colourless, and noiseless, but perfectly sharp and defined, except where it was lost in the clouds, this unearthly apparition seemed like a vision from another world; and, almost appalled, we watched with amazement the gradual development of two vast crosses, one on either side*."

He regretted not having been able to analyze the apparition in more detail being preoccupied with getting down safely. He described the phenomenon as a fogbow. In a fogbow, interference effects are more important than in a rainbow because of the small size of droplets of water present in mist. The different colored bows broaden and overlap, washing out the color, resulting in a broad white bow. Fogbows are smaller in angular extent but broader in arc width than rainbows.[2] The mist's droplet size affects both of these parameters.

The Sun angle seems to be well specified from Whymper's description: "*The sun was directly at our backs; that is to say, the fog-bow was opposite the sun. The time was 6.30pm*" (local time was Berner Zeit: Greenwich Mean Time (GMT) + ½ hour). The climbers were above the shoulder of the Hornli ridge at 45.97° latitude and 7.66° longitude. At this location, on 14 July, the Sun sets at 2000 h local time. At 1830 h the Sun would have been fairly low, at about

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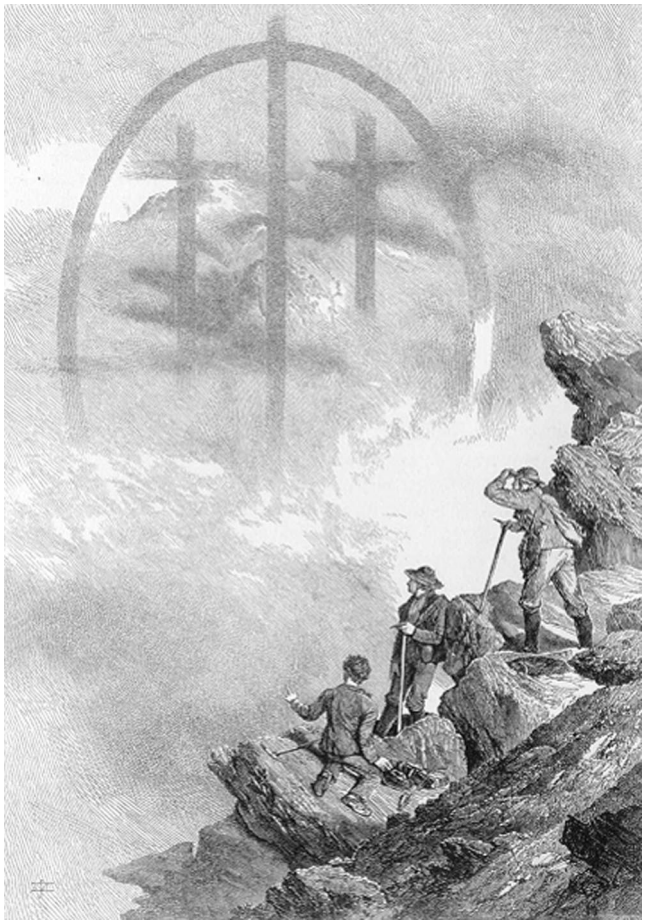

Fig. 1. Whymper's wood cut of the apparition.

11°. The azimuthal angle of the Sun at this time would have been 20° north of west.

3. Veracity of the Observation

Whymper had a general scientific approach to expeditions and had keen observational skills. His book[3] on his trip to climb several Ecuadorian volcanoes is an impressive work cataloging Andean flora, fauna, geology, and archaeology in much detail. Here, he also undertook experiments on the performance of aneroid barometers carrying heavy fragile mercury barometers to the summits for calibration purposes.

Nevertheless, Whymper has been accused of fabricating some of his escapades. In particular, a dramatic jump referred to as Almer's Leap necessary to affect the descent of the Barre des Écrins in France was dismissed by Collidge.[4] However, Whymper went to great lengths to refute this allegation. More recently, Sir Arnold Lunn[5] was critical of Whymper's character in general and of the veracity of his apparition sighting in particular, but Lyall[6] suggests Lunn's objectivity was compromised by a personal agenda to discredit Whymper and concludes that Whymper was of good character and was a reliable observer.

Both Whymper's biographer Smythe[4] and Haensel[7] in their books claim that an Italian team

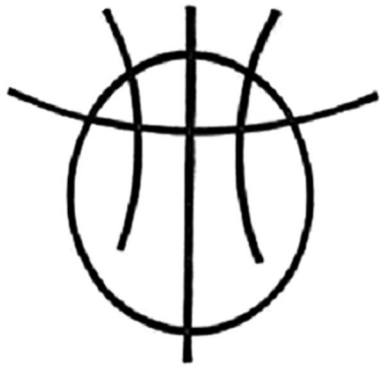

Fig. 2. Whymper's later sketch showing the presumed geometry of the bows.

attempting to climb the mountain on the same day also saw the apparition from the Italian side when they were at about the same height. This would seem to be a confirmation of the observation. However, their source is not stated, and it is possible this was a misreading by them of Whymper's report (a footnote in "Scrambles") that the Italians had observed a Brocken specter and glories when at the same height, but three days later.

Whymper admitted that his woodcut was perhaps not a scientific rendition. In fact the woodcut had a complex process of production: an original "memorandum" was Whymper's, it was then drawn on wood by James Mahonney, and the woodcut was finished by Whymper.[5] Whymper was a fellow of the Royal Geographical Society, a member of the British Association, and a friend of Robert Scott of the Meteorological Office in London.[8] It is most likely he discussed his vision with Scott and other scientists of the day leading to the "Scrambles" footnote where he remarks: "*It has been suggested that the crosses are incorrectly figured in the accompanying view* (Fig. 1) *and that they were probably formed by the intersection of other circles or ellipses as shown in the annexed diagram* (Fig. 2)."

While Whymper stated "*If the Taugwalders had not been the first to perceive it, I should have doubted my senses,*" in later correspondence reproduced in Lyall's book the younger Taugwalder said that he "*noticed nothing whatever of the three crosses in the sky that [Whymper] claimed to have seen,*" which casts doubt on Whymper's report. However, Taugwalder made this assertion in 1917, fifty two years after the incident, near the end of his life. Whymper's sketch was done from memory, and given his preoccupation with other events, it is possible all details were not accurately recorded. However, it would seem most unlikely that his report would have been a complete fabrication.

4. Previous Explanations in the Literature

A. Minnaert and Lynch

Minnaert[9] and Lynch[10] both note that ice crystal displays such as vertical pillars and horizontal arcs can

form a cross in the sky; together with a circular ice halo, they claim this gives an explanation of the Whymper apparition. However, the circular ice halos, in contrast to the fogbow, are generally only seen when one looks toward the Sun, so such an explanation is not convincing because the climbers were looking away from the Sun.

B. Valette

Valette[11] also notes that usually circular ice halos are seen when one looks toward the Sun, and so an explanation based on circular halos and crosses is too simplistic. Valette also notes that Whymper rendered the image as black on white. He takes this feature as representative and proposes some kind of reflection of circular halos around the Sun by thin ice clouds above the Liskamm, somehow giving rise to a negative image. This explanation seems to have little scientific basis.

Valette does, however, make the point that Whymper's sighting does not correspond to a Brocken specter as is sometimes stated in mountaineering literature. In a Brocken specter it is likely that the three men, presumably huddled close together, would have seen three shadows projected onto the mist. The movement of the shadows would have been clearly discernable. However, Whymper was very specific that their movement had no effect on the form of the apparition: "*They* (the Taugwalders) *thought it had some connection with the accident, and I, after a while, that it might bear some relation to ourselves. But our movements had no effect on it. The spectral forms remained motionless.*"

C. Harries

Harries[12] notes the problem with Minnaert's explanation and also suggests that the crosses could be produced by a specific form of ice crystals. In particular he notes the observations of the anthelion as a candidate for the central cross and the 120° parhelia (due to Parry-aligned crystals) as candidates for the crosses, though these would be 60° from the antisolar direction, making them even wider than a fogbow.

D. Hardwick

Hardwick[13] proposes a fogbow plus ice crystal arcs. However, he proposed that the ice crystals were local in the mist that Whymper depicted near the climbers. The temperature at the height of the mist deduced from the Meteo Swiss annals had a value between +1 and −8 °C. At such modest temperatures below freezing, ice crystals can form, but ice nuclei (IN) are required. On the day, it was very calm so the wind could not whip up snow fragments from the mountain. Hence the temperature was probably not low enough for the copious production of ice crystals. A morbid explanation would be that the avalanche on the north face initiated by the falling climbers would put some IN in the air. However, at greater heights where the air is much colder, halos can appear even in summer at such latitudes, so in retrospect, there is no need for the ice crystals to be present in the mist, provided that the mist was thin enough not to obscure any ice crystal arcs that might have been present. In principle, such halos above the Liskamm could have been observed from Zermatt and elsewhere. In the "Veracity of Observation" section, we have already discussed various claims that the Italians on the mountain saw the apparition. Whymper noted in his description (see above) that in part the apparition was lost in cloud, suggesting that ice crystal arcs were visible through the mist.

Anthelic ice crystal arcs, depending on the ice crystal shapes, give a variety of forms, and several ice crystal ensembles are discussed by the author. While a form of central cross could be produced, side crosses required a rather speculative crystal shape and alignment. These simulations are described in more detail below in the discussion. A weakness of Hardwick's paper is that the simulations used populations of perfectly shaped crystals of a single type and orientation. In practice there will usually be ensembles of several crystals types, some irregular crystals, and several orientations.

5. Discussion

In this section we discuss some features expected of a fogbow and ice crystal arcs.

A. Size

It is not possible to tell from Whymper's sketch the angular extent of the arcs. The mountain in the clouds in Fig. 1 appears to be Liskamm. Although this is a big mountain, when viewed from the Matterhorn it has an angular extent of only ±5°. The relative sizes of the apparition and mountain in Fig. 1 indicate that the bow had a similar and relatively small angular extent. Such a small angular extent is more like that of a glory than a fogbow. Given his many days in the mountains, Whymper should have been familiar with Brocken specters and glories. Indeed, he reported their observation in a footnote in "Scrambles" by the Italian party who made the second ascent on the 17 July. Therefore it is hard to imagine him confusing Brocken specters and glories with the much larger fogbow. Moreover, he referred to a "mighty arch" and "vast crosses" implying considerable size. Whymper was very pedantic in the use of words so he would not have used these adjectives without reason. Moreover, artistic renditions of atmospheric optical effects can be inaccurate. For example, Turner's Buttermere rainbow when compared to the mountains in his painting is far too small.[14]

To get an idea of the mountain scene viewed by the climbers, Fig. 3 shows the landscape looking toward the Liskamm from the top of the Hornli piste adjacent to the Hornli Ridge of the Matterhorn. The mountain on the right is the Breithorn and that on the left the Monte Rosa. As an example, a ±38° fogbow has been superposed on the scene in the figure. With an azimuth value noted above for 1830 h, the fogbow would be centered on the antisolar point, 11° below the horizon between Monte Rosa and Liskamm, whose

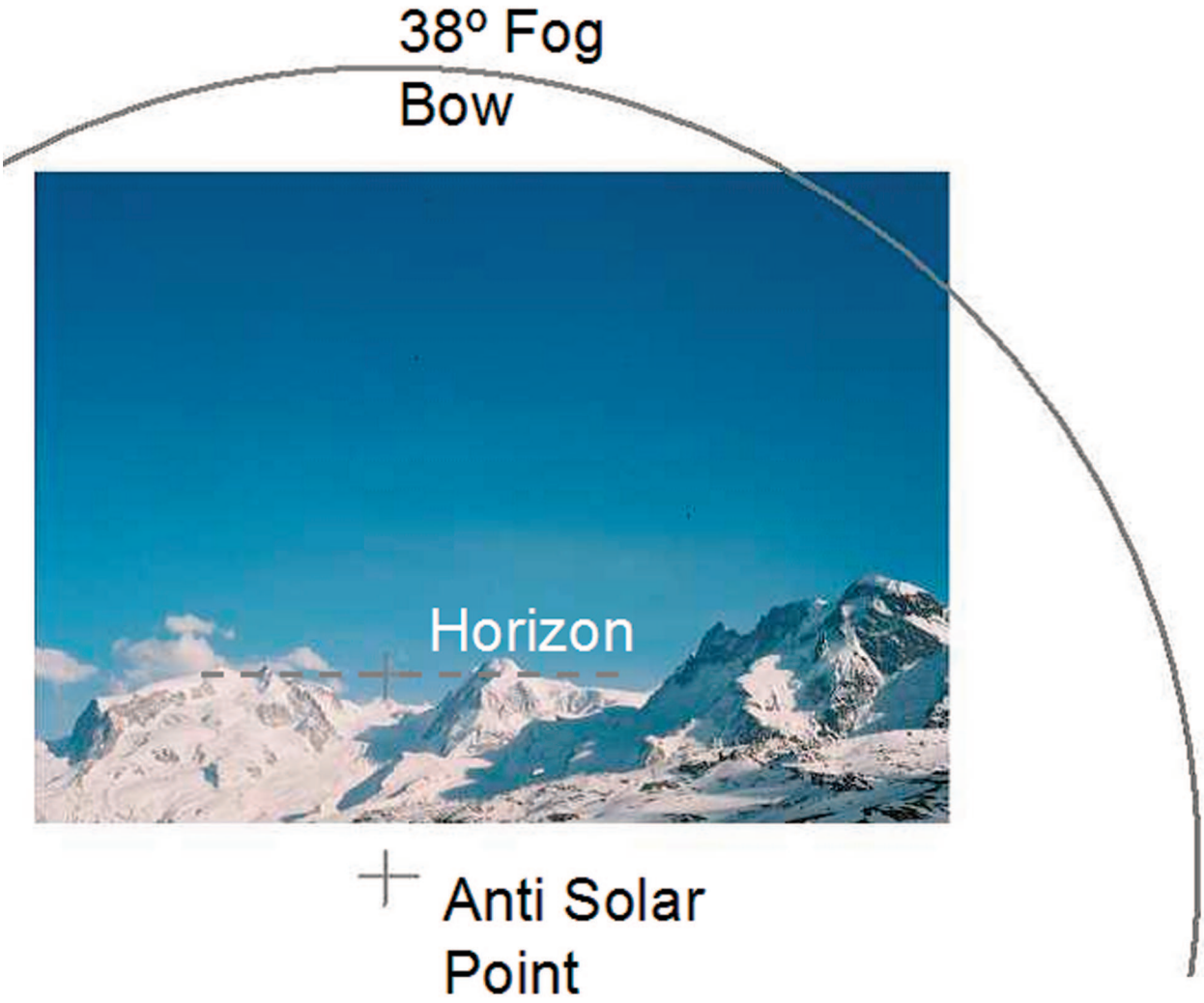

Fig. 3. Camera view from near the Hornli ridge with a 38° fogbow superposed.

summit lies about 5° farther round to the south. It would extend in the horizontal from left of the Monte Rosa, right around the crown of 4000 m peaks above Zermatt, to south of the Breithorn. Liskamm is 4527 m high and 14 km away from the climbers, who were at 14000 ft (4267 m). Its summit would subtend a vertical angle of about 1°; the top of the fogbow arch would be at 38° − 11° = 27° above the horizon and high above the mountain, consistent with Whymper's report. Moreover, as the mountain's shadow would prevent sunlight falling on the mist below −11°, an incomplete circle as shown in Fig. 1 would be expected.

B. Color and Sharpness

The form and color of the arcs were reported as "*at once tender and sharp; neutral in tone; were developed gradually and disappeared suddenly.*" A neutral tone can be the case for fogbows and halos. One interesting feature of Whymper's woodcut is that he rendered it dark rather than light. This is odd, as he would certainly have had the technique to render it light. One possibility is that fogbows often show an inner supernumerary bow, giving a narrow dark band between the broad, white primary and supernumerary bows, which, because of the contrast, can appear more distinct and sharp than the fogbow itself. Because of this, Minnaert suggests the narrow dark band is a good way to measure a fogbow's diameter.[9] Of course, it may also have been drawn that way purely for dramatic effect.

C. Absence of Glories

At the center of the fogbow we might expect glories; however, none were mentioned. As already noted, Whymper was certainly aware of the phenomenon of glories, so they could not have been very noticeable. If the mist droplets were large it is possible that the glory would not be so evident because its angular size would have been reduced. Moreover, the climber's interest was perhaps drawn to the more dramatic and large arch and crosses. Another possibility is that a rock feature was between the observers and the antisolar point.

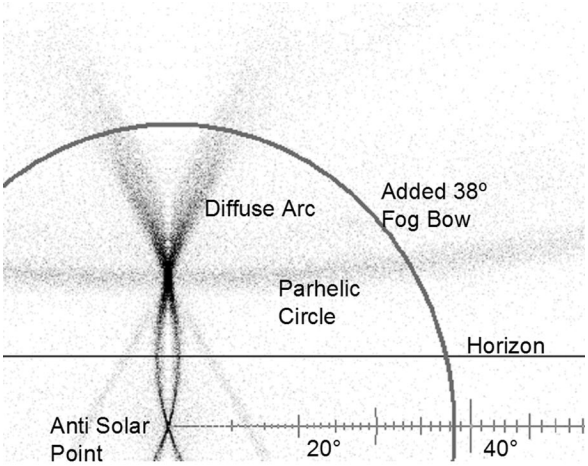

Fig. 4. Simulation with singly aligned (0.2° spread), hexagonal cylinder crystals; 11° Sun angle and added fogbow.

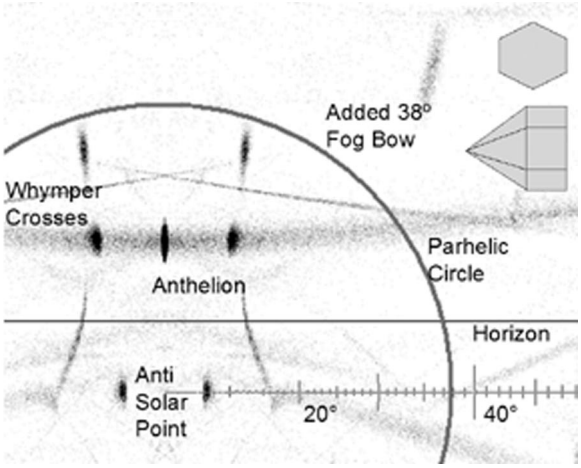

Fig. 6. Simulation with alternate Parry alignment (0.5° spread), pyramidal capped cylinder crystals; 11° Sun angle. Insert shows crystal shape and orientation.

D. Shape

The elliptical shape in Whymper's woodcut and sketch is also strange; we would expect a fogbow to be circular. Hardwick proposed that it could appear as an ellipse if the edge of the mist is set at an angle to the vertical plane. This perception effect is similar to that reported for the elliptical appearance of fogbows originating from horizontal cloud layers when viewed from aircraft above the cloud.[15]

E. Ice Crystal Arcs

The simulations presented by Hardwick in the journal *Weather* have been redone with a later version (3.5.3) of the HaloSim3.5 program developed by Cowley and Schroeder.[16] They are illustrated in Figs. 4 to 6 and have been done using the gray-scale feature of the program rather than black on white as used in figures presented in the *Weather* article. This gives an idea of the relative intensities of the different features in the simulations. Although simulations of ensembles populated by 100% of the same crystal type and orientation have been used for the figures as in the *Weather* paper, using mixed ensembles did not make the features disappear.

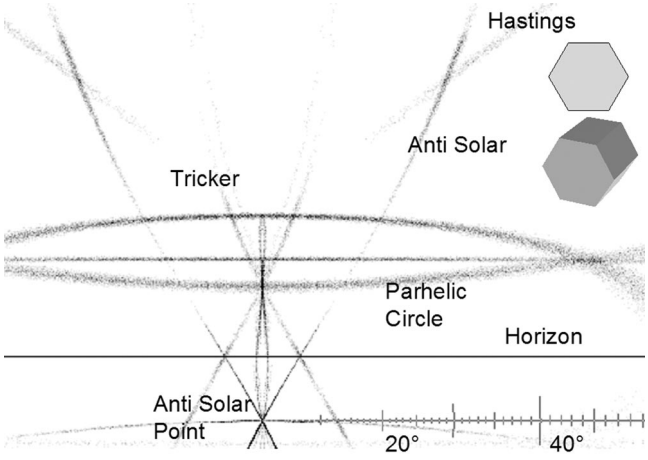

Fig. 5. Simulation with Parry aligned (0.2° spread), hexagonal cylinder crystals; 11° Sun angle. Insert shows crystal shape and orientation.

The landscape on which we need to superpose the simulations is that already described and shown in Fig. 3. The simulations have approximately the same field of view and camera angle so the relative size of the expected arcs in relation to the landscape can be appreciated. In all the figures the position of the horizon is indicated by the horizontal line. There is also a horizontal scale extending from the antisolar point; the scale's major tick marks are at 10° intervals.

The type of ice crystals that form depend on the temperature and humidity.[17] From 0 to −4 °C, hexagonal plates can form, and from −4 °C to −10 °C, hexagonal columns can form, which gives rise to the more frequently observed halo types. In fact, quite a wide variety of forms are possible. Crystal sizes between 50 and 500 μm will tend to become aligned as they fall.[10] Columnar crystals align with their column axes horizontal. Such an orientation is termed "singly" oriented. Such crystals will give rise to an antisolar "cross" formed from the diffuse arcs and the parhelic circle (see Fig. 4, which also has a ±38° fogbow drawn centered on the antisolar point, 11° below the horizon). In some cases two opposite side faces of the hexagonal columns can be aligned horizontally too ("Parry" orientation). The simulation in Fig. 5, also with a Sun angle of 11°, shows well documented features that can occur in this case.[17] The Tricker arc above the parhelic circle (horizontal) and both the Tricker arc and diffuse arcs below it (off-vertical arcs) form a cross with the parhelic circle as we also obtained with singly oriented crystals. In addition, there are intersections of the antisolar arc with the parhelic circle and at higher elevation angles, with the Hastings arc at horizontal angles of 13° and 28°, respectively. However, neither of these intersections are vertical and hence do not correspond to Whymper's sketch. Moreover, the intersections, particularly those with the parhelic circle, are very

faint. There is a broad arch above the central cross and parhelic circle, but it is quite a lot lower and much broader than a fogbow, so has a quite different aspect ratio to the ellipse forming the mighty arch of Whymper's sketch.

At lower temperatures, bullet crystals comprising a hexagonal column with one end face capped by a pyramidal crystal can be formed. These pyramidal crystals produce odd-radius arcs, and recently there has been evidence for singly aligned pyramidal crystals.[18] M. Riikonen *et al.* suggest column arcs resulting from Parry-aligned pyramidal crystals may one day be observed. Figure 6 shows a simulation made with pyramidally capped hexagonal cylinder crystals having an alternate Parry alignment. The alternate Parry alignment has two opposite side faces of the hexagonal columns aligned vertically rather than horizontally. In our case it does produce some bright spots and side ellipses that have a geometry similar to the side crosses of Fig. 2. These result from multiple internal reflections involving at least one of the pyramidal crystal faces and the flat end face. The side crosses above the parhelic circle and at their intersection with the parhelic circle are fairly bright and still visible when the fraction of alternate Parry-aligned pyramidal crystals is reduced to 20%. However, the lower side cross is less visible with this ensemble. The intensity of the side crosses is fairly sensitive to the ratio of the cylinder and pyramid lengths; Fig. 6 has a ratio of 0.5. In the figure, a $\pm 38°$ fogbow has been drawn centered on the antisolar point, 11° below the horizon.

While there is evidence for such crystals, there is scant evidence for the alternate Parry orientation. The halos that would be produced with such a crystal ensemble when one looks toward the Sun have never been observed. However, this orientation is sometimes cited as giving an attractive explanation of 46° parhelia and the anthelion.[17,19] The anthelion is a diffuse colorless patch of light up to 5° in angular extent opposite the Sun that can occur in the absence of other anthelic arcs. Lynch *et al.*[19] claim that ray optics associated with alternate Parry-oriented hexagonal columns would account for the fact that the anthelion has never been observed with Sun angles above 46°. The authors note that an earlier suggested mechanism for the anthelion invoked a crystal shape known as a "C2a bullet composite" crystal. These comprise four cylindrical hexagonal columns, joined together at the vertices of their pyramidal end caps. Two faces of the cylinders are perpendicular to the plane of the composite snowflake. Lynch *et al.* cite two papers where such rare crystals are reported. Falling through the air, such a snowflake is expected to give an alternate Parry alignment to the cylinders. Such a crystal form might be a candidate to produce parts of the display of Fig. 6, but the extra spokes could intercept some of the ray paths computed for single crystals. It should be stated, such combinations of orientation and ice crystal form proposed would be very rare indeed. Nevertheless, if the apparition was really as described and as unique as Whymper claimed: "*It was a fearful and wonderful sight, unique in my experience, and impressive beyond description, coming at such an instant*," a rare crystal shape and unusual alignment might have some merit.

6. Other Explanations

Ice crystal arcs opposite the Sun are fainter than those toward the Sun and are therefore more noticeable in the Polar regions where copious ice crystal formation is more frequent. Therefore an explanation based on these forms is perhaps unlikely. Other possibilities include shadows cast on the mist by features on the mountain itself and anticrepuscular rays. The former, one might expect to be observed periodically by climbers other than Whymper during the many thousands of subsequent ascents of the mountain by the Hornli ridge route. However, most climbers would be off the ridge much earlier in the day. The climbers were on the NE ridge and so there would not have been be many rock features higher than the climbers to the west that could cast shadows. Anticrepuscular rays would form a radial-spoke pattern and so would not be representative of Fig. 1 or 2. However, Whymper and the guides might have misinterpreted angled segments of such rays as vertical, given the climbers' highly agitated state. Anticrepuscular rays are consistent with other parts of the story, such as their steady appearance as the climbers moved around the ridge. Still, anticrepuscular rays are not extremely rare, so Whymper may have seen some examples in his Alpine adventures prior to 1865, and it is unlikely that he would not have recognized such rays for what they were.

7. Summary

Whymper's description and his vast experience of the mountains suggest that his "mighty arch" was not a Brocken specter as is sometimes stated but could have been a fogbow. The crosses remain a mystery. It could be possible that they resulted from ice crystals higher in the sky above the Liskamm. Anthelic arcs from hexagonal cylindrical crystals that have their cylinder axes aligned horizontally would appear to offer an explanation for some kind of central cross comprising the parhelic circle and Tricker and diffuse arcs. Hexagonal cylindrical crystals with a Parry alignment give other arcs to each side of the central cross and possibly the "mighty arch" too as an alternative to the fogbow. However, none of these have the form of Whymper's sketch. Pyramidal capped cylinders having an alternate Parry alignment would produce crosses with a form similar to Whymper's revised sketch, but while there is some evidence for alternate Parry alignments and pyramidal capped hexagonal prisms separately, the two together would be a very rare occurrence indeed.

References

1. E. Whymper, *Scrambles amongst the Alps in the Years 1860–69* (John Murray, London, 1871).

2. D. Lynch and P. Schwartz, "Rainbows and fogbows," Appl. Opt. **30,** 3415–3420 (1991).
3. E. Whymper, *Travels amongst the Great Andes of the Equator* (John Murray, London, 1882).
4. F. Smyth, *Edward Whymper* (Hodder and Stoughton, London, 1940).
5. A. Lunn, *Matterhorn Centenary* (George Allen and Unwin, London, 1965).
6. A. Lyall, *The First Descent of the Matterhorn; a Bibliographical Guide to the 1865 Accident and its Aftermath* (Gomer, Wales, 1997).
7. C. Haensel, *La Lutte pour le Cervin* (J.-H. Jeheber, Genève, 1930).
8. I. Smith, Alpine Club, Charlotte Street, London (personal communication, 2004).
9. M. Minnaert, *Light and Color in the Open Air* (Dover, New York, 1954).
10. D. Lynch, "Atmospheric halos," Sci. Am. **238,** 144–152 (1978).
11. L. Valette, "The phenomenon of 14 July on the Cervin," Les Alps, Revue du Club Alpin Suisse (1957), translated and reproduced in the Alpine J. **85,** 97–101 (1980).
12. J. Harries, "Optical phenomena for mountaineers," Alpine J. **77,** 39–47 (1972).
13. J. Hardwick, "Simulation of the Whymper apparition," Weather **57,** 457–463 (2002).
14. J. Hardwick, "The subtlety of rainbows," Phys. World **17,** 29–33 (2004).
15. R. Greenler, *Rainbows, Halos and Glories* (Cambridge University, Cambridge, 1980).
16. L. Cowley and M. Schroeder, HaloSim3.5, version 3.5.3 (2003), "Atmospheric halo simulation by numerical ray tracing," www.sundog.clara.co.uk/halo/halosim.htm.
17. W. Tape, *Atmospheric Halos*, Vol. 64 of Antarctic Research Series (American Geophysical Union, Washington, D.C., 1994).
18. M. Riikonen, J. Moilanen, M. Sillanpaa, and F. Nieuwenhuys, "Rare odd-radius column arcs," Weather **58,** 346–350 (2003).
19. D. Lynch and P. Schwarz, "The origin of the anthelion," J. Opt. Soc. Am. **69,** 383–386 (1969).