Marko's column arc 362—how do we name it?

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In the *Ice Crystal Halos* entry for October 18, 2009, Marko Riikonen announced yet another new halo—the column arc 362 or 352—and he raised the question of what to name it. I am not proposing an answer, but I will offer some thoughts on how the halo forms. Perhaps that will suggest a name. Of course the halo is already named by its crystal orientation and ray path, but "column 362" or "column 352" may not be so appealing to observers.

The new halo is related to the supralateral arc in the same way that the Kern arc is related to the circumzenith arc. There is also a yet-to-be-reported halo that is related to the infralateral arc in the same way, and that situation is a bit easier to see than that for the supralateral, so I am going to treat the infralateral first.

Circumzenith, Kern, infralateral, and you-name-it

For the sake of the argument, I will assume that the Kern arc is the plate arc 136. (It is only partly true.) In Fig. 1 you see the circumzenith arc and the Kern arc. Together they make up a horizontal circle. The circumzenith arc and the Kern arc are related as shown in the right-hand diagram.[1] Although the points **H** on the circumzenith arc and **H**′ on the Kern arc differ by a reflection in a plane parallel to crystal face 3, that plane changes with crystal orientation, so probably we do not want to say that the Kern arc is a reflection of the circumzenith arc. The two arcs are not mirror images of each other, as is clear from the figure. Rather than being a reflection of the circumzenith arc, the Kern arc is a kind of complement of it; together they make up the circle.

[1] The relation between the circumzenith arc and the Kern arc depends on what ray path you decide to associate with the Kern arc. So the right-hand diagram in Fig. 1 will change if you decide that the Kern arc is, for example, plate arc 135.

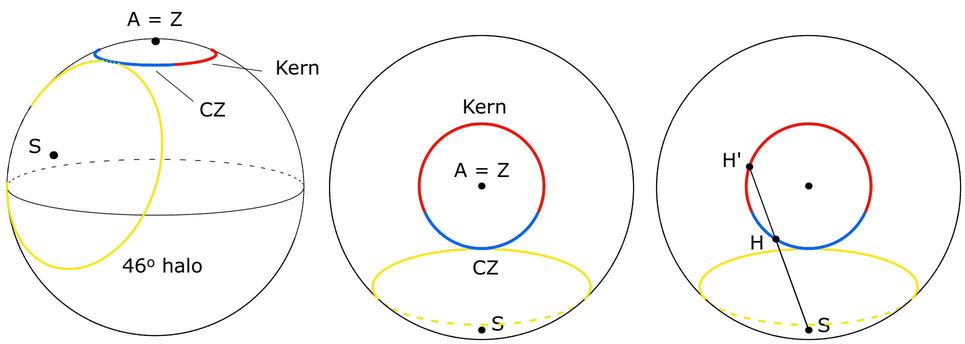

Figure 1: (*Left*) The plate arc 13 (blue) and the plate arc 136 (red). The former is the circumzenith arc CZ, and the latter is the Kern arc. The axis **A** of the responsible crystals coincides with the zenith point **Z**. The yellow circle centered at the sun **S** is the 46° halo. The sun elevation is 20°. (*Middle*) Same but viewed from above. (*Right*) Illustrating the relation between the circumzenith arc and the Kern arc. The point **H** on the circumzenith arc and the point **H′** on the Kern arc arise from the same crystal orientation.

If instead of pointing to the zenith, the crystal axes could all somehow point in some other, single direction, then, as in Fig. 2, you would get a circumzenith arc and Kern arc that have been rotated from their normal positions.

Crystals with column orientations have their (principal) axes horizontal but are otherwise constrained. For any column arc we can ask for the contribution to the halo that arises from crystals with axes pointed in some specified horizontal direction **A**. For example, if **A** were as in the right-hand diagram of Fig. 2, then the blue arc would be the contribution to the column arc 13, that is, to the infralateral arc, and the red arc would be the contribution to the column arc 136, however you choose to name it.

You get the entire column arc 13 (infralateral) by letting **A** vary along the horizon. As in Fig. 3, the infralateral is just a bunch of circumzenith arcs, suitably rotated, each in a vertical plane. And you get the entire column arc 136 the same way. It is a bunch of Kern arcs, suitably rotated, each in a vertical plane. Together, the column arcs 13 and 136 consist of vertical circles.

Although a reflection in the horizontal plane takes the combination of column arcs 13 and 136 to itself, that reflection does not interchange column arc 13 with column arc 136—neither is the reflection of the other.

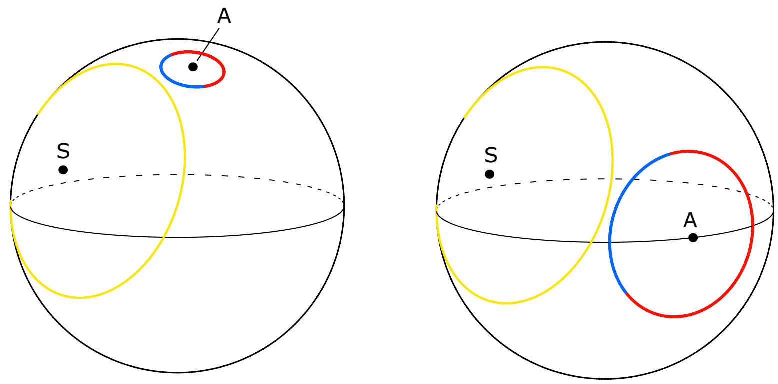

Figure 2: (*Left*) Similar to Fig. 1, with all crystal axes pointing in the direction **A**, but now **A** is no longer the zenith point. You get rotated circumzenith (blue) and Kern (red) arcs. (*Right*) Same but with **A** horizontal. The circle made up of the (rotated) circumzenith and Kern arcs is therefore vertical. Although a reflection in the plane of the horizon takes the circle to itself, the reflection does not interchange the circumzenith and the Kern arcs.

Circumhorizon, circumhorizon Kern, supralateral, and you-name-it

Now you just repeat all of the above but with ray path 32 (circumhorizon and supralateral) instead of 13, and with 362 (circumhorizon Kern and you-name-it) instead of 136. As before, this is a simplification, since there are other ray paths involved.

I will let Figs. 4–6 tell the story. The point is that Marko's new halo, that is, the column arc 362, is not exactly a reflection of the supralateral arc (column arc 32). Rather it is a kind of complement of the supralateral arc.

If you turn the middle diagram in Fig. 6 upside down, then you get something resembling the new halo in Marko's photo.

Some Parry arcs

Marko asked about the Parry arcs that would be subsets of the halos of Fig. 6. Several such arcs are shown in Fig. 7. The halos of Fig. 6 are

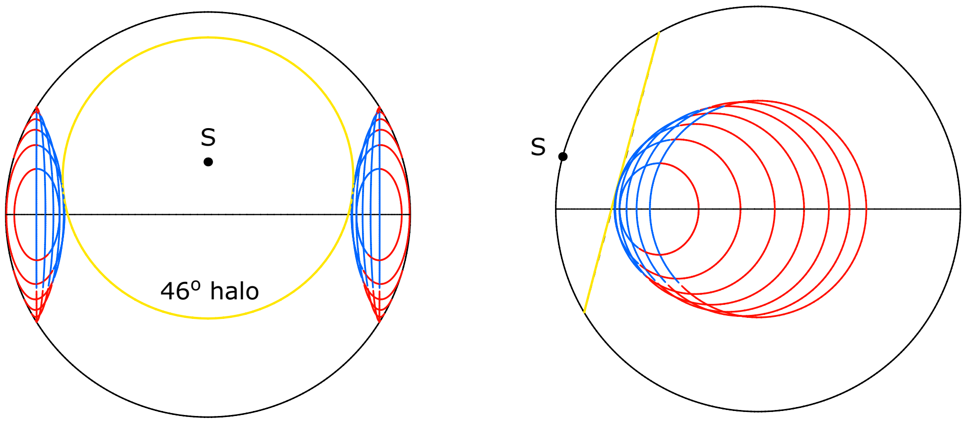

Figure 3: (*Left*) The column arc 13 (blue) and the column arc 136 (red). The former is the infralateral arc, the latter is unnamed except by its crystal orientation and ray path. Together, the two halos are made up of circles with centers on the horizon, each being similar to the blue and red circle in the right-hand diagram of Fig. 2. The sun elevation is 15°. (*Right*) Same but viewed from the right. Each circle is taken to itself by a reflection in the plane of the horizon, but the reflection does not interchange the red and blue halos.

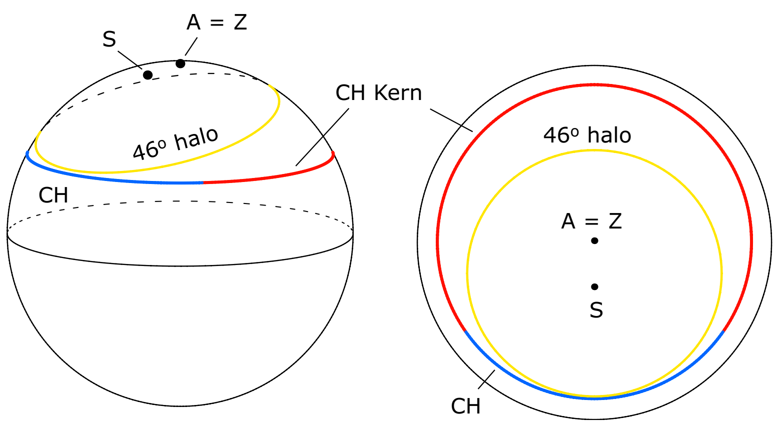

Figure 4: (*Left*) The plate arc 32 (blue) and the plate arc 362 (red). The former is the circumhorizon arc CH and the latter is the "circumhorizon Kern arc." The axis **A** of the responsible crystals coincides with the zenith point **Z**. The sun elevation is 75°. (*Right*) Same but viewed from above.

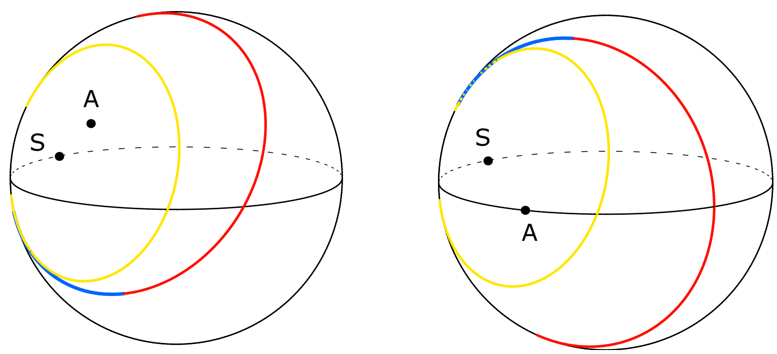

Figure 5: (*Left*) Similar to Fig. 4, with all crystal axes pointing in the direction **A**, but now **A** is no longer the zenith point. You get rotated circumhorizon (blue) and circumhorizon Kern (red) arcs. The sun elevation is 15°. (*Right*) Same but with **A** horizontal. The circle made up of the (rotated) circumhorizon and circumhorizon Kern arcs is therefore vertical. Although a reflection in the plane of the horizon takes the circle to itself, the reflection does not interchange the circumhorizon and the circumhorizon Kern arcs.

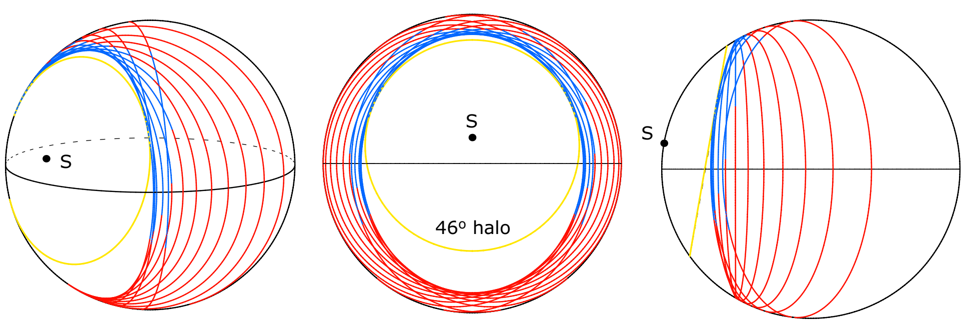

Figure 6: The column arc 32 (blue) and the column arc 362 (red). The former is the supralateral arc, the latter is as yet unnamed, except by its crystal orientation and ray path. Together, the two halos are made up of circles with centers on the horizon, each being similar to the blue and red circle in the right-hand diagram of Fig. 5. Each circle is taken to itself by a reflection in the plane of the horizon, but the reflection does not interchange the red and blue halos. The sun elevation is 10°.

included as well, but now in light black rather than in blue and red.[2]

The Parry arcs 32 (circumzenith arc), 42, and 72 are familiar (?) 46° Parry arcs. Figure 8 illustrates how some of the other arcs in Fig. 7 are related to them. In the upper left diagram, for example, you see that the line segment from the sun **S** to the halo point $\mathbf{H}_{42}$ is in the direction[3] of the normal vector $\mathbf{N}_4$ to crystal face 4, and the segment from $\mathbf{H}_{42}$ to $\mathbf{H}_{482}$ is in the direction of $\mathbf{N}_8$. To see why this magic works, please read about light point diagrams in Ref. [1].

The diagrams in this article are not simulations. There is virtually no intensity information in them, and, in particular, shielding by crystal faces is ignored. Perhaps one of you would like to run a simulation in order to see how many of the arcs in Fig. 7 you can get to show up. You would want to filter the simulation to allow only prism-basal and prism-prism-basal ray paths. And you would want to customize the crystal shapes in various ways, without, of course, changing interfacial angles. Some of the resulting crystals would be hard-pressed to fall with Parry orientations, so this exercise would be more for amusement than for guidance for observers.

There is plenty of potential for error in these figures, so everything needs to be checked. Please say so if you find bugs.

References

[1] Walter Tape and Jarmo Moilanen. *Atmospheric Halos and the Search for Angle x*. American Geophysical Union, Washington, D.C., 2006.

[2] The blue and red coloring would be relevant for the upper right diagram in Fig. 8 but not for the other three diagrams.

[3] More precisely, it is the *projection*, onto the plane of the paper, of the segment from **S** to $\mathbf{H}_{42}$ that is in the direction of $\mathbf{N}_4$.

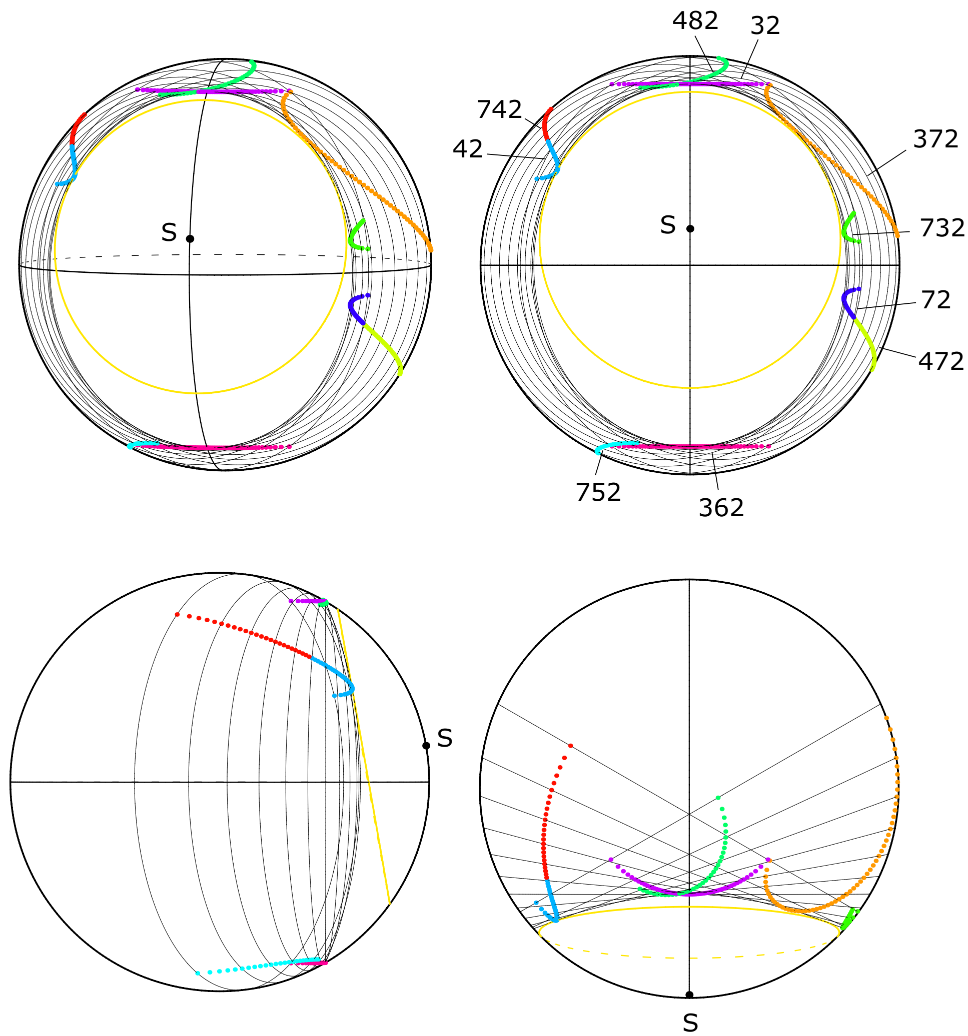

Figure 7: Some 46° Parry arcs associated with the two halos of Fig. 6, the latter being blue and red in that figure, light black here. The four diagrams here are the same as each other except for the viewpoint. We are seeing the celestial sphere from the outside, so the Parry arc 42, for example, when seen from inside the sphere, is actually a *right* Parry arc. The yellow circle centered on the sun **S** is the 46° halo as usual. The sun elevation is 10°.

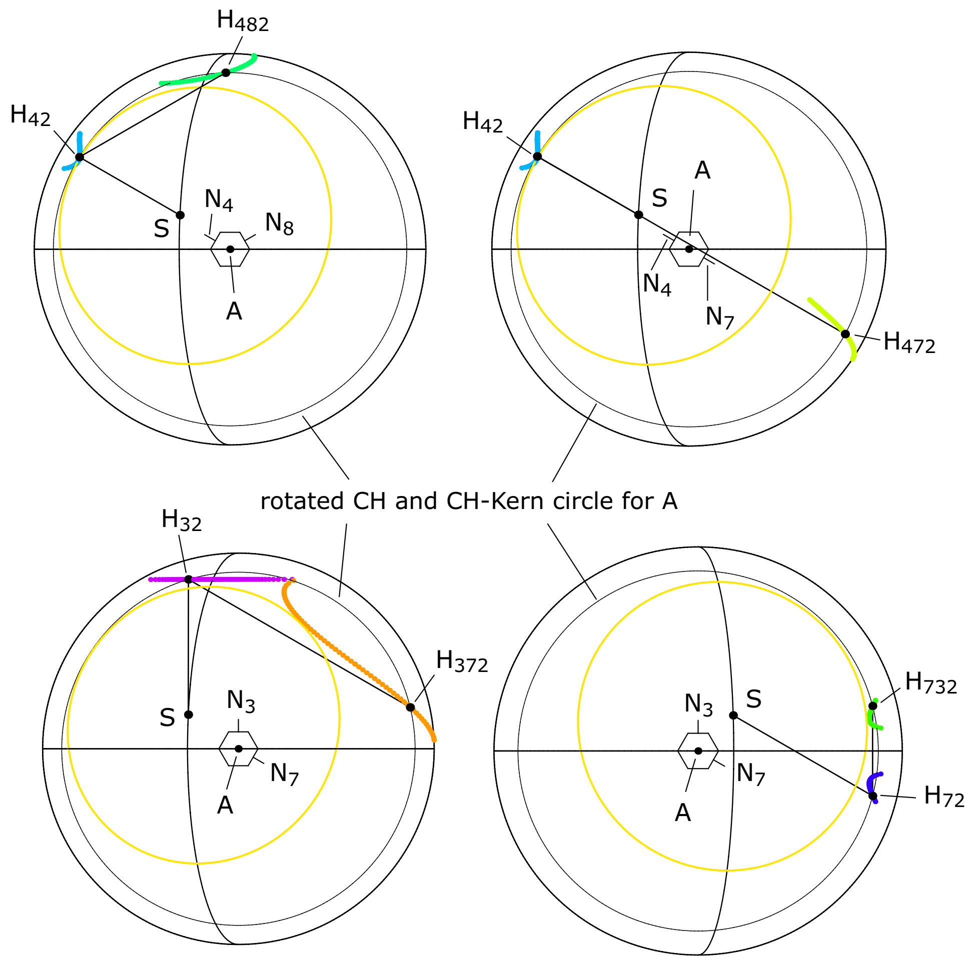

Figure 8: (*Top left*) Illustrating the relation between the 46° Parry arcs 42 and 482. The points $\mathbf{H}_{42}$ and $\mathbf{H}_{482}$ are the respective halo points arising in a Parry-oriented crystal with principal axis $\mathbf{A}$ ($= \mathbf{N}_1$) as shown, with $\mathbf{A}$ seen end-on. The points $\mathbf{H}_{42}$ and $\mathbf{H}_{482}$ are just as if the crystal orientations were plate orientations and $\mathbf{A}$ were the zenith. The sun elevation is 10°. (*Top right*) Same but for the Parry arcs 42 and 472. (*Bottom left*) For the Parry arcs 32 and 372. (*Bottom right*) For the Parry arcs 72 and 732. The point $\mathbf{A}$ is the same in the first three diagrams but different in the fourth.