particular impression of plasticity, which the Porro binocular is offering, and which has been referred to as true »3D-imaging«, can be a pleasant experience, sometimes more rewarding than certain measures of fine tuning invested by the manufacturers to minimize optical aberrations.

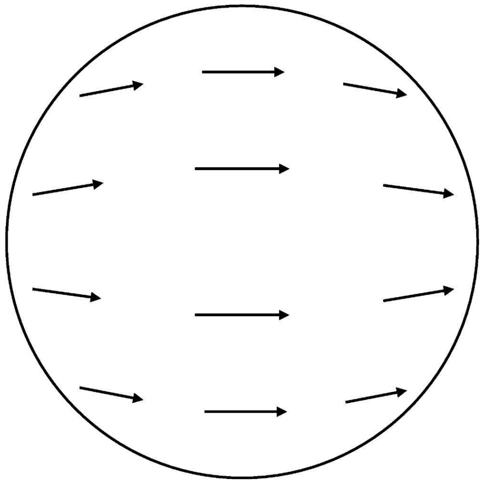
10.10 Distortion and globe effect

In 1827, G.B. Airy defined the condition under which an optical instrument had to be regarded free of rectilinear distortion[16]. This so called tangent condition has been mentioned above (section 4.1.4); it relates the half-angle A of an object (with respect to the line of view) to the half-angle a of its image (to the center of field):

$$\tan a = m \tan A \,, \qquad (10.43)$$

with m being the magnification of the binocular (or telescope). Before 1950, most binoculars were designed, whenever possible, closely around this recipe, and their images thus were – as per definition – free of distortion. Surprisingly, user complaints persisted about an unpleasant feature of these images when the binoculars were panned. This *globe effect*, also known as *rolling ball effect*, makes the image appear to roll over a convex surface. Users have reported side effects of this optical illusion, ranging from minor irritations to symptoms of motion sickness. In any case, the emergence of unnatural motion patterns during panning was running a danger of masking true movements in the field that was under surveillance, and had to be addressed accordingly.

The origin of this apparent rolling motion of an image, which – when static – seemed distortion free, remained unclear. Zeiss designer H. Köhler speculated about »unnatural perspective shifts among motives that were scattered over a three-dimensional landscape«[17], but he failed to notice that the same effect occurred under the night sky as well – conditions, under which perspective shifts could be excluded.



10.20

Optical flow during a horizontal scanning motion, in the presence of barrel distortion (schematic).

Only recently, the author of this book has pointed out a possible connection between the globe effect and the barrel distortion of the visual field (as discussed in section 9.6): Computer simulations have shown that the amount of visual barrel distortion would suffice to generate the impression of a globe effect in perfect absence of any instrumental distortion[18]. Figure 10.20 displays the optical flow field of image points, when barrel distortion enters the image chain. The point is that it is the visual perception, not the instrument, which is the source of that distortion. According to simulation results, a globe effect may arise once the visual distortion parameter, as introduced in equation (9.12), assumes

[16] George Biddell Airy, *On the spherical aberration of the eyepieces of telescopes*, Cambr. Phil. Trans. **3**, p. 1 (1827).

[17] H. Köhler, *Grundsätzliches zum Fernrohrsehen*, Deutsche Optische Wochenschrift **35**, S. 41 (1949).

[18] H. Merlitz, *Distortion of binoculars revisited: Does the sweet spot exist?*, J. Opt. Soc. Am. A **27**, p. 50 (2010).