A Bristol (U.K.) sky is photographed through a "black-light sandwich," producing patterns of interference of polarized light. (From M.V. Berry, R. Bhandari and A. Klein, 1999, Black plastic sandwiches demonstrating biaxial anisotropy, *European Journal of Physics* 20:1–14.)

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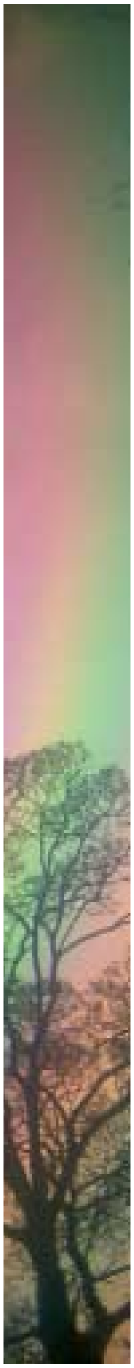

Felice Frankel

Michael Berry is a Royal Society Research Professor in the physics department at the University of Bristol in the U.K., where he has been for many years. He has received numerous awards, including the Dirac medals and prizes awarded by both the Institute of Physics (1990) and the International Centre for Theoretical Physics, Trieste (1996), a knighthood (1996) and the Wolf Prize in Physics (1998). Michael is a dear friend and a staunch advocate of the principle underlying Sightings*—the power of visually representing ideas in science. Here, he and I have a short conversation about one of the first images I saw of his work.*

F. F. You describe the material you used to photograph this image as "a black-light sandwich." Tell us more.

M. B. The "bread" consists of two polarizing sheets with their optic axes at right angles, and the "filling" is a sheet of transparent viewgraph foil. Different parts of the image correspond to light traveling through the sandwich in different directions. Without the filling, the polarizer closer to the camera would cut out the light transmitted by the other one, so the sandwich would appear black. But the filling acts like a transparent crystal and transforms the state of polarization so that some light gets transmitted. Inside the crystal, two light waves travel at different speeds, which depend on direction; therefore the waves get out of phase and can interfere. The colored rings are interference fringes, centered on a bull's-eye indicating a particular direction where the two speeds are the same. The black "brush" through the bull's-eye arises from a geometric peculiarity of the polarizations of the two waves.

F. F. We see a number of colors. Is there any particular information we get from those colors?

M. B. The colors always appear in the same order, as a result of the interference of light with different wavelengths. In the slightly different situation of a crystal with optical activity (twisted internal structure), the center of the bull's-eye is not black, and its color gives information about the amount of twist.

F. F. Can you tell us how you made/captured this particular image?

M. B. In optics these colored bull's-eyes are well known as "conoscopic figures." Usually they are produced by filling the sandwich with a thin slice of crystal (such as aragonite). It was Rajendra Bhandari, in his laboratory in India, who showed me how easily the bull's-eyes could be produced with transparency foil. We worked on the phenomenon with Susanne Klein. Because the bull's-eye is not localized anywhere, it always appears along with whatever the eye or camera is focused on (in this picture, it is the trees).

F. F. Did you find that visually expressing this particular phenomenon clarified some of the physics involved?

M. B. Certainly. The sandwich beautifully illustrates interference and polarization, geometric phases and an aspect of crystal optics that was historically important in the understanding of light. Moreover, it is a model for the preparation, propagation and measurement of a quantum state (of spinning photons in this case). It illustrates mathematics too: matrix algebra, needed to describe the polarization states (the sandwich can be interpreted as a nontrivial square root of zero), and singularities (the bull's-eye and the black brush). I like to discover "the arcane in the mundane," and this is one of the best examples I know.

F. F. Did new questions crop up when you actually studied this visual representation?

M. B. Yes. Seeing the bull's-eye led to a general reformulation of crystal optics, developed with Mark Dennis, making comprehensible the complications occurring when the material is absorbing and twisted as well as anisotropic. And if the polarizer farther from the eye is removed, the "open sandwich" becomes a device for revealing and exploring the polarization of the blue sky through the faint bull's-eyes that are still visible, leading to clarification of the pattern of polarization singularities in the sky (still incompletely understood after its discovery nearly 200 years ago).

F. F. When you work with a formula, do you ever actually imagine a pictorial representation of that formula, or is it a different kind of thinking?

M. B. When I was starting out as a physicist, I thought sequentially and algebraically. But, under the influence of a strong geometric culture in the Bristol physics department, I soon learned to visualize much of the mathematics I needed to use, to the benefit of my physical understanding. This process accelerated in the late 1980s, with easy computer visualizations made possible by Mathematica, etc. Peter Atkins has written: "Determining where mathematics ends and science begins is as difficult, and as pointless, as mapping the edge of a morning mist." I spend my life wandering in and out of that mist; in such obscure terrain, visualization is a very helpful navigational device.