COVER ILLUSTRATION

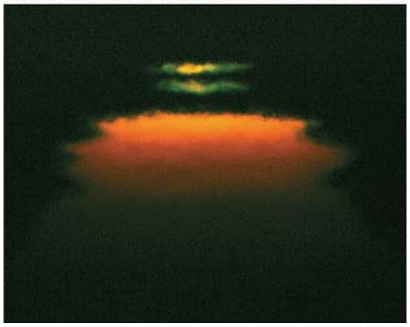
Better one or two?

As the largest terrestrial lens, the atmosphere produces myriad interesting effects, but perhaps none so fabled as the green flash. And yet, for all of its stories, its description is recent. Any society can that can construct structures like the Pyramids or Stonehenge for astronomical purposes must surely have observed the green flash, yet it was not described in writing until 1836 when Captain George Back on the HMS *Terror* wrote about seeing it while on an expedition to the Arctic (Meinel, Meinel, *Sunsets, Twilights, and Evening Skies*, Cambridge: Cambridge University Press, 1983). Later, the phenomenon was mythologised when Jules Verne wrote of it in a book entitled *Le Rayon Vert*. He described a controversial Norse legend regarding the phenomenon which states that anyone who witnesses a green flash will always be true ''in matters of the heart.'' Little evidence, however, exists that this indeed was a Norse legend.

Nevertheless, the green flash is legendary and many suspect that it does not actually exist, that it is an afterimage. This suspicion is belied by the two images on the cover showing different aspects of the same phenomenon. A camera cannot record an afterimage, and furthermore, the phenomenon has also been witnessed at dawn before sunrise. So, what else might be at work?

Our atmosphere has density that varies with altitude, but other factors can change the density too. Usually, there is a gradually declining temperature gradient with altitude, but in certain circumstances, such as presence of an inversion layer or layers, there may be significantly different, and warmer, temperatures in various cake-like layers well above the surface. This is especially true above surface features that are consistent in temperature and contour, such as large bodies of water or deserts.

Over large bodies of open water, such as the ocean, especially where there are currents creating colder than expected water, there can be significantly different temperatures in the layered atmosphere. The first few metres of air immediately above the water level will be colder than the air above it. Since air is an excellent insulator, and cold air is heavier and denser, the air mass nearest the ocean tends to stay in place even when the sun warms the air above it.



Sometimes there are even multiple layers of alternately cold and warm air, much like a wedding cake with layers of denser icing between layers of spongy cake.

Light rays are slowed and bent towards the denser medium and thus can be ducted in a curved manner. Additionally, when there are layers of cold dense air topped by warmer less dense air, the equivalent of a prism exists—an atmospheric prism.

When the sun sets, white light is directed tangentially through the earth's atmosphere towards the observer. As these light rays pass through the atmosphere, they are bent towards the surface (cooler, denser) especially over cold water. This bending of the light rays will displace the image of the sun vertically, making it appear to the observer to be higher in the sky than it actually is. Simultaneously, this white light is divided into its colour components with red being refracted the least, as the longest wavelength, and violet being refracted the most, as shortest visible wavelength. As the sun sets, red rays will be the first to disappear because the longer wavelengths are not refracted and bent as much as the shorter wavelengths. The next colour is yellow and is followed by green, blue and the last, violet. But the molecular grouping of the atmosphere will scatter shorter wavelengths more, and hence the shorter wavelengths—blue and beyond—are almost never seen. What is left, as the sun sets with the proper conditions, is a red sun, a yellow sun, and eventually a green sun or green ray or flash, although occasionally a blue flash will be seen. Visual physiology may play a subtle but meaningful part in explaining why photographs are not as brilliant as perception. The photoreceptors are a bit more sensitive to the wavelengths of green and slightly less so to red. As the sun sets, the photoreceptors sensitive to red will be stimulated to fire, and are bleached somewhat, and this adaptation will produce the sensation of a more intense green than is actually present.

Sometimes, the green flash is merely a green rim just above the sun's yellow upper limb, but sometimes it is a brief emerald green so captivating and charming as to be nearly mystical, as can be seen on the cover. There can be a variety of subtle phenomena, including rays, rims, and other ethereal sights, although these phenomena are usually very brief or very difficult to see. With proper atmospheric conditions and telescopic magnification (be careful, remember that Galileo developed solar retinopathy because of his telescopic observation of sunspots, *BJO* June 2001 cover), a green rim can frequently be seen along the upper limb of the setting or rising sun for several seconds. But remember, the green flash is just that—a quiet, peaceful, emotionally powerful glimpse so extraordinary as to be unbelievable. Perhaps that is why it was not described until Captain Back.

Our cover images, then, show two different aspects of this curious event. The photograph at the top was taken over the Malagasy strait and shows a true flash the instant after sunset. The photograph at the bottom was taken over a cold Pacific Ocean following a hot summer day with little air mass movement. This created a layered atmosphere with at least two significant layers of cold and warm air alternating with one another creating two prisms resulting in this beautiful double green flash. Both photographs were taken using a telescope. Better one or two?

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Photograph at the top by © Vic & Jen Winter (www.icstars.com). Photograph at the bottom by the author. Thanks to Jay Pasachoff for review of the essay.

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