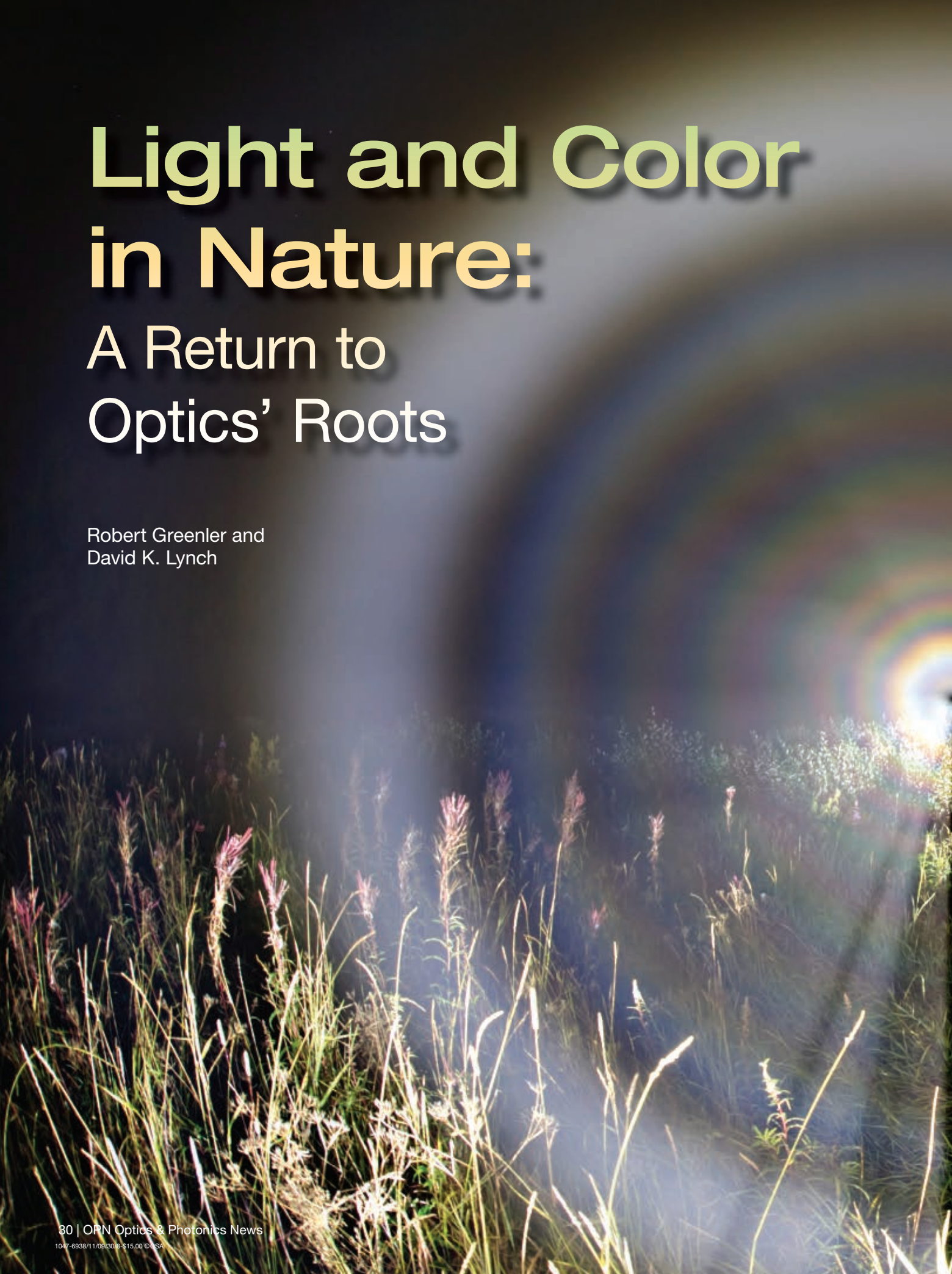
Light and Color in Nature:

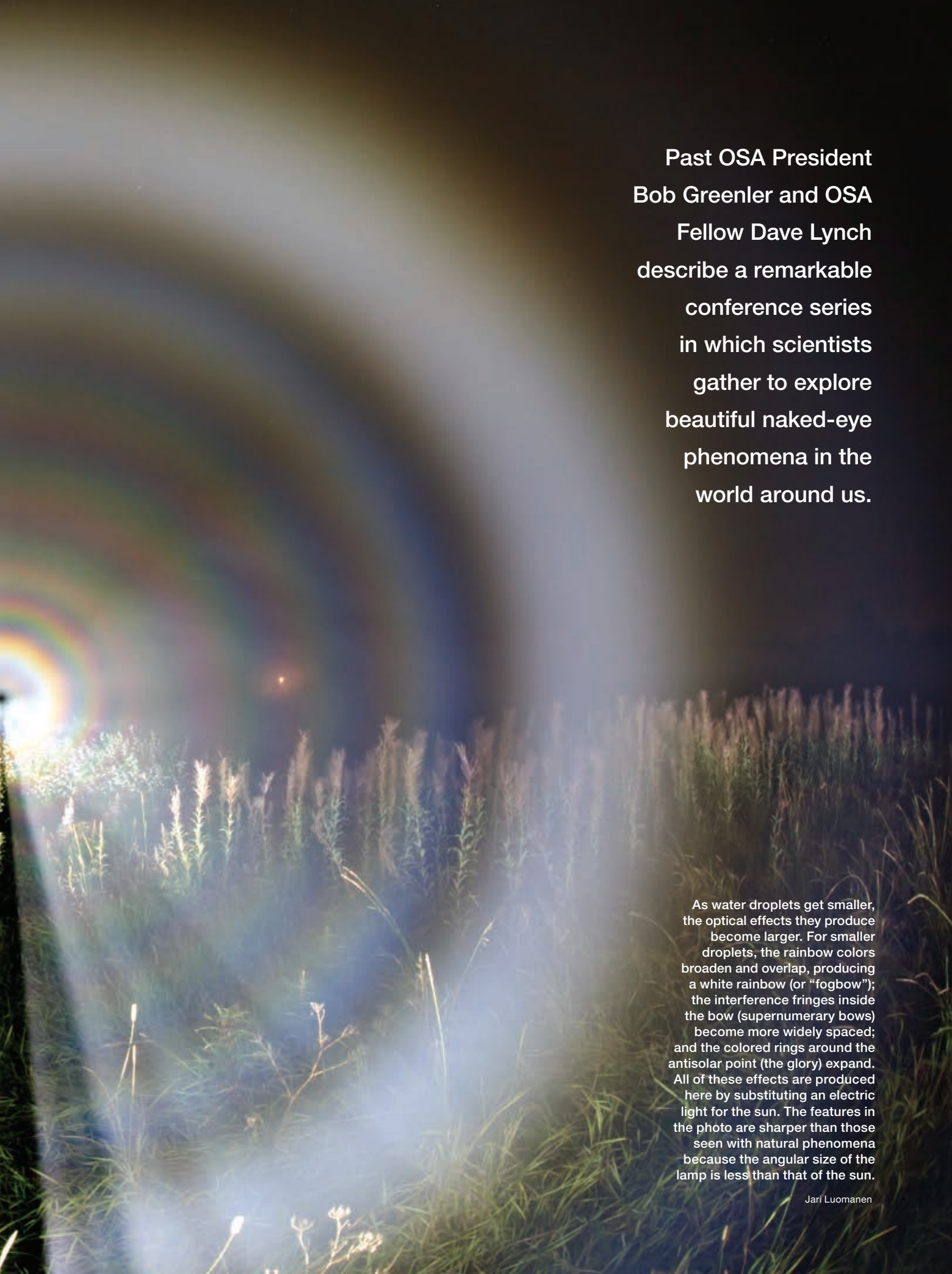
A Return to Optics' Roots

Robert Greenler and
David K. Lynch



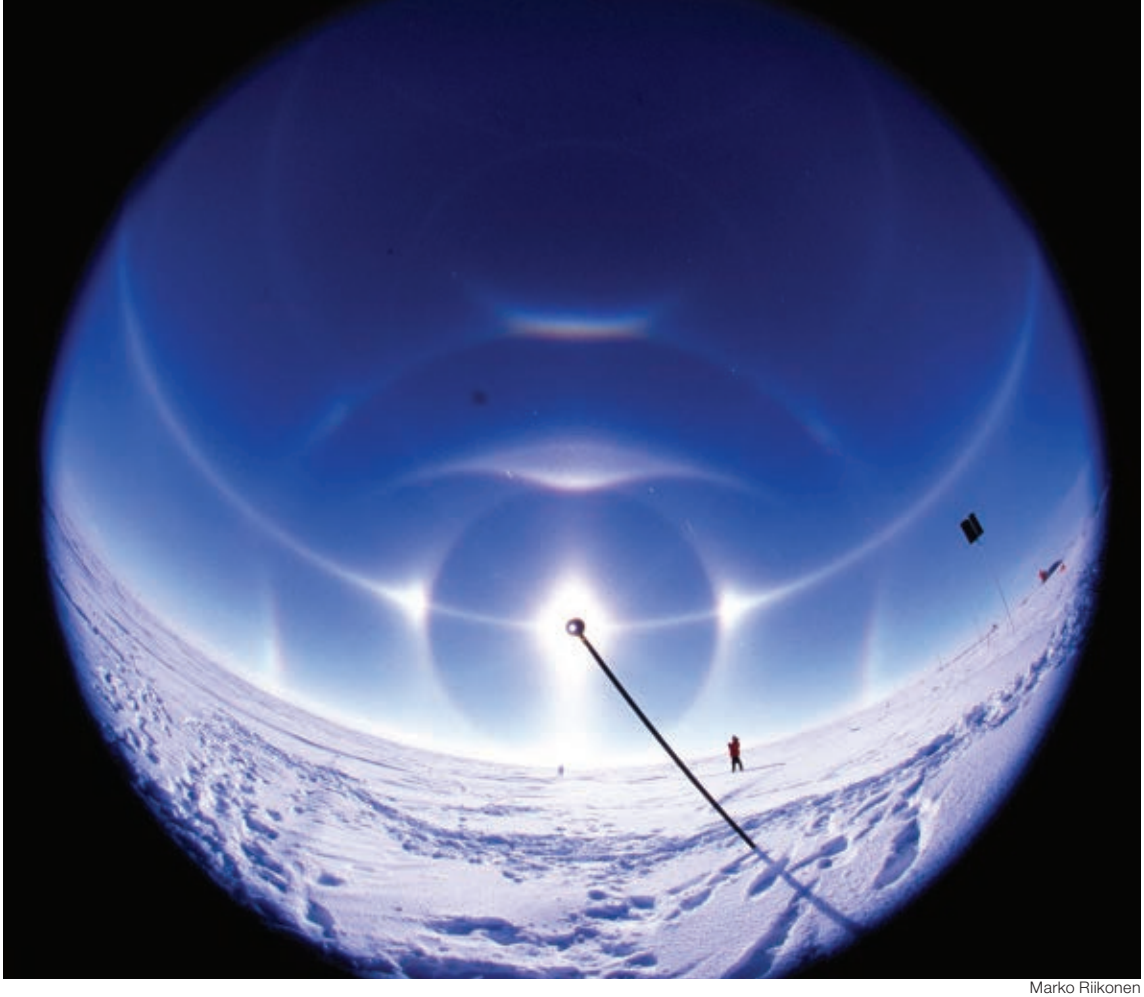
1047-6938/11/09/30/8-$15.00 ©OSA

Past OSA President Bob Greenler and OSA Fellow Dave Lynch describe a remarkable conference series in which scientists gather to explore beautiful naked-eye phenomena in the world around us.



As water droplets get smaller, the optical effects they produce become larger. For smaller droplets, the rainbow colors broaden and overlap, producing a white rainbow (or "fogbow"); the interference fringes inside the bow (supernumerary bows) become more widely spaced; and the colored rings around the antisolar point (the glory) expand. All of these effects are produced here by substituting an electric light for the sun. The features in the photo are sharper than those seen with natural phenomena because the angular size of the lamp is less than that of the sun.

Jari Luomanen



Marko Riikonen

This display of ice-crystal halo effects around the sun, photographed at the South Pole, includes at least a dozen effects, some of which have been recorded by sketches over the past few centuries. The mechanisms for many of them have only been understood for the past few decades. All are formed due to the interaction between light and airborne ice crystals in the shape of hexagonal plates or columns.

Back in the 19th century and earlier—in the days of Rayleigh, Tyndall, Maxwell and Snell—science was often conducted by natural philosophers—generalists whose primary tools were their own eyes. The subjects of their curiosity were everyday phenomena such as the blue sky, white clouds, the flattened horizon sun, haloes and mirages.

Every few years, a diverse group of scientists carries on this tradition when they gather for the international "Light and Color in Nature" conference. The meetings cover anything having to do with naked-eye optical phenomena, including rainbows, halos, reflections in water, etc. In this forum, curiosity—not job security or advancement—reigns supreme.

Participants include physicists, meteorologists, mathematicians, computer scientists, astronomers, biologists, geologists, teachers and even artists. You don't need to belong to any scientific organization to attend, and there are no vendors, workshops, parallel sessions or town hall meetings.

Although most presentations are quite technical and wind up in refereed journals, the conference is relaxed and friendly. There's free beer and no one takes themselves too seriously: The conference's highest (and only) award is the Lord Rayleigh Prize, a small plastic toy truck emblazoned with the words "Fresh Milk from Lord Rayleigh's Farm."

Begun in 1978 at the initiative of OSA Fellow David Lynch, the Light and Color in Nature meeting takes place every three or four years. The most recent one took place in St. Mary's, Md., U.S.A., in 2010, and the next will occur at the University of Alaska Fairbanks in August 2013. Although recent meetings have been arranged independently of any organization, OSA played a key role in launching these conferences: The first few were sponsored as OSA topical meetings.

Today, papers from each meeting are published as special issues in the *Journal of the Optical Society of America* or *Applied Optics*. In a number of cases, these special issues have provided the largest single-issue (non-subscription) sales for those journals. Here, David Lynch and Bob Greenler reminisce on the meeting's origins, purpose and evolution.

Bob: It is interesting to consider the connection between these gatherings and the very origins of optics, which were based on individuals' attempts to understand the world around them. The motivation was often simple curiosity. Of course, as understanding began to yield practical benefits, other incentives arose. This conference is an attempt to get back in touch with the idea that simple curiosity can be a powerful motivator for scientific discovery.

In 1954, the astronomer Marcel Minnaert inspired many optical scientists with his book *The Nature of Light and Colour in the Open Air*, a paperback translation of his original Dutch work published in 1937. The book explores optical phenomena in the sky, sea and water, and the author's constant message is to look with questioning eyes at the world around us. To this day, it remains a text that many of us refer to and treasure.

When an observer views a landscape, he or she usually sees a bright spot that is a few degrees across. This is called the opposition effect, and it is due to the absence of shadows. The average brightness of the landscape is a combination of sunlit and shaded regions. Shadows tend to be bluish because, without direct sunlight, the only light that reaches them is blue skylight.

Alan Clark

Dave: In 1977, I started wondering how I could put together an international scientific meeting devoted to "Minnaert-type" things. My main concern was that such a gathering would be considered too amateurish and therefore inappropriate for a mainstream scientific conference. I was an NSF postdoc in the physics department at Caltech at the time, and I had never organized a meeting before. But at the same time, I had published a few papers and read the literature. In addition, I was teaching a course at the UCLA extension called "Color and Light in Nature," which used Minnaert's book as a text.

So I wrote to Jarus Quinn, the executive director of the Optical Society of America at that time, and pitched the idea for the meeting. A couple of weeks later (this was in the days before e-mail), he wrote back and enthusiastically endorsed the concept. "Round up your organizing committee, figure out a tentative program and tell me what you think it will cost," he said. "If we can do it, we will."

Deciding on the organizing committee was easy. I simply picked all of my heros: Alistair Fraser (Penn State), Bob Greenler (Univ. of Wisconsin-Milwaukee), Freeman Hall and Bill Mankin (NOAA), and Bill Livingston (Kitt Peak National Observatory). I chose the name "Meteorological Optics" because R.A.R. Tricker's book *Introduction to Meteorological Optics* was the most up-to-date technical book in the field at the time.

The technical council agreed to sponsor the meeting, with the American Meteorological Society as a cooperating partner. OSA even allocated travel funds for several invited speakers,

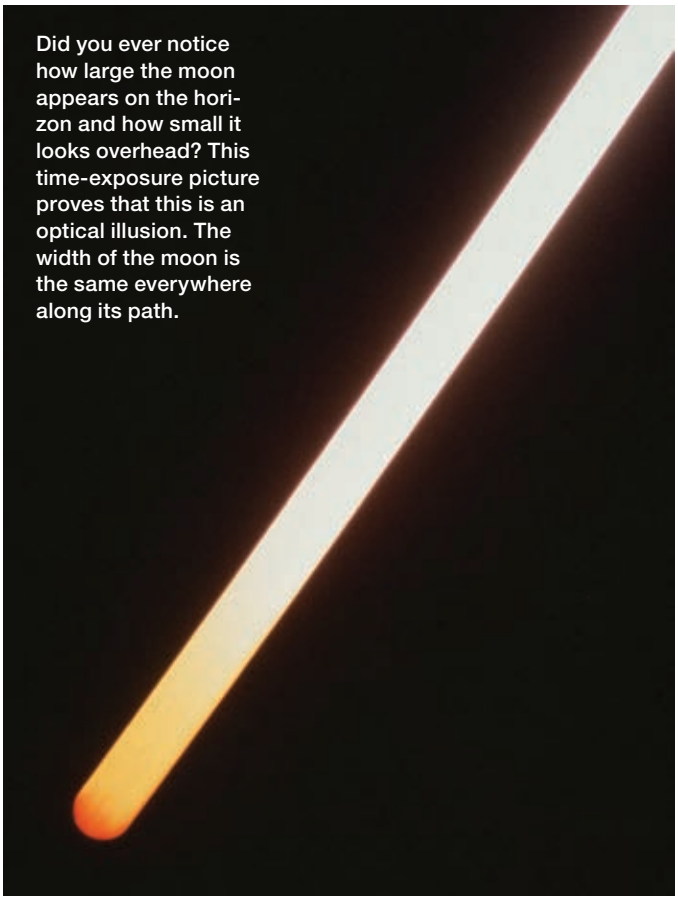
Marcel Minnaert and *The Nature of Light and Colour in the Open Air*

The Dutch astronomer Marcel Minnaert (1893-1970) was a pioneer in solar research who specialized in spectroscopy and stellar atmospheres. Like many scientists of his time, he was passionate about many things beyond his formal research topics—and one of them was the study of light and color in the natural world.

In 1937, he wrote *The Nature of Light and Colour in the Open Air*, which became a classic among researchers and was also appreciated by nature enthusiasts, amateur scientists and many others. The book, originally published in 1937 in Dutch, was released as a translated paperback in 1954, inspiring many American scientists of that era and beyond.

In the book, Minnaert discusses a wide variety of optical phenomena that can be observed in the sky, on the earth, and in the water. The common thread is that all of these things can be seen with the naked eye. He writes:

"The phenomena described in this book are partly things of everyday life, which it is fascinating to study from a scientific point of view, and partly things unfamiliar to you as yet, though they can be seen any moment if only you will touch your eyes with the magic wand of 'knowing what to see.' … However extraordinary it may seem, it remains a fact the things one notices most are the things with which one is familiar; it is very difficult to see new things, even when they are before our very eyes … and it is strange to think how blind and deaf we must be to so many things around us that posterity is bound to notice."



Did you ever notice how large the moon appears on the horizon and how small it looks overhead? This time-exposure picture proves that this is an optical illusion. The width of the moon is the same everywhere along its path.

David K. Lynch

Spider webs can show brilliant colors, especially when viewed against a dark background and in the general direction of the sun. The colors result from diffraction of sunlight around a thread and from equally spaced sticky droplets on the threads.

William C. Livingston

including H.M. Nussenzveig from Brazil. We were all just a bunch of enthusiastic people from all fields who loved naked-eye optical phenomena. That became the meeting's theme.

Bob: I would put Dave's initiative to organize the first of these meetings into a larger historical context. Many famous scientists of the earlier centuries were involved in explaining the rainbow and other optical sky effects, but in the first half of the 20th century, the investigation of beautiful sky effects seemed to go out of fashion. My impression is that several factors contributed to this decline of interest.

At the beginning of the 20th century, the attention of physicists was captured by the new quantum physics and relativity, which changed the way we looked at the world. Then, during World War II, physicists were drawn into new methods of warfare, and physics was seen as pretty serious stuff. I think the process was also influenced by the way science was supported after WW II. Government granting agencies came to play a bigger and bigger role in defining what areas of science were "serious enough" to merit grant support.

That impression was bolstered for me by a conversation I had had with an editor of the Cambridge University Press in the late 1970s. I was proposing a book, targeted to that part of the general public interested in science; I had originally thought of it as a sequel to Minnaert's book. The editor was interested. He acknowledged that, since WW II, serious scientists had become preoccupied with other topics and rarely communicated to a wide audience.

The first meeting was held in Keystone, Colo., U.S.A., and the location was perfect: a ski resort with clear days, cool nights and no city lights.

However, he told me that Cambridge had a long tradition of publishing science books written for the public by prestigious researchers such as James Jeans, Arthur Eddington and George Gamow. At a recent policy meeting, Cambridge executives had decided to revitalize this tradition and, again, publish books for the public, written by serious scientists. The timing seemed right, and thus Cambridge published my first book, *Rainbows, Halos, and Glories*, in 1980.

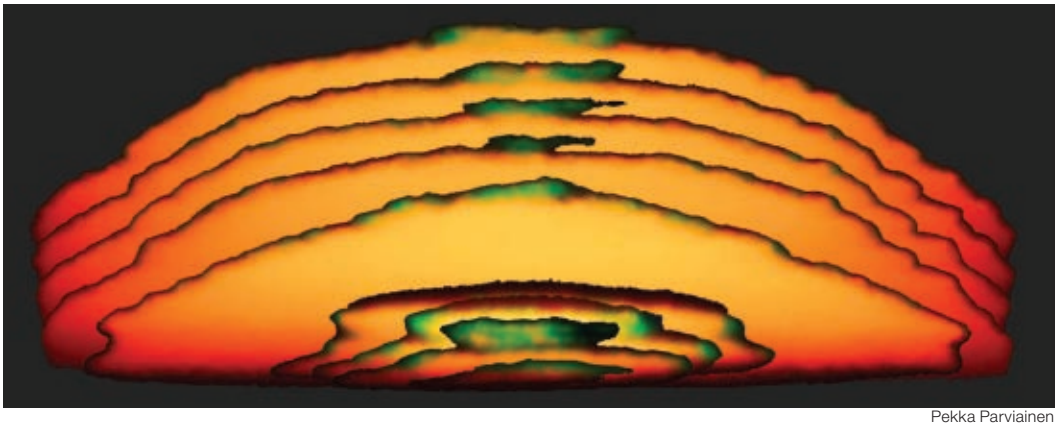
Looking back, I see a renewal of interest in optical sky phenomena that took place in the last half of the 20th century. For me the stage was set by Minnaert's book. A group of students and I started in 1965 to use the University's new computer to understand the origins of sun pillars. The computer-simulation project was begun as the result of a conversation I had had with an undergraduate student, George Blumenthal, who is currently the chancellor of the University of California, Santa Cruz. That project continued for two decades, shedding light on the origins of many ice-crystal sky phenomena.

John A. Adam

Consider this photo to be a puzzle. It involves the kind of distortion of objects often seen in reflection from a water surface, but what is going on here? This is an actual photo, unaltered in any way. If you need a hint to understand it, look at the end of this article.

Robert Greenler

This display is a form of mirage sometimes called the Fata Morgana, named after the Fairy Morgan, the legendary half-sister of King Arthur, who, with her magic, could create castles out of thin air. The Fata Morgana appears above the original object—in this case, the rough surface of distant sea ice. Inferior mirages appear below the object, like that of shimmering "water" on a highway, where the object is actually the sky above the horizon.



Pekka Parviainen

The distortions of the setting sun and the green flash have fascinated observers for centuries. Some participants in the Light and Color meetings have studied the atmospheric conditions that produce the wide variety of beautiful effects, while others have captured a catalog of low-sun effects in photographs. This is a composite from nine successive photos.

Meanwhile, Tricker published his *Introduction to Meteorological Optics* in 1970, contributing to the renaissance of interest in this area of optics. Enthusiasm for naked-eye optics was further bolstered when our group gathered for the first Light and Color in Nature meeting in 1978.

Dave: The first meeting was held in Keystone, Colo., U.S.A., and the location was perfect: a ski resort with clear days, cool nights and no city lights. Among the many fascinating presentations we heard, three have a special place in my heart: Bill Livingston's opening tribute to Marcel Minnaert, astronaut Owen Garriott's presentation of the Earth from orbit, and the now-traditional evening slide show, during which everyone showed their favorite pictures.

Never before had I seen such an exuberant group of scientists. We were like a bunch of kids who had just gotten away with something. "Despite my limited experience, it was obvious that the Keystone meeting was not a normal conference," recalled Ken Sassen, a meeting participant and, now, professor in the Geophysical Institute at the University of Alaska Fairbanks. "It may have been conducted like one, but the words eccentric, eclectic and iconoclastic came to mind; absolute legends of the scattering community attended," said Sassen, who was a postdoc at that time. "The rare mixture of experimentalists and pure and applied theorists worked."

A whole new generation of observers has been motivated to "go outside and look up."

Bob: The tenth, and most recent, meeting was held in 2010 in St. Mary's, Md. In an era dominated by big science, the activity we engaged in might seem like an anomaly. Most of the papers concerned research that was supported by modest grants if it was supported at all, and the investigations were inspired by curiosity and based on naked-eye phenomena. It was similar to the way science was done in an earlier age.

Of course, the participants conducted their research using modern techniques and technologies. With the explosion of the Internet, fast computers, spectroradiometers, digital image manipulation software and lasers, researchers have made significant progress in deepening our understanding of many optical phenomena.

Now, a whole new generation of observers has been motivated to "go outside and look up." Many new tools and websites have sprung up, notably the "Optics Picture of the Day," where photographs and optical ray-trace simulations go hand in hand.

Dave: Many natural philosophers of previous centuries were trained in one field but excelled in others—something rare today. For example, Charles Darwin had been a medical doctor, but he made his greatest scientific contributions to geology and evolution. Alfred Wegener, who provided significant early insight into ice-crystal halos, had been educated as an astronomer, but spent most of his career doing meteorology.

You can always spot these enthusiasts by their solar salute—blocking the sun with their hand in order to see a halo or corona. Here, conference participants check out the sky in Yellowstone National Park during a break in the 2007 meeting.

Joseph A. Shaw

And somehow he also found time to prove continental drift—a feat that precipitated the plate tectonics revolution of the 1960s. Descartes's greatest contributions were to philosophy, yet he invented the X-Y coordinate system and analytic geometry. While no one in our group would compare themselves to these giants, there is a certain kinship: passion and curiosity beyond the day job.

You can keep up with the planning for the next Light and Color in Nature meeting at http://LightAndColorInNature.org/. In addition, the Light and Color special issue of Applied Optics*—which will feature papers based on the 2010 Light and Color in Nature meeting—is scheduled for publication in October. Guest editors include Joseph A. Shaw, Raymond L. Lee Jr. and Philip Laven.*

Credit for the success of this series of meetings is shared, among others, with those individuals who took on the responsibilities for organizing the meetings: William Mach, Craig Bohren, Kenneth Sassen, Stanley Gedzelman, Michael Vollmer, Joseph Shaw and Charles Adler in addition to the authors. We are indebted to those who offered suggestions for this article, including many who contributed photos or offered pictures that we were unable to use for various reasons. Over the years, the Optical Society of America and the American Meteorological Society have supported the meetings, and the National Science Foundation and others have awarded small grants to facilitate travel by invited speakers.

Robert Greenler (greenler@uwm.edu) is retired from the physics department at the University of Wisconsin-Milwaukee and currently lives in Madison, Wis., U.S.A. **David K. Lynch** (david@alumni.caltech.edu) is an astronomer who studies optical effects in nature for fun.

OSA Member

[References and Resources]

Relevant Books by Meeting Participants

- R. Greenler. Rainbows, *Halos and Glories*, Cambridge University Press (1980).
- G.P. Können. *Polarized Light in Nature*, Cambridge University Press (1985), translated from the Dutch (1980).
- C. Bohren. *What Light through Yonder Window Breaks?* Dover Science Books (1987).
- W. Tape. *Atmospheric Halos*, American Geophysical Union (1994).
- D.K. Lynch and W. Livingston. *Color and Light in Nature*, Cambridge University Press (1995, 2010).
- C. Bohren. *Absorption and Scattering of Light by Small Particles*, Wiley-VCH (1998).
- R.L. Lee Jr. and A.B. Fraser. *The Rainbow Bridge: Rainbows in Art, Myth, and Science*, Pennsylvania State University Press (2001).
- C. Bohren. *Clouds in a Glass of Beer*, Dover Publications (2001).
- J.A. Adam. *Mathematics in Nature*, Princeton University Press (2003).
- M. Vollmer. *Lichtspiele in der Luft*, Spektrum Akademischer Verlag (2005).
- W. Tape and J. Moilanen. *Atmospheric Halos and the Search for Angle X*, American Geophysical Union (2006).
- G. Hoeppe and J. Stuart. *Why the Sky Is Blue: Discovering the Color of Life*, Princeton University Press (2007).
- J.A. Adam. *A Mathematical Nature Walk*, Princeton University Press (2009).

ONLINE EXTRA: Please visit www.osa-opn.org for additional photos and a list of other related books and Web resources.

A hint to understanding the photo on p. 35: View it upside down. The entire photo (except the far shore) is a reflection from the water surface that was disturbed by a rock thrown in the water by the photographer.