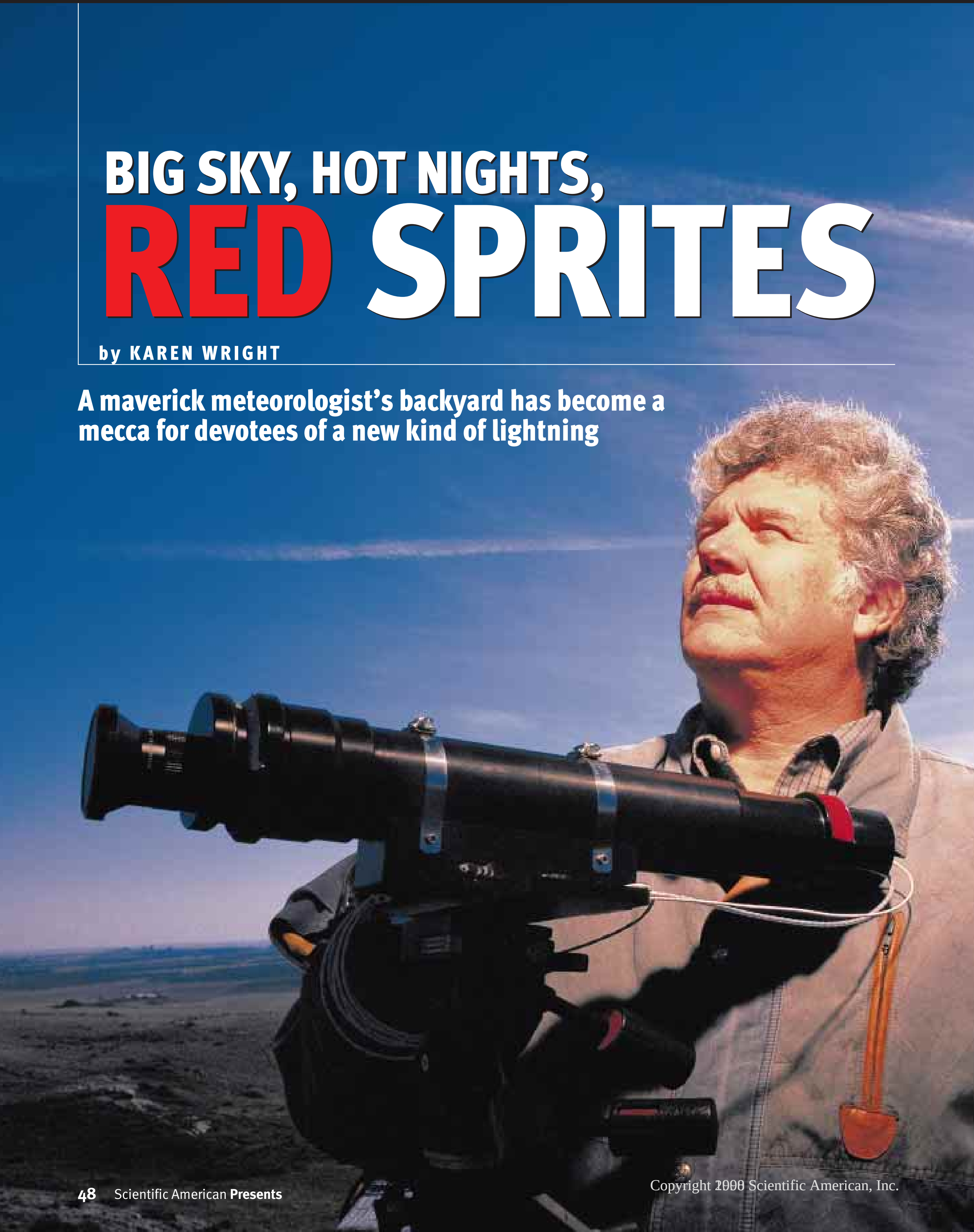
BIG SKY, HOT NIGHTS, RED SPRITES

by KAREN WRIGHT

A maverick meteorologist's backyard has become a mecca for devotees of a new kind of lightning



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When speeding along the straight arrow of State Highway 14 outside Fort Collins, Colo., it's easy to miss the turnoff onto the dirt road that runs past Walt Lyons's house. From the dirt road it's easy to miss his driveway, too, which winds up a low bluff to the east. The land here is like an open palm, its contents—prairie, farms, horses and cattle—standing in plain view. Even so, roads and houses are inconspicuous, dwarfed by the sheer scale of their expansive surroundings.

On a clear, still morning in October, it's hard to imagine summers at the Lyons place, when hordes of scientists from all over the globe converge on a rooftop deck for all-night skywatching sessions. The sky they're watching stretches from North Dakota to Texas and hosts some of the largest, most energetic thunderstorms on the planet. High above those storms, split-second flashes of colored light dance in bewitching displays that have escaped the notice of trained observers for millennia. Only a decade has passed since the phenomena—a kind of cross between lightning and auroras—were discovered. Yet they may play a pivotal role in passing energy between the earth and space, helping to maintain an ethereal network known as the global electrical circuit and making gamma rays in the bargain.

And through a combination of storm savvy, people skills and serendipity, freelance meteorologist Walt Lyons has become a central figure in efforts to understand these enigmas of the upper atmosphere. His prairie home observatory serves as both technical training ground and conceptual watering hole for the people who study them. "Never underestimate the role of pure dumb luck in science," jokes Lyons, a towering nimbus of a man with a genial smile and cloud-gray curls. He is referring to the day in 1989 when a physics professor at the University of Minnesota called to tell him about a videotape he had made

THE LONG VIEW: Walt Lyons surveys the sky from the deck of his Colorado home, which offers a panorama of the Great Plains, the vast arena for the thunderstorms that produce sprites, elves and blue jets.

STEVE STARR *SABA*

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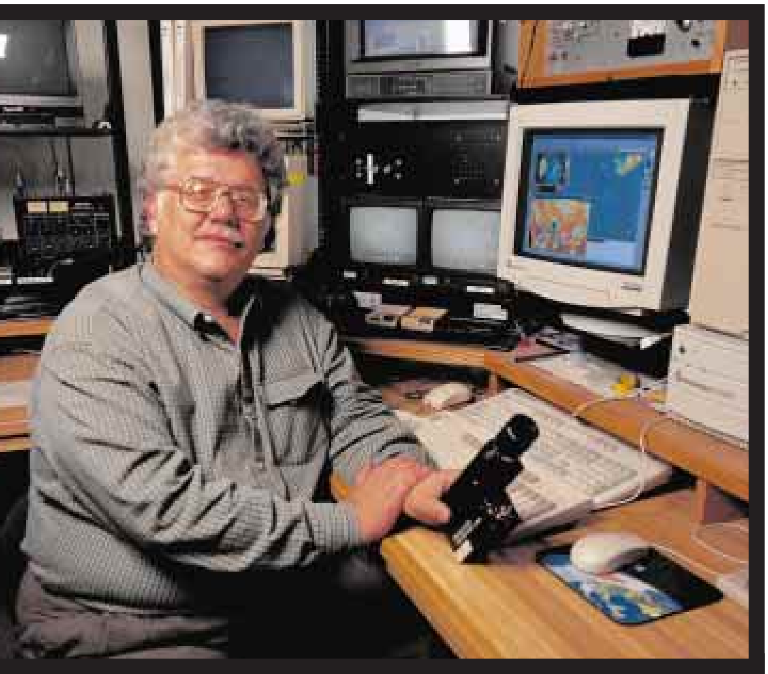

STEVE STARR SABA

SPRITE CENTRAL: The office in Lyons's house serves as a control room for sprite investigators, who come to observe from as far away as Russia, Japan and New Zealand.

while testing a low-light camera for a rocket launch. Lyons was spending his daytime hours at the university's supercomputer center developing a national lightning-detection network and his nights at a local TV station doing the weather for the evening news. His colleague John R. Winckler wanted to show him a frame of the tape that seemed to have captured by chance the image of a giant column of light rising above a thunderstorm near the Canadian border.

On viewing Winckler's video, Lyons decided that the strange light show was no technical glitch. He had heard rumors of such things before, eyewitness accounts in the fringe literature of phantom lightning that apparently went upward from the tops of clouds rather than downward to the ground. Here, he recognized, was the first and only hard evidence of these sightings. "To make a long story short, this was the first time that a sprite had ever been actually caught on videotape," Lyons explains.

Stupid Hurricanes

Sprite is the name the experts later gave to the branching columns and plumes that appear above thunderclouds at heights up to 55 miles. They typically glow orange-red and last just one tenth of a second—long enough to be seen with the naked eye but not quite long enough for the viewer to be sure what has been seen. Because their light is so faint and fleeting (hence the name), catching sprites in the act proved to be a technical challenge. In the years following Winckler's report, a few dedicated teams of atmospheric researchers would document their existence using ground-based video cameras, photographs and videos taken from airplanes, and images collected from the space shuttle's payload-bay camera.

These investigations also turned up two more varieties of luminous high-altitude phenomena that came to be called elves and blue jets. Elves are enormous expanding rings of light that can extend more than 250 miles in diameter but that pulse for a millisecond at most—too briefly to be seen without special equipment. Blue jets, by far the rarest member of the menagerie, shoot up from cloudtops at speeds of more than 60 miles a second to heights of 30 miles. All three of these phenomena are now known to occur primarily in conjunction with giant storm systems called mesoscale convective complexes. These megastorms have thousands of times the cloud volume of the average thunderstorm, last up to 20 hours and make lots of lightning. "They're basically hurricanes too stupid to form over the ocean," Lyons says.

It just so happens that these giant storm complexes are responsible for much of the summer weather on the Great Plains. And it just so happens that from Yucca Ridge, his home on the range since 1990, Lyons has an outstanding view of the sky above the Great Plains. The ridge is the highest point for 20 miles, and it's all downhill to the east. Because of the rural environs, the horizon in that direction is dark at night (the only time that light from sprites and so on can be detected). These facts were not lost on Lyons when, in 1993, he got a contract from the National Aeronautics and Space Administration Kennedy Space Center to study the potential hazards to space shuttle launches posed by the newly found flashes.

Lyons suspected that his backyard might be an ideal place to catch a sprite. He borrowed a low-light video camera from a California optics company and pointed it out the window of his office on the second floor one dark and stormy night in July. "There was a big thunderstorm complex over eastern Kansas," he recalls. "You could see the lightning flashing on the horizon." He aimed above the clouds, and for two hours nothing much happened. Then, around midnight, a sudden spark broke the black field on the video monitor. A few minutes later it happened again. "By the time the sun came up, we'd seen 248 of them," Lyons declares.

By the end of the season, Lyons had taped hundreds more sprites, and his home office had earned a reputation as "Sprite Central." In the following summers, rotating squadrons of physicists, engineers, meteorologists and sundry students of the atmosphere camped out at Yucca Ridge for weeks or months, eagerly awaiting the big storms that would launch their nocturnal vigils. In the beginning they set up their equipment on Lyons's wood-shingled roof while his wife, Liv, experimented with sleep beneath it. "One night we had five people up there, plus one very big dog," Lyons remembers. In 1996 he built a 400-square-foot observation deck and expanded his office to a full-fledged control room, complete with rolling swivel chairs, stacks of computer screens and video monitors, and black cables looping down from open panels in the ceiling.

Lyons's colleagues come from as far away as Russia, Japan and New Zealand to learn how to anticipate the timing and location of sprite formation and to gather and integrate data from a variety of instrument sources. "It's an amazing collection of people—

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everything from theoreticians who have come up to see what the real world looks like, to the people working on spectroscopy, all sorts of photometric measurements, also some radio-wave propagation," Lyons says. "My job is to predict which storms are going to make sprites and tell everybody to look there."

It sounds simpler than it is. Scientists still don't agree on exactly what sprites and their kin are. Sprites and elves happen in a part of the atmosphere that was thought to be electrically inert and so wasn't of much interest—the mesosphere (or "ignorosphere," as Lyons calls it), above the meteorologically active troposphere and the ozone-laden stratosphere. Because so little is known about that part of the sky, it's not clear what effects the electric fields and electromagnetic energy generated by thunderstorms might have in the thin air above the flat tops of cloud anvils. Indeed, until sprites were discovered, most experts assumed that thunderstorm effects stopped there.

But they don't. Blue jets, according to one theory, can occur above almost any kind of storm cloud that has whipped up enough positive charge. A spark will leap between the positively charged anvil and the negatively charged air just above it, and a column of current will form above the cloud by a sort of domino effect that culminates in the release of short-wavelength photons. Yet if the chain of events is this simple, then why are blue jets so rare? What distinguishes a storm that spawns blue jets from one that doesn't?

Sprites and elves pose similar conundrums. Both are known to occur immediately after strokes of so-called positive cloud-to-ground lightning, which drain positive charge from the tops of thunderclouds as negatively charged electrons rush up from the ground. Positive lightning is the exception, not the rule: the vast majority of lightning strokes issue from the lower part of a cloud, which is negatively charged, and deliver negative charge to the ground. Positive lightning carries far more current than negative lightning does. When it flashes, it creates an electromagnetic pulse that rises in an expanding ring. The ring meets the free electrons above cloudtops, boosting their energy, and the collisions of these electrons with nitrogen molecules release the reddish light that characterizes an elf.

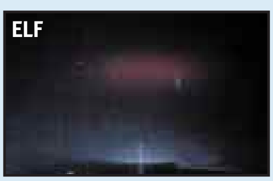
At least that's the theory hatched by physicist Umran S. Inan and his colleagues at Stanford University, who first recorded the color spectra of elves at Yucca Ridge in 1996 using a photometric array called the Fly's Eye. Designed explicitly for sprite- and elf-watching, the Fly's Eye can detect both the movement of an elf and the wavelengths of light in it—no mean feat, considering that elves come and go in less than one thousandth of a second. Based on analyses of the energetics of lightning, Inan's group had posited the existence of elves several years before finding one. "They turned out to be remarkably close to what we had predicted," Inan notes.

A-Bombs and Carmen Miranda

Sprites are the subject of the most fervid study, in part because they are more plentiful and easier to detect than their psychedelic sisters. Sprites come in a seemingly endless variety of shapes and sizes that have spawned descriptors such as broccoli sprites, octopus sprites, A-bomb sprites and Carmen Miranda sprites. They seem to be caused by an upward flow of accelerated electrons that occurs after a positive lightning stroke drains charge from the cloudtops. But how does the architecture of a thundercloud influence the shape of a sprite? And what causes the sprite "clusters" that can stretch for 200 miles and last for more than half an hour? To answer these questions, experts from a number of fields are sharing their knowledge—and confronting their ignorance.

"This area of research has broken us out of our traditional disciplines," observes Davis D. Sentman, an atmospheric researcher

DIFFERENT STROKES: CATALOGUING NEW TYPES OF LIGHTNING



Name	Color	Shape & Size	Duration	Visible to the Naked Eye
Sprite	Salmon red fading to purple or blue in lower tendrils	Blobs, columns and plumes extending from 30 up to 55 miles in altitude	10 to 100 milliseconds	Yes
Elf	Red	Flattened rings up to 250 miles in diameter rising from 45 to 60 miles in altitude	Up to 1 millisecond	No
Blue jet	Indigo blue	Narrow fountains of light shooting between 10 and 30 miles in altitude	10 to 100 milliseconds	Yes, but very rare and faint

STEPHEN B. MENDE AND R. L. RAIRDEN, COLORIZATION BY LAURIE GRACE (*sprite*); STEPHEN B. MENDE (*elf*); PATRICE HUET (*blue jet*)

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SPRITE GALLERY

COURTESY OF WALT LYONS

NAME THAT SPRITE: Researchers compete to come up with the most whimsical name for this bizarre atmospheric phenomenon.

at the University of Alaska Fairbanks who was part of the team that first photographed sprites from airplanes. “The lightning specialists know a lot about lightning, although this isn’t exactly lightning. The space and ionospheric physicists are experts in plasma physics, but this isn’t really your normal kind of plasma. And the atmospheric chemists aren’t used to dealing with the electrical aspect of chemistry, so they’re scratching their heads over it, too. It’s interdisciplinary in the extreme.”

Lyons’s colleagues credit him with creating a sense of community among these disciplines by bringing researchers together. “Walt’s big contribution was, first of all, providing a place where people could come,” Sentman comments. “He’s got all the infrastructure there that you need to do a complete study. Once we learn how to do it, working at Walt’s place, then we wander off and find our own dark place.”

“Yucca Ridge has really been a clearinghouse for the sprite work,” says physicist David M. Suszcynsky of Los Alamos National Laboratory, who witnessed the spectacle of a sprite induced by a meteor from Lyons’s deck in 1998. “Walt is kind of a spiritual leader in that sense.”

Lyons describes himself as a meteorologist by nature as well as by training. His earliest memory is of measuring snowfall as a four-year-old during a record-breaking storm in New York City that dumped three inches of the white stuff in one hour. “December 26, 1947,” Lyons relates, with the chronological precision that is his habit. Although neither of his parents were meteorologically inclined, “there was never an issue of what I was gonna be when I grew up.”

After attending St. Louis University for what was then one of the country’s rare undergraduate programs in meteorology, Lyons went on to the University of Chicago to continue his studies under the late T. Theodore Fujita, an iconoclastic weatherman who devised the F scale used to rank the ferocity of tornadoes (as featured in the movie *Twister*). Fujita emphasized a pragmatic approach to observation combined with broad thinking. “One thing I learned from Ted is that you can’t just look within one narrow discipline for answers,” Lyons says. “And the other thing I learned from Ted is simply to look out the window.”

Out the two-story windows of Lyons’s den, the Front Range of the Rockies is visible to the west and south, a hazy-gray massif sprawled under the sun’s autumn glare. But the business end of the house faces east, over the tawny, rolling fields that introduce the vast expanse of the Great Plains. The sameness of the view makes the horizon seem deceptively close. In the immediate foreground, half a dozen rare varietals of garlic grow in small brown plots, and turkeys named Thanksgiving, Christmas, New Year’s and Easter poke about in a wire pen. The garlic is part of a commercial sideline; the turkeys are for private consumption. “We can see forever from here—or at least a thousand miles,” Lyons remarks.

The pleasures of a home office in a rural setting are offset by the difficulty Lyons has had getting funding for his freelance sprite research. “The phrase ‘blood from a turnip’ comes to mind,” he concedes. Although in the course of his career he has remained loosely affiliated with academia, his official title is president of Forensic Meteorology Associates and FMA Research. He subsidizes his pet projects with government and industry contracts for pollution research and with forensic work for attorneys and insurance companies. In short, when it comes to sprites, he’s an outsider studying a freak phenomenon. “This is basic, pure science that only peripherally meets any of the [funding] agencies’ needs,” he says.

Sprite research has already overturned several fundamental assumptions about the planetary energy budget and its relationship with space. By sending columns of current into the atmospheric outback, for example, sprites are fueling the so-called global electrical circuit, an electric field maintained in air during fair weather by the difference in charge between the ionosphere and the ground. During studies of the circuit in the 1920s, Nobel Prize–winning Scottish physicist Charles T. R. Wilson proposed that upward flows of current probably accompany the downward discharges in thunderstorms and that such flows might glow at high altitudes. Wilson even claimed to have witnessed such an event in 1956, but his speculations on the subject were largely ignored. Now it seems that sprites do in fact deliver current to the upper atmosphere and that they may cause localized disturbances in the chemical and electrical properties

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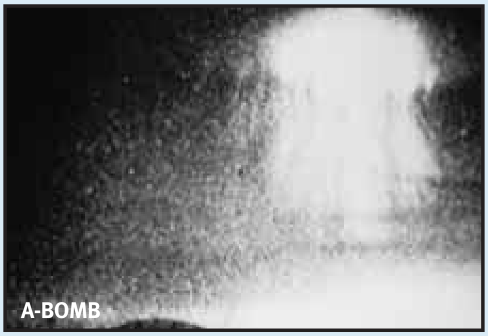

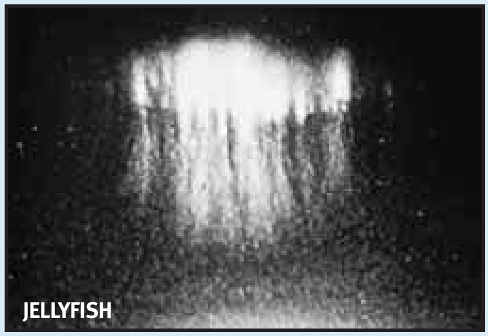

of the ionosphere. They may also be contributing high-energy particles to the Van Allen radiation belts that surround the earth; researchers used to believe that these particles came exclusively from the sun. "Sprites provide visible evidence that electrical effects extend all the way up into space," Sentman observes.

Homegrown Gamma Rays

In a truly remarkable development, sprites are now suspected of generating gamma rays, the most energetic radiation in the universe. Before the discovery of sprites, all gamma-ray sources were presumed to be buried in deep space. In 1994, though, a satellite observer detected bursts that seemed to be emanating from the earth's atmosphere. Acting on a hunch, Inan and his colleagues later matched the timing of such bursts to that of sprite-producing lightning bolts. The evidence, though circumstantial, suggests that sprites give rise to high-energy beams of "runaway" electrons, Inan says, that create gamma rays as they dodge molecules in the air.

Skeptics point out that the number of homegrown gamma rays seems to be a small fraction of the number of sprites produced. But current satellites can barely see earth-generated rays, Inan comments, because they are designed to detect rays coming from space. "We think there may be a whole lot of gamma rays out there waiting to be detected," he notes.

No one's sure yet just how many sprites are happening around the world, either. To answer that question, one of Lyons's closest collaborators, Massachusetts Institute of Technology physicist Earle R. Williams, is conducting a sprite census by monitoring fluctuations in ultralow-frequency radio waves. Ordinary lightning strokes, which occur at a rate of about 100 per second worldwide, produce a constant radio "hum" in the earth's atmosphere at these ultralow frequencies. During a long telephone conversation one night in 1994, Williams and Lyons discovered that each sprite Lyons observed from Yucca Ridge corresponded with an abrupt spike in the radio hum that Williams was reading at his oscilloscope station in the Rhode Island woods. The source of these spikes, called Q-bursts, had eluded physicists for decades. Williams has since determined that the Q-bursts occur because sprite-producing lightning strokes last thousands of times longer than ordinary lightning strokes, making an extralong pulse of electromagnetic energy that synchronizes with and amplifies the extralong radio waves.

"Sprite lightning is the biggest lightning on the earth's surface, in the biggest storms on the earth's surface," Williams marvels. "Every time there's a sprite, the whole earth resonates—it rings—for some fraction of a second." This resonance can be detected with equipment positioned almost anywhere on the planet. According to Williams's studies, sprites probably occur somewhere on the earth every 30 seconds or so.

Whereas experts like Williams stick to their specialized domains, Lyons has made it his mission to champion storm observations rather than abstract notions of upper-atmosphere effects. He's convinced that a more detailed understanding of thundercloud architecture and the electrical forces within will help reveal the secrets of sprites. Paul R. Krehbiel of the New Mexico Institute of Mining and Technology is already planning remote sensing of the lightning patterns within clouds to help expand knowledge of thunderstorm dynamics. Lyons points out: "That will keep the theorists from running off and saying silly things."

Meanwhile the theoretical disarray that plagues research on sprites, elves and blue jets is evident in the difficulty experts have had in coming up with a single name for the electromagnetic menagerie. "Above-ground discharges" was popular for a while, Los Alamos's Suszcynsky remarks, although sprites and whatnot probably aren't discharges in the usual sense. "So we gave up on that name." "Cloud-to-stratosphere discharge" suffered a similar fate. "They don't always go from the cloud up to the stratosphere," he says. "Certain parts go from the stratosphere down to the cloud." Ditto for "upward lightning."

Lyons recounts that he was happily deploying the acronym TLEs, for transient luminous events, until a colleague pointed out that "transient electromagnetic events" would better describe the full range of observed phenomena. So Lyons switched to TEEs. Then a friend at the National Oceanic and Atmospheric Administration told him that TEEs may also produce acoustic signals, at infrasound frequencies of several hertz, as well as electromagnetic emissions. "We may be able to hear them, too!" Lyons enthuses. But name them? Not yet. W

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