Roussel-Dupre says that sprites may need an explanation in two parts—top and bottom. To account for sprites from the waist down, he invokes an otherworldly connection—cosmic rays.

Raining continuously on Earth from space, cosmic rays pack so much energy that they shatter molecules in the upper atmosphere and generate a maelstrom of subatomic fragments and radiation that fizzles out at about the height of clouds.

With cosmic rays in the picture, says Roussel-Dupre, the length and color of angels' skirts could explain another vexing conundrum: Bursts of gamma rays hurtling out of the atmosphere from the vicinity of thunderstorms. Satellites have detected the bursts.

In the atmosphere, only cosmic ray impacts could provide the energy it takes to produce gamma rays, Roussel-Dupre says. Furthermore, only a massive electric field—such as that created by a positive lightning stroke—could turn this energy around and send it flying back in the direction from which it came.

The question remains whether this scenario happens within sprites. The observation that gamma rays emanate from thunderstorms is suggestive evidence, he says, but not proof.

Roussel-Dupre and his colleagues presented calculations in the March 15, 1999 GEOPHYSICAL RESEARCH LETTERS. They reported that they can explain both the amount of gamma rays that satellites have detected and the blue tendrils that sprite watchers have seen.

Their calculations also explain why the process would occur only in the lower part of sprites, Roussel-Dupre says. The particles that come hurtling upward from thunderstorms are by-products of cosmic ray collisions and not the cosmic rays themselves, he says. They're electrons, careering at nearly the speed of light, that start heading upward on a lucky rebound. Only the high-intensity field created fleetingly by a positive lightning stroke can sustain this upward momentum, he says.

This sustenance runs out because Earth's magnetic field pushes electrons sideways, out of the cloud's influence, particularly when the electrons are moving fast. At the latitudes of the Great Plains, where observers usually search for sprites, this happens at midsprite height, Roussel-Dupre says.

Siefring notes that theorists are doing well at explaining the details of sprites as they've emerged, but he hopes to see their hypotheses put through more of a shakedown. "Right now," he says, "a theoretician can choose any [electric] field he or she wants because no one's measured it."

Siefring says he endorses the grand designs of Edgar A. Bering, a physicist at the University of Houston. Last summer, Bering organized about half the world's sprite-analyzing talent, by Lyons' reckoning, for an observational campaign centered on the Great Plains.

About 40 space and terrestrial scientists at mountain-top observatories, field stations, and an airport in Otumwa, Iowa, coordinated their efforts as an unmanned NASA balloon lofted a panoply of instrumentation through the ozone layer to an altitude of 32 km—more than three times as high as commercial jets fly. The balloon lifted off as thunderstorms formed on the eastern slopes of the Rockies.

The results of that enterprise have only started to emerge. On the basis of data Bering has seen, however, he predicts that theorists indeed will face some new work.

"I don't think many of the extant models are going to survive confrontation with our data," says Bering.

An air of mystery may surround sprites for a while longer. □

Mathematics

Losing to win

It's a gift to born losers. Researchers have demonstrated that two games of chance, each guaranteed to give a player a predominance of losses in the long term, can add up to a winning outcome if the player alternates randomly between the two games.

This striking new result in game theory is now called Parrondo's paradox, after its discoverer, Juan M.R. Parrondo, a physicist at the Universidad Complutense de Madrid in Spain. Gregory P. Harmer and Derek Abbott of the University of Adelaide in Australia use a combination of two losing gambling games to illustrate this counterintuitive phenomenon in the Dec. 23/30, 1999 NATURE.

The two games involve tossing biased coins. In the simpler game, the player gambles with a coin that's been loaded to make the probability of winning less than 50 percent. The second, more complicated game requires two biased coins. One of the coins wins slightly more often than it loses, and the other loses much more often than it wins. The game is set up so that even though the winning coin is tossed more often, that is outweighed by the much lower probability of winning with the other coin.

Played repeatedly, each game on its own gradually depletes a player's capital. It turns out, however, that randomly switching between the games results in a steady increase in capital.

Alternating between the games produces a ratchetlike effect. Imagine an uphill slope with its steepness related to a coin's bias. Winning means moving uphill. In the single-coin game, the slope is smooth, and in the two-coin game, the slope has a sawtooth profile. Going from one game to the other is like switching between smooth and sawtooth profiles. In effect, any winnings that happen to come along are trapped by the switch to the other game before subsequent repetitions of the original game can contribute to the otherwise inevitable decline.

"There are actually many ways to construct such gambling scenarios," Harmer and Abbott note. The researchers also suggest that similar strategies may operate in the economic, social, or ecological realms to extract benefits from what look like detrimental situations. —*I.P.*

Squares, primes, and proofs

In studying whole numbers, mathematicians have discovered a variety of surprising patterns. One of the most important results of elementary number theory is the so-called law of quadratic reciprocity, which links prime numbers (those evenly divisible only by themselves and one) and perfect squares (whole numbers multiplied by themselves).

For a positive integer, d, the law describes the primes, p, for which there exists a number x such that dividing the square of x by p gives the same remainder as dividing d by p. For example, if p is 23 and d is 3, there's a solution when x is 7. Dividing 7^2, or 49, by 23 leaves the remainder 3, as does dividing 3 by 23. The law specifies the relationship that must hold between p and d for an x to exist.

Mathematicians have sought to generalize the law to cover cases such as when the numbers are not squares but cubes or larger powers. In the late 1960s, Robert Langlands, now at the Institute for Advanced Study in Princeton, N.J., described how such reciprocity laws might work in a general context in number theory, in which integers represent a special case.

Michael Harris of the University of Paris VII and Richard Taylor of Harvard University recently proved this conjecture, called the "local Langlands correspondence." It was also independently established as a theorem shortly afterward by Guy Henniart of the University of Paris–South.

The proof of the theorem "in full generality represents a milestone in algebraic number theory," mathematician Jonathan Rogawski of the University of California, Los Angeles remarks in the January NOTICES OF THE AMERICAN MATHEMATICAL SOCIETY. —*I.P.*