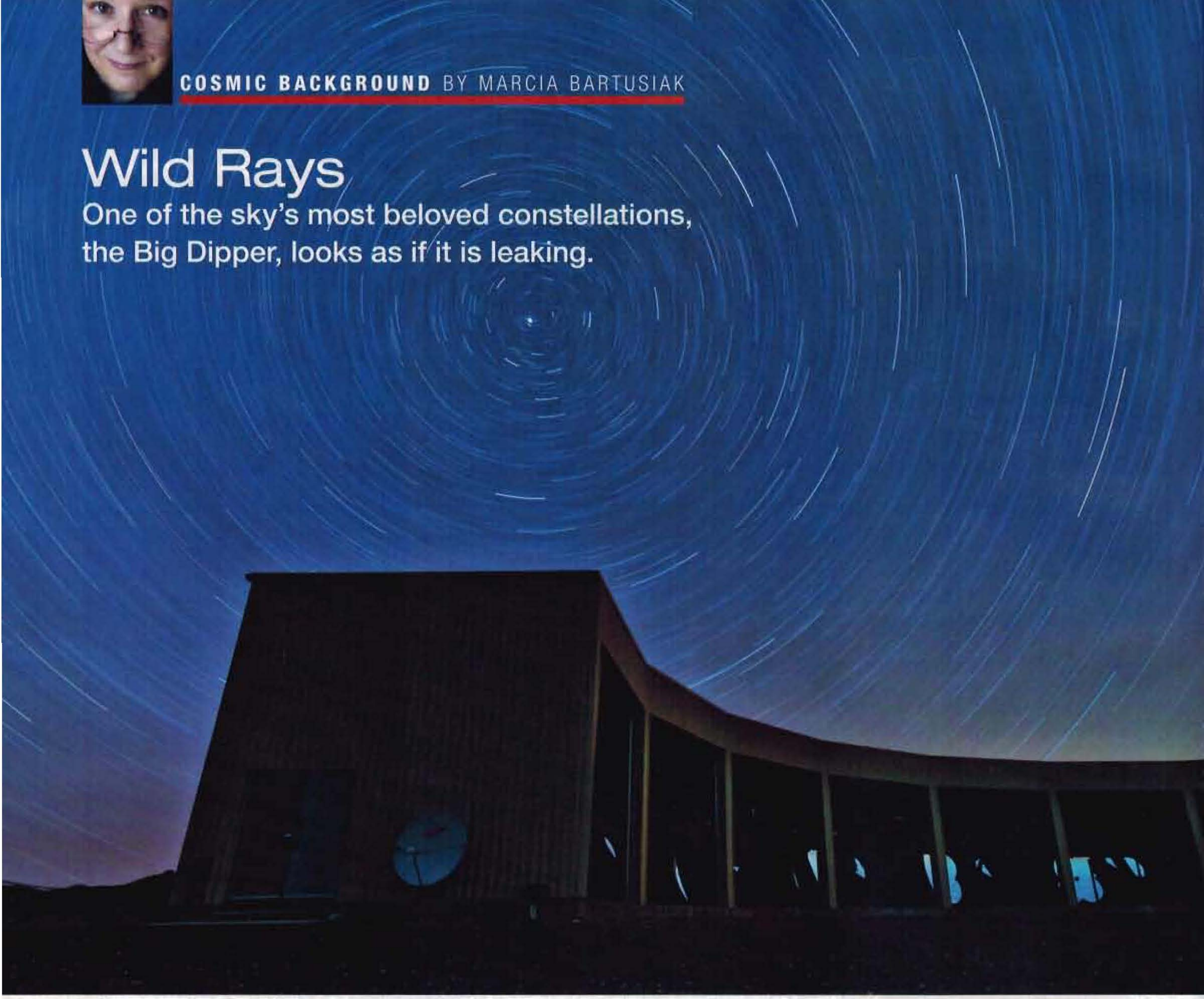
Wild Rays

One of the sky's most beloved constellations, the Big Dipper, looks as if it is leaking.



One year after it opened in 2007, the northern hemisphere's largest cosmic-ray detector, the Telescope Array, situated in western Utah, began observing a relatively large number of ultra-high-energy cosmic rays emanating from just below the handle of the Big Dipper. What might be the exact cause of this "hotspot" of rays? Even after nearly six years of observation and study, no one knows for sure. "All we see is a blob in the sky," says University of Utah astrophysicist Gordon B. Thomson, "and inside this blob there is all sorts of stuff—various types of objects—that could be the source."

An international team of astronomers found the hotspot by tracking a cascade of secondary particles that showered down upon the Earth and were captured by the Telescope Array when particularly powerful cosmic rays—those above 57 billion billion electron volts (14 million times the energy of the particles accelerated recently in the Large Hadron Collider)—hit the atmosphere. The array, a high-tech wonder, consists of more than 500 scintillation detectors, each about the size of a ping-pong table, spread out over 300 square miles of desert like myriad chess pieces. Positioned around these detectors are three stations, each with a set of mirrors watching for blue flashes created by incoming cosmic rays. [*See photograph above.*] It's a modern-day method that's a far cry from the cruder instruments used by cosmic-ray observers a century ago, when cosmic rays were first discovered.

At the start of the twentieth century, researchers were only just discovering that charged ions reside in the air. Did this ionization originate from the Earth's crust, they wondered, or from radioactivity within the atmosphere, or from *out there*, the atoms getting ionized by some type of radiation journeying from the Sun?

BEN STOKES, UNIVERSITY OF UTAH

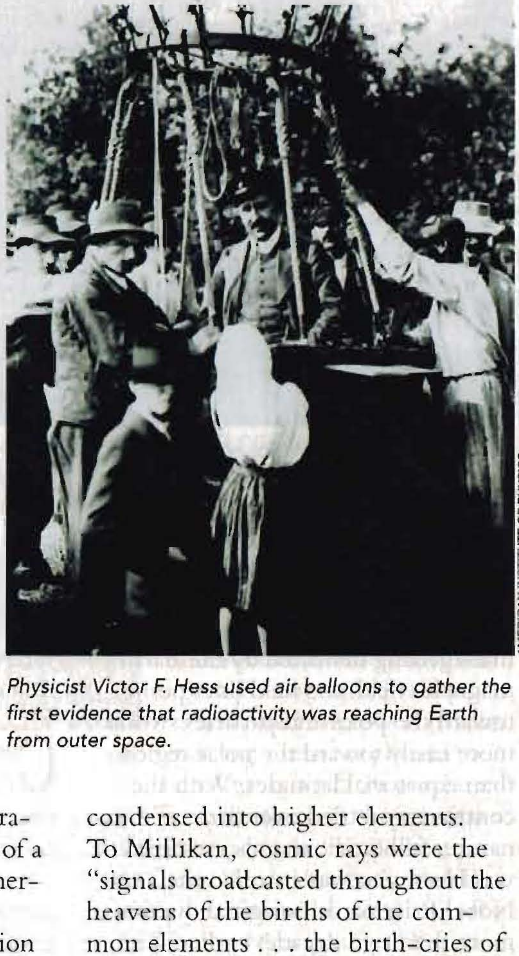
A mirror station in the University of Utah's Telescope Array helped detect a cosmic-ray hotspot near the handle of the Big Dipper.

Fascinated by this mystery, Theodor Wulf, a German priest and physicist, built a sensitive electroscope (the era's standard charge detector consisting of wires or metal leaves suspended in a vessel) and, while on a trip to Paris in 1910, took his new instrument to the top of the Eiffel Tower, then the world's tallest structure. Figuring the radiation emanated from the ground, he expected to measure a far weaker signal nearly one thousand feet above the cityscape. But instead his signal was surprisingly strong. Perhaps, Wulf mused, it was coming from radioactive iron within the tower's ornate lattice.

Continuing this quest, a number of scientists started taking measurements aboard balloons, which could reach higher altitudes, but their results were contradictory. It was Austria's Victor Francis Hess who gathered the first convincing evidence that the radiation was arriving from outer space [*see image below*]. Hess, an ardent amateur balloonist, was a physicist at the newly opened Institute for Radium Research in Vienna. His moment of discovery came on August 7, 1912, after he and two companions took off in a hydrogen-filled balloon from the Bohemian town of Aussig for the seventh in a series of flights he had been conducting that year. Using three electrometers of improved accuracy, he detected a noticeable increase in his ionization readings as his balloon rose to an altitude of 3.3 miles. In fact, the ionization was three times higher than on the ground. Hess knew he was too far up for this radiation to be arriving from below. That meant it must be *Höhenstrahlung*, as he called it, "radiation coming from above."

This was not a Eureka moment for the scientific community, however. Many were still skeptical, including the world-renowned Caltech physicist Robert A. Millikan, who in the 1920s used unmanned balloons to take his instruments to even greater heights, up to nine miles. As late as 1924 he reported that "the whole of the penetrating radiation is of local origin." But after continuing his measurements atop mountains and aboard airplanes, he was at last convinced of their extraterrestrial nature. Millikan, a bit of a showboater, didn't mind that America's newspapers gave him all the credit for the find, with no mention of Hess. Millikan has "found wild rays more powerful and penetrating than any that have been domesticated or terrestrialized . . . probably completing [an] alphabet for the language by which the stars communicate with man," reported the *New York Times* on November 12, 1925. "The mere discovery of these rays is a triumph of the human mind that should be acclaimed among the capital events of these days."

Millikan, like many others at the time, believed the radiation was electromagnetic in nature. Because the radiation was so penetrating, he figured the wavelengths had to be shorter than gamma rays. At a meeting of the National Academy of Sciences, he called them "cosmic rays." With great imagination, he declared that the highly energetic photons were released when particles in interstellar space somehow



AMERICAN INSTITUTE OF PHYSICS

Physicist Victor F. Hess used air balloons to gather the first evidence that radioactivity was reaching Earth from outer space.

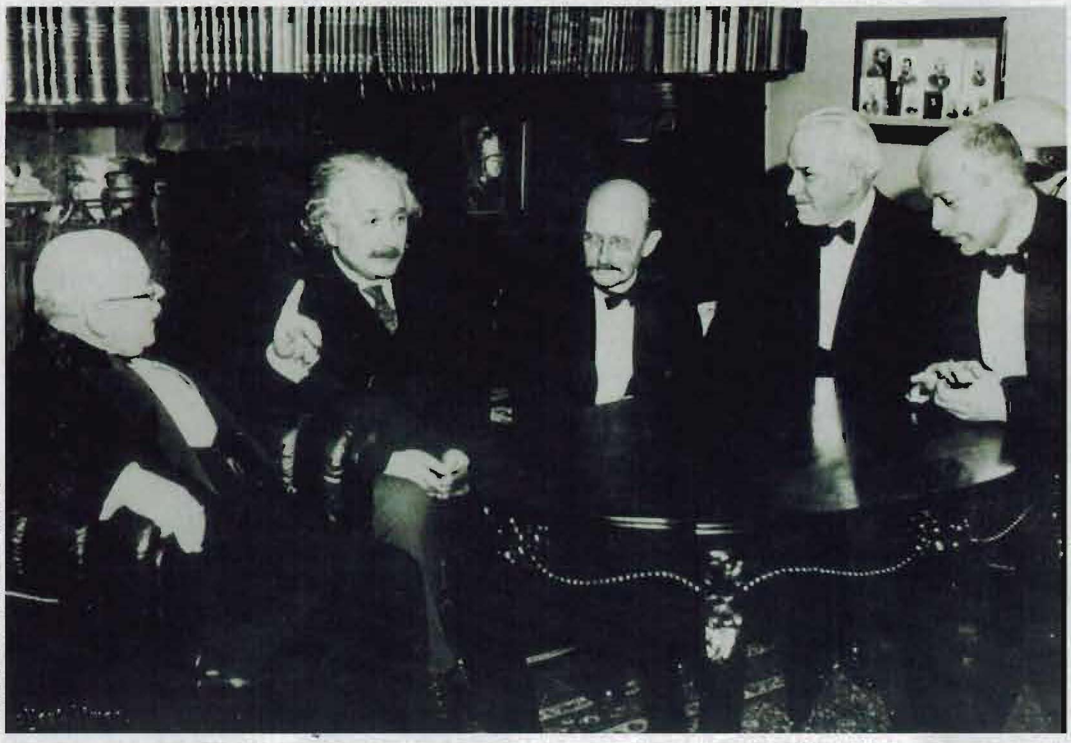
condensed into higher elements. To Millikan, cosmic rays were the "signals broadcasted throughout the heavens of the births of the common elements . . . the birth-cries of the infant atoms."

This led to a raging battle between Millikan and University of Chicago physicist Arthur H. Compton, who was sure that the interstellar "rays" were actually particles. The debate between the two was so fierce that the national press regularly covered the tussle. The particle model finally won in 1932, once Compton sent teams of researchers around the globe, from Alaska to New Zealand, and fully demonstrated that the rays varied in intensity with latitude. The cosmic rays increased in number as the researchers traveled from the equator to the poles. That meant they were particles getting deflected by the Earth's magnetic field: the field lines point toward the poles and particles swoop more easily toward the polar regions than equatorial latitudes. With the controversy settled over the rays' true nature, full credit was also restored. It was Hess who was awarded the 1936 Nobel Prize for his original discovery more than two decades earlier. The fact that everyone continued to call the alien particles cosmic *rays* was Millikan's consolation prize.

As the use of Geiger counters and cloud chambers grew more sophisticated, physicists came to see that cosmic rays were mostly protons, but could also be atomic nuclei or electrons. They enter the Earth's atmosphere, in a range of energies, from all directions of the celestial sky. Some five quintillion (5×10^{18}) strike the Earth's atmosphere each second. Upon colliding with air molecules, the primary rays generate a cascade of secondary particles that plummet to the ground (and get detected by such instruments as Utah's Telescope Array).

Cosmic rays actually gave birth to the field of particle physics. By carefully studying cosmic-ray interactions, physicists came to discover new and bizarre elementary particles, beyond the plain-vanilla proton, electron, and neutron. In 1932 the positron (the electron's antimatter mate) was discovered in a cosmic-ray cloud chamber; by 1937 the track of a speeding muon (a heavy electron) was similarly spotted in a chamber photograph.

By the 1950s, with particle physicists constructing big accelerators to search for new particles, cosmic-ray physicists began to focus more on the origin of the "rays." How and where are cosmic rays being created in the vastness of the universe? they asked. Millikan was wrong on all counts.


EMILIO SEGRÈ VISUAL ARCHIVES

Robert A. Millikan, a Caltech physicist (second from right), with Albert Einstein (second from left), Max Planck (center), and other luminaries in Berlin, Germany. Millikan coined the term "cosmic rays" and was falsely credited with their discovery by the American press in the 1920s.

But other ideas were already in the wind. As early as 1934 Walter Baade of the Mount Wilson Observatory and Caltech physicist Fritz Zwicky suggested that the rays came from spectacular stellar blasts, explosions earlier dubbed "supernovae." It's an idea that holds up to this day. More recently, active galactic nuclei have also come to be suspected as rich sources of the rays: a spinning supermassive black hole at a galaxy's center spews out blazing jets of particles into space.

All of the above may be contributing to the signal gleaned by the Utah array. The Milky Way lives in the outskirts of the Virgo supercluster of galaxies, and the hotspot resides in the very direction of that vast supercluster, home to tens of thousands of galaxies. The cosmic rays arriving on Earth from that bearing could then be the collective shout from the myriad supernovae and active galaxies occupying the supercluster. Here I am, they are saying, here I am.

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