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Review: A New Astronomy Through 'The Telescope in the Ice'

Antarctica's IceCube Neutrino Observatory was built not to view the stars but to detect extraterrestrial subatomic particles.

PHOTO: IAN REES, ICECUBE/NSF

By Alan Hirshfeld

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In December 1930, physicist Wolfgang Pauli sent his colleagues a letter that began, "Dear Radioactive Ladies and Gentlemen," in which he postulated the existence of a nearly massless, electrically neutral particle: the neutrino. This conjecture was, he admitted, a "desperate remedy" to a troubling inconsistency in the radioactive decay of atomic nuclei. At stake was the very validity of the law of energy conservation, one of the bedrock principles of physics. Not until 1956 was Pauli's hypothesized particle finally spotted, by Frederick Reines and Clyde Cowan at the Savannah River nuclear reactor in South Carolina. As for why he had undertaken the search, Reines remarked: "Because everybody said, you couldn't do it."

Neutrinos are the most nonreactive of subatomic particles, breezing their way through seemingly impenetrable barriers. Nobel Prize-winning physicist Leon Lederman described neutrinos as "barely a fact," while others have labeled them ghost particles. Billions of these peewee interlopers, most originating in Earth's atmosphere or the sun's core, pass through our bodies every second, yet the odds of an interior collision are remote. A neutrino can easily transect a million Earths, all lined up in a row. And therein lies the challenge of any research venture based on neutrino counts. Only rarely does a neutrino strike an obstructing crumb of matter, and even then the observable consequence is a brief glimmer of blue light (known as Cherenkov radiation). At the outset, neutrino detection seemed to be a scientific snipe hunt. But technology has overcome the neutrino's aversive nature and opened up a new window onto the universe.

THE TELESCOPE IN THE ICE

By Mark Bowen

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Astronomers have long surveyed the celestial landscape by capturing and analyzing forms of radiant energy, such as visible light, radio waves and X-rays. But photons are only one mediator of extraterrestrial information. Today a host of sci-fi-worthy gizmos monitor the incessant deluge of cosmic particles as well as the intermittent quiver of gravity waves washing over our planet. These photon-alternatives, key components of so-called multi-messenger astronomy, have given us entry to once-inaccessible regions of the universe, from the depths of the sun to the fringes of black holes.

Initially, neutrinos offered astronomers the opportunity to "peer through" the sun's opaque gases into its fiery innards. Unlike photons, which take up to a million years to make their way out of the sun, neutrinos birthed in the sun's core arrive at Earth some 8½ minutes later. The first neutrino "telescope," a 100,000-gallon vat of perchloroethylene (dry-cleaning fluid), dates to the late 1960s and sat a mile underground in the Homestake Gold Mine in Lead, S.D., where it would be shielded from cosmic-ray particles. But the measly number of neutrinos it detected was far short of that predicted by the accepted theory of solar energy production. This discrepancy became known as the "Neutrino Problem." Subsequent study revealed that neutrinos come in a variety of subspecies, only one of which had been tallied at Homestake. With that, solar-energy theory was vindicated, and neutrino astronomy took off.

"The Telescope in the Ice: Inventing a New Astronomy at the South Pole," by physicist-writer Mark Bowen, is the story of the global collaboration that created and operates Antarctica's IceCube Neutrino Observatory. The unconventional instrument, completed on time and on budget in December 2010, comprises some 5,000 ultrasensitive light detectors drilled a mile down into the polar ice. This frigid matrix is nature's clearest substance, surpassing even diamond in its ability to transmit light. In the Stygian gloom, such clarity allows the detectors to pick up the exceedingly faint blue flickers that signal the rare interactions of neutrinos with the ice.

The crucial features of IceCube are its size—a cubic kilometer—and the three-dimensional arrangement of its photosensors, which together allow IceCube to determine the direction, if not the specific source, from which a gust of neutrinos originates. Perhaps the strangest operational aspect of IceCube is that it is designed to detect neutrinos emanating from Earth's northern sky, after the particles have traversed the entire body of our planet. Earth filters out unwanted particles and passes IceCube's quarry: ultra-high-energy neutrinos originating outside the solar system, from exploding stars, hyperactive galaxies or other cosmic powerhouses.

Although chockablock with technical details, “The Telescope in the Ice” is richly intimate, drawing on Mr. Bowen’s long involvement with the IceCube project and its participants. (He learned about the proposed project in 1997 atop a snow-capped peak in Bolivia, while reporting on a team of ice-core-drilling paleoclimatologists.) Human emotions are palpable in the author’s you-are-there framing. The drilling of ice holes, for example, becomes a nail-biting contest between brute force and finesse, the team (and the reader) ever alert to the mechanical shudder that precedes calamity. All this in a windswept, snowbound wasteland. Is there any keener expression of scientists’ dedication to the pursuit of knowledge?

Mr. Bowen acknowledges the business and public-relations side of today’s Big Science: News releases, interviews and advocacy are obligatory adjuncts to the research. He also digs deeply into the social dimensions of collaborative science, especially the sort conducted in forbidding environments like Antarctica or outer space. IceCube requires a lavish team of researchers, student assistants, engineers and computer experts, along with helicopter pilots, galley cooks, ice drillers and septic-tank pumpers, all of whom must operate as a unified organism. At the Pole, the dual imperatives of science and survival flatten the social hierarchy. Even the project’s nominal major-domo, the principal investigator, is totally dependent on the ancillary employees. To the PI, failure is the albatross that hangs around one’s professional neck. The PI in this case is Francis Halzen, of the University of Wisconsin, an “oracular” presence, Mr. Bowen tells us, whose formidable intellect gushes forth in scientific forums: “Ideas splashed across his mind so fast that his mouth couldn’t keep up.”

The story’s ending, although a happy one from the scientific perspective—the sought-after neutrinos are found—has a poignancy as the project’s old guard retire or attend the funerals of their colleagues. Success at a decades-long endeavor must serve as their consolation, knowing that the icebound eye they helped create still watches over the heavens.

—Mr. Hirshfeld, a professor of physics at UMass Dartmouth, is the author of “Starlight Detectives: How Astronomers, Inventors, and Eccentrics Discovered the Modern Universe.”