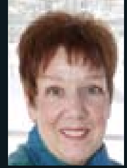

COSMIC BACKGROUND BY MARCIA BARTUSIAK

Catching the Wave

Sometimes scientists don't realize the answer is hidden in plain sight.

Sometimes a great scientific idea needs time to take root. Sometimes the world simply isn't ready. Continental drift comes to mind as an example, as well as germ theory. Continents moving about? Microscopic bugs? Each of those propositions seemed too bizarre to accept right off. In such situations, scientists have to be convinced that a new concept is worth looking into.

Astronomy is no exception. A famous case is a prediction of cosmic proportions that first appeared in a 1948 scientific paper almost as an afterthought, and was soon forgotten. Decades passed before the dismissed conjecture turned into cosmology's greatest tool.

By the late 1940s, scientists had been grappling for several years with a tough question: how did the universe come to manufacture its vast array of elements? Until the end of the nineteenth century, everyone had just assumed that matter always was and would always be, but revelations coming out of atomic physics laboratories in the first half of the twentieth century—ranging from radioactivity to nuclear transformations—overturned that notion. The elements obviously came from somewhere. The most plausible factory was inside a star, but no physicist in that era could get stellar models to build an atom heavier than helium. Anything more weighty quickly disintegrated within their theoretical computations.

What to do? In 1942 the Russian-American physicist George Gamow simply looked around for another locale for cooking up the elements, and he found one in the "primordial atom." The idea, a relatively new one, was that the universe had emerged and expanded from an initial hot plasma. (The term *big bang* didn't arrive until 1949.)

As Gamow's graduate student at George Washington University in the mid-1940s, Ralph Alpher took on the challenge for his doctoral thesis and demonstrated theoretically how it could be done. Like some skilled astrophysical chef, he started with a highly compressed stew of neutrons. As the temperature of the cosmos began to plunge, some of those neutrons decayed into protons, which promptly began to stick to remaining neutrons. Step by step, each element was built up from the one before it—from helium to lithium, lithium to beryllium, beryllium to boron, and so on through the periodic table. In less than half an hour, when the last of the free neutrons decayed away, the cosmic meal was complete, with Alpher and Gamow concocting the full complement of universal "flavors," all the way up to uranium.

Their first report on this mathematical recipe, a one-page synopsis published in *Physical Review,* is more famous for its byline than its content. Gamow, a merry prankster, listed the paper's authors as Alpher, Bethe, and Gamow, even though noted physicist Hans Bethe never participated in the work. Gamow couldn't resist the pun on the first three letters of the Greek alphabet: alpha, beta, gamma. That the 1948 paper chanced to be published on April Fool's Day only added to the fun.

While earning his master's and PhD, Alpher had been working at the Applied Physics Laboratory of Johns Hopkins University. There, after getting his doctorate, he continued to collaborate on Gamow's campaign to study the physics of the Big Bang model. He was joined by fellow lab employee Robert Herman. The two young scientists went on to develop a detailed account of the evolution of the newborn universe, work described in 1977 by physicist Steven Weinberg as "the first thoroughly modern analysis of the early history of the universe" (*The First Three Minutes: A Modern View of the Origin of the Universe*).

Early in their investigations, the pair came to realize that Alpher's original scheme for elemental cooking had an insurmountable flaw: while the newborn universe could make a few light elements, the cosmic expansion both dispersed and cooled the primordial plasma before the heavier elements had any chance of forming. With better stellar models, others would later prove that stars could do the job after all. But no matter: in the course of their investigations, Alpher and Herman made a historic calculation that has stood the test of time.

This result was revealed in an unusual manner. On October 30, 1948, Gamow published an article in the British journal *Nature* titled "The Evolution of the Universe." But in checking over Gamow's reported results, Alpher and Herman found some errors. They soon dashed off a correction, a brief letter to the editor barely four paragraphs long that was published within two weeks. With their more accurate figures, Alpher and Herman showed how the density of matter and the density of radiation changed as the universe evolved. In doing so, they curtly noted at the end of their letter that "the temperature in the universe at the present time is found to be about 5° Kelvin." That's only 5 degrees above absolute zero, the point at which all motion ceases. (On the Fahrenheit scale, that's 9 degrees above absolute zero, which is −459.67 F.)

With little fanfare, Alpher and Herman were telling the world that the present-day universe is bathed in a uniform wash of radiation left over from the flood of highly energetic photons released in the fury of the Big Bang. Cooled down over the eons with the expansion of the cosmos, the waning fire now surrounds us as centimeters-long radio waves. Today it is known as the cosmic microwave background radiation (CMBR).

When their note was published, the primordial atom theory was still highly controversial. Many astronomers preferred the steady-state model of the universe, a theory that postulated that space-time had neither a beginning nor an end. But Alpher and Herman's calculation was a clear-cut means of deciding between the two opposing theories of the universe's behavior.

Yet no one followed up. Looking back, it's hard to fathom why astronomers in the 1950s didn't jump at the chance to point their instruments at the sky and capture this primordial whisper of creation. But some thought radio telescopes weren't yet sensitive enough for the task; and when a few astronomers did peg an overall temperature of interstellar space at around 3 degrees K, they didn't link it to cosmology at all. Some of them thought it was an error in their instruments.

Radio astronomers may have been unresponsive because their field was just establishing itself after World War II, and cosmological tests were not taken seriously. As Weinberg noted, they "did not know that they ought to try" to detect the background radiation. The radio sky was all so new. There were too many objects—radio stars, radio nebulae, radio galaxies—grabbing their attention. Amid such distractions, Alpher and Herman's prediction was either dismissed or utterly overlooked. And since both men later went into industrial research, the two didn't have the opportunity to keep pushing astronomers to take a look. They did try, at one point even holding a press conference to generate attention.

The idea didn't resurface until the mid-1960s, when a team of astrophysicists at Princeton University (and some Soviet cosmologists independently) again reasoned that the Big Bang's residual heat must be permeating the universe. At the same time, two Bell Lab researchers in New Jersey, Arno Penzias and Robert Wilson, accidentally detected what proved to be the primeval microwaves. They were trying to eliminate excess noise in a horn antenna they were calibrating for astronomical work, but a stubborn residue always remained. Once Penzias and Wilson learned of the Princeton team's work, they at last understood that their radio interference was cosmic. In 1965 the two groups published papers simultaneously in the *Astrophysical Journal.* Neither paper mentioned Alpher and Herman's earlier contribution. For detecting the cosmic microwave background radiation, Penzias and Wilson received the 1978 Nobel Prize in Physics.

Herman died in 1997, Alpher ten years later. Both were deeply pained that the career rewards for making their momentous prediction never came to pass for them—election to prestigious academies, sizable research grants, prized promotions. The honors that were bestowed arrived late (Alpher received the National Medal of Science in 2007, when he was hospitalized with his final illness). "But we should not indulge in sermonizing about the nature of science," the two noted in a scientific memoir of their work published in 2001. "On to more about the CMBR," they proclaimed. And so it should be.

Over the last two decades, detectors in space have measured the cosmic microwave background, now pegged at 2.7 degrees K, in exquisite detail. By mapping the barely perceptible ups and downs of this signal across the breadth of the celestial sky, astronomers have revealed a wealth of cosmological information. They've viewed the quantum jiggles that led to galaxy formation, tallied the exact amount of ordinary matter contained in the universe, verified that there is five times more cosmic stuff of an unknown nature (called dark matter), and confirmed that space-time is permeated with a dark energy that is causing the universe not just to steadily expand, but to accelerate outward like a runaway drag racer. And to think that all this knowledge was gleaned from a radio murmur, a faint heat first mentioned unceremoniously in a note tucked away in a scientific journal's letters sixty-three years ago.

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of modern cosmology.