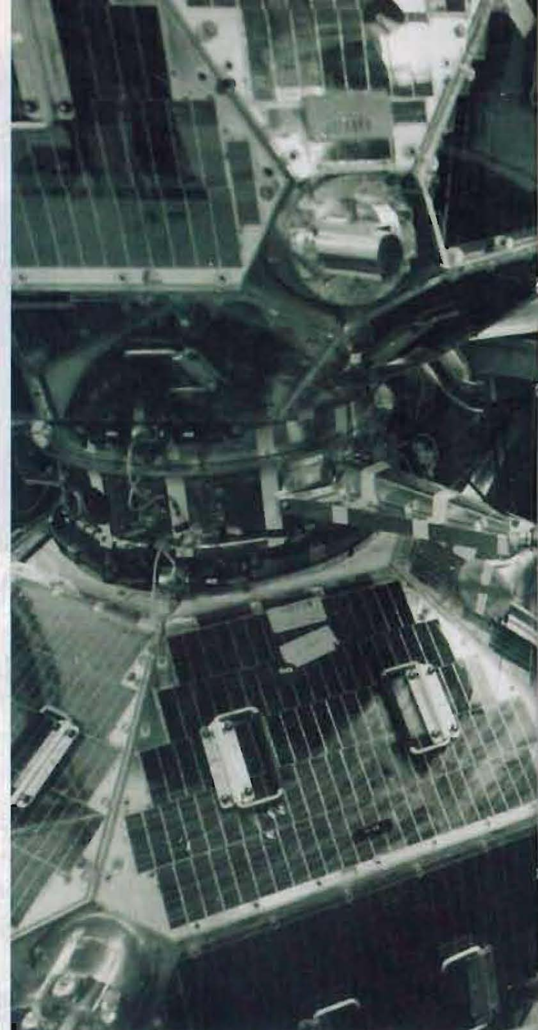
COSMIC BACKGROUND BY MARCIA BARTUSIAK

The Great Escape

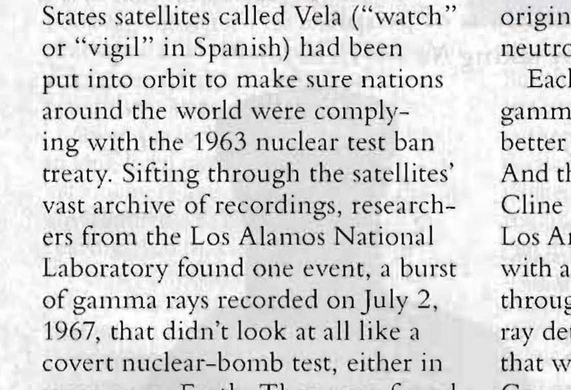
"Black holes ain't so black."



Los Alamos National Laboratory engineer Richard D. Belian in 1970 with a Vela satellite, for which he worked on instrumentation to detect cosmic radiation

Gamma rays from deep space were first discovered by accident in the early 1970s. A group of United States satellites called Vela ("watch" or "vigil" in Spanish) had been put into orbit to make sure nations around the world were complying with the 1963 nuclear test ban treaty. Sifting through the satellites' vast archive of recordings, researchers from the Los Alamos National Laboratory found one event, a burst of gamma rays recorded on July 2, 1967, that didn't look at all like a covert nuclear-bomb test, either in space or on Earth. They soon found similar bursts in the records, and all appeared to come from outside the solar system.

The duration of the bursts ranged from less than a tenth of a second to some thirty seconds—popping off like a cosmic flashbulb, flickering for a moment, then fading away. Over the succeeding years various countries launched space detectors that were specifically designed to discern the origin of these powerful cosmic eruptions, and gradually an answer emerged. Today it's generally accepted that the most common bursts emanate from the gravitational collapse of massive stars—located as far away as the most distant and ancient reaches of the universe—into black holes; others may have had their origin in collisions between pairs of neutron stars.



COURTESY OF DONALD HILLGER

Each successive generation of gamma-ray instrumentation offered better and better timing resolution. And that presented physicist David Cline at the University of California, Los Angeles, and several colleagues with a unique opportunity. Plowing through the data from seven gamma-ray detectors, they came to suspect that what they called Very Short Gamma Ray Bursts—those lasting less than a tenth of a second—might represent a class of phenomena with a distinct cause.

How to explain these ultra-brief, super-high-energy bursts? Cline and his colleagues claim they could be evidence for tiny "primordial black holes," perhaps with the mass of a small asteroid packed into the volume of an atomic nucleus, that formed within the extreme densities of the early universe—a phenomenon first predicted by Stephen Hawking in the 1970s. That would be *big* news in the physics community, if true, for such bursts would then offer the means to study what happens when general relativity (the rules that govern the universe at large) merges with quantum mechanics (the tenets of the atomic world). Such a union of the macrocosm with the microcosm has long been sought by physicists.

Hawking's musings were partly sparked during a visit to Moscow in the fall of 1973, where he talked with Soviet physicists Yakov Zel'dovich and Alexander Starbinsky. Those two men had suggested that under special circumstances—that is, when a black hole rotates—it should convert that rotational energy into radiation, thus creating particles. This emission would continue until the spinning black hole wound down and stopped turning.

Devising his own mathematical attack on the problem, Hawking was surprised to discover that *all* black holes—spinning or not—would be radiating. As Hawking later put it, "Black holes ain't so black."

Hawking announced his discovery in February 1974 at a quantum gravity conference held in England, and his report was soon published in the journal *Nature*. In this endeavor,

Hawking looked at the black hole from the perspective of an atom and found that quantum mechanical effects caused black holes to create and emit particles as hot bodies would. As a consequence, the black hole slowly decreases in mass and eventually disappears in a final explosion! Such a finding turned black-hole physics upside-down; a black hole, by definition, holds on to everything it swallows. It's supposed to emit nothing and never go away.

Hawking estimated it would take longer than the age of the universe for a regular black hole, weighing a few stellar masses, to disappear. The decay of such a hole would take more than 10^{60} years. But what if extremely small holes were created in the turbulence of the big bang? They could be popping off right now. Hawking estimated that in its final breath—its last tenth of a second of life—that tiny object would release the energy of a million 1-megaton hydrogen bombs.

Needless to say, his fellow physicists were not enthralled by this idea. At that February conference, it was greeted with total disbelief. At the end of Hawking's talk, the chairman of the session, John G. Taylor from Kings College, London, got up and responded, "Sorry, Stephen, but this is absolute rubbish."

But gradually, over the following two years, it came to be recognized that Hawking had made a startling breakthrough: his argument demonstrated that gravitation and quantum mechanics were somehow deeply connected. Even though these two laws of nature have yet to be fully joined, here was evidence that unity was achievable.

Hawking saw that space-time gets so twisted near a black hole that it enables pairs of particles (a matter particle and its antimatter mate) to pop into existence just outside the black hole. You could think of it as energy being extracted from the black hole's intense gravitational field and then converted into particles.

But because we're talking about the submicroscopic scale, the exact line of the black hole's boundary is quite fuzzy. So, at times, one of the newly created particles can disappear into the black hole, never to return, while the other remains outside and flies off. As a result, the hole's total mass-energy is reduced a smidgen. This means the black hole is actually evaporating. Ever so slowly, particle by particle, the black hole is losing mass.

While it would take trillions upon trillions of years for a regular black hole to shrink away to nothing, what if the universe did manufacture those multitudes of tiny black holes—mini–black holes—during the first moments of the big bang, as Hawking has suggested? Like a ball rolling down a hill, the evaporation of a mini–black hole would accelerate as time progresses. The more mass this tiny primordial object loses, the faster and faster it fizzles away, until it reaches a cataclysmic end.

If the big bang did forge such holes, the smallest would have vanished before their dying light could catch our attention; but objects containing the mass of a mountain, yet compressed to the size of a proton, would have continued shedding the last of their mass in short and spectacular bursts of gamma rays.

That's what Cline and his colleagues believe they might be seeing within the gamma-ray detector records. Others are not so sure. Such signals could be also be arriving from a more mundane stellar activity, one not yet identified. As Carl Sagan liked to say, "Extraordinary claims require extraordinary evidence." Cline agrees and is urging other researchers to start studying these events as well, to see if his team's claim holds up to scrutiny. If the distinctive *pop* of a primordial black hole is at last verified, it will be a significant moment in astronomical history.

MARCIA BARTUSIAK teaches in the MIT Graduate Program in Science Writing and is the author of five books, the latest of which, *The Day We Found the Universe,* won the History of Science Society's 2010 Watson Davis and Helen Miles Davis Prize for best science history book written for a wide public.