Entering the Final Frontier

SETH SHOSTAK '65

BACK in the early 1960s, we thought we understood everything. In truth, we understood precious little. Now I'm not talking about our failure to get a firm grip on international relations, the meaning of life, or the social benefit of eating clubs. I'm speaking about how little we understood about the universe. Frankly, what we knew was within a stone's throw of zip.

It wasn't really our fault. Our tenured mentors on this subject—the jacketed-and-tied faculty members who regaled us at 8:40 am each morning—exuded impressive confidence in their cosmic facts. But they had a poor grasp of the big picture. True, most of the content that filled our Physics 101 or astronomy primers is still in the textbooks today. The problem wasn't what was in those courses, but what wasn't. It's been a body blow to our hubris, but what we've learned about the universe in the past five decades has surpassed the imagination of even avant-garde science fiction writers.

Let's recap. In 1965, the canonical description of the cosmos began inside out. It started with the familiar, and nearby, bodies of our solar system—the planets and moons that were the Sirens of the sky for thousands of years. Beyond these local hunks of stony crud were the stars, a hundred billion knots of glowing gas in the Milky Way galaxy. These stars swam in a thin mist of gas and dust. And thanks to the work of name-brand astronomers such as Edwin Hubble, we knew that our galaxy was only one of millions. At least millions.

That was it. That was the traditional inventory of the universe: stars, planets, a tenuous fog of gas and dust, and some inconsequential small rocks (think comets and asteroids) running around like wild Chihuahuas. We had cataloged what was out there.

To be sure, there were still mysteries. For example, Hubble's work had strongly suggested that the universe began billions of years ago in a furious explosion dubbed the Big Bang. But exactly how many billions was that? And despite its nice accord with Genesis, was this primal event for real? Many people felt antsy about the idea that the cosmos had a beginning. If everything came into existence at once, where did it come *from*? There was philosophical resistance to the suggestion that all history traces back to some sort of enigmatic, out-of-nowhere blast.

There was also resistance by science. Some smart people had offered alternative theories, postulating a universe without start or finish. The Big Bang, they said, might be just an ugly illusion. Soon, cosmologists were taking sides.

Uncovering new truths

As the 1960s ground on, this ferment led to a couple of truly revolutionary discoveries. The first concerned the reality of the Big Bang. If this mother-of-all explosions really occurred, then physicists insisted that some of the explosive glow should still be around, permeating space like a bad odor. A faint radio noise bathing the cosmos was a solid prediction of the Big Bang idea. It could be tested by aiming an antenna at the heavens and listening. That sounds simple, but in 1964 no one had done it. And that leads me to recall a personal footnote to a historic event.

Seth Shostak is Senior Astronomer and Director of the Center for SETI Research.

It was spring term, and Rudolf Thun and I were busy every week on the second floor of Palmer Physical Laboratory doing the many hands-on experiments that laced the curriculum of physics majors. Rudi was my steadfast lab partner and—like me—partial to the occasional practical joke. One afternoon, while busy with our lab books, we heard a hubbub outside. From the window, we saw a small cohort of faculty in the parking lot, including Dave Wilkinson,a new hire at Princeton who eventually became my senior thesis advisor. The professors were clustered around an odd electronic contraption perched on a small cart. Neither Rudi nor I had a clue regarding the nature of this device, let alone its intent. But we did see that it sported a small, brass horn that pointed straight up. That horn, we knew, was the front end of a microwave receiver.

By coincidence, a small microwave *transmitter* (known in the trade as a klystron) was part of the apparatus we were using for our lab work. With no hesitation, we wheeled the klystron to the window. Rudi aimed it toward the parking lot while I used the switch on the power supply to tap out "what hath God wrought" in Morse code. None of the small coterie of scientists below seemed to notice.

A few months later, the scientific world was startled by the news that a faint radio glow had been found in the sky, a measurement that solidly vindicated the Big Bang idea. Unfortunately, the discovery came not from the ivy-upholstered Princeton campus, but from Bell Telephone Labs in Holmdel, about 25 miles away. The Princeton group, and its efforts to find the Big Bang's ancient footprint, had been "scooped," in the words of Professor Robert Dicke. Rudi and I wondered if our secret little prank was the reason. I think we felt additional guilt when, fifteen years later, those Bell Labs engineers won the Nobel Prize.

Sometime in the 1990s, I confessed our misdeed to Wilkinson. I was prepared to hear the worst, but my former advisor just laughed. He gave a brief explanation involving time constants and such, and assured me that we had done nothing to interfere with the efforts of that small knot of physicists outside Palmer Lab. The Holmdel guys really did get to the goal post first.

THE repercussions of this discovery continue. A succession of orbiting spacecraft has measured the background glow (known in the scientific literature as the CMB, or cosmic microwave background) with ever-increasing precision. One of these craft was renamed the Wilkinson Microwave Anisotropy Probe, or WMAP, in honor of Dave. This work has allowed astronomers to pin down the age of the universe—the time since the Big Bang—to an accuracy of a few hundredths of a percent. It's 13.8 billion years, in case you get asked at a party.

More recently, studies of the CMB using a radio setup in Antarctica seem to indicate that in the earliest moments of the Big Bang, in the first trillionth of a trillionth of a trillionth of a second, the universe expanded incredibly fast, far quicker than the speed of light (space can do this, even though matter can't). This phenomenon, called inflation, was very short-lived. But it has mind-boggling implications. One possibility is that the Big Bang is only one bang of many—perhaps infinitely many—that are going off all the time in a kind of "hyperspace." This hyperspace is the landscape from which all universes sprout, thereby providing a handy, if still perplexing, answer to the perennial question "what existed before the Big Bang?"

If this turns out to be true—and doubt has been thrown on this measurement—then our universe, as vast as it is, is no more significant than a dust mote floating in an old hangar. No one would have entertained such an idea when we were in school.

Invisible stuff

Two additional discoveries have radically transformed astronomers' understanding of the cosmos since our days at Old Nassau. The first of these quietly appeared when no one was looking, which seems to be the general *modus operandi* of science. In the late 1960s, as a graduate student in California, I was using radio telescopes to measure the rotation of galaxies. We already knew that galaxies spin (the Milky Way has rotated about 50 times in the history of the universe), but a detailed study would reveal something interesting about their mass. That was our naïve incentive for doing the measurement.

We collected data for two years and then examined the results. To our dismay, we found that the galaxies in our observing list spun much faster than predicted, at least on their outer edges. This was not only unexpected but also of profound importance because it betrayed the presence of stuff that we can't see with our telescopes (or, to date, with any other instruments): dark matter. The name is no more than a childlike description, and physicists are still trying to nail down what dark matter really is. But the bottom line is that for every pound of ordinary matter in the universe—the stuff of your daily existence—there are five pounds of invisible dark matter. Who would have thunk? Not our professors, and certainly not us.

A SECOND discovery is more recent, dating from the late 1990s. Astronomers had been trying to refine Hubble's early measurement of just how fast the universe was expanding. They assumed that this cosmic explosion was slowing down, thanks to the gravitational tug of everything on everything. Simple. Straightforward. And wrong.

The universal expansion is actually speeding up. Something is causing the space between galaxies to become larger at an ever-faster rate. The politically correct term for this "something" is dark energy. We don't know what it is, and if you think you do, you can write up your ideas and get in line for a Nobel Prize.

The take-home message from these two discoveries is that the principal ingredients of our universe are dark matter and dark energy. Together, they account for 95 percent of all the mass and energy in the cosmos. The remaining 5 percent is the stuff they were talking about in undergraduate days. Our professors spent their time and ours describing one-twentieth of existence. We thought we knew it all, but in fact we only knew of a superficial veneer on the body of the universe.

Past is prologue, and I have no doubt that in the next 50 years we'll be surprised again, and probably more than once. The universe is even stranger than the Kardashians.

Are we alone?

If, as could be true, the cosmos is boundless and our universe is only one of an infinity of universes that have (and will) exist, then it's understandable that some people will see life as somewhat devalued. How can we feel special—biologically, intellectually, or morally—in the face of such physical insignificance?

Well, one thing that might salve this soul-destroying situation would be to find someone, or something, with whom to share the pain. Which brings me to my day job: the search for extraterrestrial intelligence, or SETI. We're looking for cosmic company—not simply life in space, but life that's our cognitive peer (or superior).

SETI in its current incarnation is a half-century old. A year before our class entered Princeton, astronomer Frank Drake spent two weeks in West Virginia doing an unusual kind of experiment. He pointed an 85-foot-diameter antenna at a couple of very nearby stars and tuned a sensitive receiver up and down the dial, hoping to pick up broadcasts from aliens. This was the first modern SETI experiment. Today I work at a non-profit research organization—the SETI Institute—that continues these attempts at interstellar eavesdropping. To my personal delight, Drake has an office down the hall from my own.

So what's the bottom line? Have we found the extraterrestrials? That's a question I get asked all the time. The answer may disappoint: despite all the listening, we still haven't managed to tune in a transmission from another world.

Given the long history of null results, some people think this is a fruitless enterprise, much like talking to the dead. But that's wrong. The equipment we can bring to bear on SETI experiments is rapidly improving. In addition, there are some new developments in astronomy that encourage our listening efforts.

Principal among these developments is learning that planets are not just occasional companions to stars; they're as plentiful as phone poles. In 1995, two astronomers in Switzerland made a headline-grabbing discovery: they found the first instance of a planet orbiting another star similar to the Sun. The Swiss duo wasn't looking for planets, and the one they discovered was as odd as Tiny Tim; it had a year that was only four days long. Nonetheless, their work will be cited in textbooks centuries from now.

In the last two decades, researchers have found many other worlds—several thousand, in fact. But more important than the tally is learning how frequently they occur and what they're like. Recent analyses suggest that the majority of stars have planets, with perhaps a trillion such worlds in the Milky Way. Equally impressive is the result (admittedly still tentative) that one in five stars could host a planet that's similar to Earth—with the right size and temperature to have liquid oceans, a blanket of air, and possibly biology.

This implies the existence of billions of habitable worlds in our own galaxy. And unlike the situation when Robert Goheen was Princeton's president, we now know that there are more than 100 billion

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Entering Space

When, as callow youths, we first entered the ivied halls of academe, only one human had ever loosed the bonds of Earth and traveled to space. In the late spring of 1961, Yuri Alekseyevich Gagarin spent 90 minutes in a cramped Russian capsule, making a single orbit of our planet. He thereby became Earth's first astronaut, a title he will wear forever.

Once the final frontier was breached, the pace of exploration picked up. Scarcely a year later, John F. Kennedy told the nation that we were going to heft Americans a thousand times higher than Gagarin had gone – sending them to the moon. A massive cadre of engineers got to work designing, building, and testing the requisite hardware.

It's safe to say that every class member recalls the culmination of these efforts: the hot July day in 1969 when Neil Armstrong gingerly stepped off a short ladder onto the ancient lunar dust. Here was a world that had spun in airless silence for four billion years, its solitude unbroken until this moment.

Putting men on the moon was a technological (and political) triumph. But the moon is 80 million trillion tons of dead rock. There is more interesting real estate elsewhere in the solar system, and space agencies were soon considering how to explore it. A quick inventory of some of the more appealing locales included Mars, everyone's favorite extraterrestrial planet; Jupiter, with its five dozen moons; Saturn, with a similar tally of satellites but with bright rings for added bling; and the dim and dimly perceived worlds beyond. By the end of the 1970s, spacecraft were launched in the directions of all of these. And while even today, humans have visited no bodies other than the moon, it's quite possible that members of our class will see another "small step for a man" in a few decades' time as astronauts plant their rubberized footwear on the red sands of Mars.

Of course, we already know what they'll see: a dry, bitterly cold sterile landscape of rock and dust. Today, nearly everyone is familiar with the desolate panoramas of Mars sent from cameras on our rovers. And while it's true that the Red Planet remains a favorite destination, our robotic proxies go everywhere. They've orbited, passed by, or alighted on all the planets of our solar system. Every one. And in July, 2015 the New Horizons spacecraft will do a drive-by of Pluto which, when the craft was launched in 2006, was still a card-carrying planet.

In addition to these mechanical forays to nearby worlds, we've put hundreds of telescopes, and Earth-monitoring and telecommunication satellites into orbit. The public has been repeatedly thrilled by the colorful photos taken by the Hubble Space Telescope, but it should be similarly impressed by the ease with which we can make an overseas telephone call, watch TV news from distant countries, or simply use GPS in the family car to navigate to an unfamiliar address.

These astounding developments are all a consequence of the Cold War space race – an international competition that was barely warm as we filled out our application forms for Princeton. In a thousand years, when armchair historians look back on the twentieth century, few will recall – or even much care about – the Great Depression, the rise of the middle class, the auto age, or even the world wars. What they will remember is that in that dim and distant century, humanity made its first, modest steps into the void beyond Earth.

other galaxies in the part of the cosmos we can see, each with its own planetary entourage.

That's a lot of planet pleasure. And it strongly implies the existence of countless societies spread through the universe. Of course, for this to be true we also have to assume that life cooks up readily on suitable worlds and occasionally evolves into human-level intelligence. But if you don't think that happens a lot, then you're saying that Earth and its biota are some sort of miracle, given that the number of habitable worlds in the visible universe is roughly a thousand billion billion. I note that miracles enjoy little status in science.

Allen Telescope Array listening for radio signals

So how do we square a cosmos redolent with real estate with the failure to detect a peep from the aliens? The most likely explanation is also the simplest: Our search has been too limited. SETI is an extraordinarily niche enterprise. The total number of scientists and engineers who are regularly engaged in the hunt for signals from space is about a dozen. That's worldwide. Funding for SETI (at least in this country) is almost entirely from private donors. The finances are precarious, which is reflected in the limited nature of the search. To date, only a few thousand star systems have been carefully examined over a broad swath of the radio dial.

The team at the SETI Institute is now checking out star systems at the rate of several dozen a week. We do so using an ensemble of 42 antennas known as the Allen Telescope Array, perched on high-and-dry pasture land about 300 miles north of San Francisco. It's slow going, but there's hope: improvements in digital technology (read: computers) are accelerating our work, and a not-unreasonable extrapolation suggests that we could reconnoiter a million or more star systems in the next two decades. Call me Pollyanna, but I think that's a sample size large enough to offer a decent chance at success.

And what would that mean? What would be the consequences if we eavesdrop on signals from another world—tuning in intelligence that's not only many light-years' distant, but also far more technically advanced than us? Indeed, would learning that we're not the only thinking beings be so disruptive that the government would simply bury the news?

Many among the public think so, but they're wrong. We've had several false alarms and, while officialdom has never shown any interest, the media have. If we find a signal, you can be sure it will be tweeted and Facebooked long before the discoverers have even verified their data. But in addition, the idea that the public couldn't handle the news is ludicrous. Extraterrestrials prance across screens every week on television and in the movies. A century ago, an accomplished astronomer by the name of Percival Lowell authoritatively claimed that there was a sophisticated civilization on Mars, busily grooving that planet with canals. The public found the idea interesting, but hardly alarming. Today, a third of the populace is so comfortable with the notion of cosmic company that they think extraterrestrials are buzzing the countryside and occasionally conducting tasteless experiments on their bodies.

The real consequence of finding a signal from space will not be a horrifying, short-term disruption of society. Its importance will lie in the long-term consequences of discovering something that no previous generation could know: that what has happened on our planet—the rise of biology, complexity, intelligence, and culture—is just one occurrence among many.

That's something the class of 1965 didn't know. But the class of 2065 will.