In the beginning…

Half a century ago, two scientists stumbled on the proof that the Big Bang was real. *Marcus Chown* tells their extraordinary story

The greatest discovery in the history of science is that there was a day without a yesterday. The universe has not existed for ever but was born. Almost 14bn years ago, all matter, energy, space — and even time — burst into being in a titanic fireball called the Big Bang. The fireball expanded and, out of the cooling debris, there eventually congealed the galaxies: great islands of stars of which our Milky Way is one among an estimated two trillion. This, in a nutshell, is the Big Bang theory.

The idea that the universe popped into existence out of nothing is stark staring bonkers. It immediately prompts the question: what happened before? Largely because nobody wanted to address this awkward matter, most scientists had to be dragged kicking and screaming to the idea of the Big Bang. What forced them to accept it was the evidence. And that evidence is literally in the air all around us.

In the spring of 1965, however, two young astronomers at Bell Labs, in New Jersey, had no idea about that. Instead, they were at their wits' end because of a persistent hiss of radio static that appeared to emanate from everywhere in the sky, and which for six months had thwarted their plans to make observations of the universe.

Arno Penzias and Robert Wilson had been attracted to Bell Labs, part of the giant American phone company AT&T, by the prospect of using a giant radio "horn" for astronomy. It stood on Crawford Hill, near the town of Holmdel, and was basically a railway-carriage-sized version of the microwave horns that once festooned London's BT Tower. Radio waves entered the 20ft-square opening and were funnelled down to a radio receiver, housed in a wooden cabin strapped to the tapered end of the horn.

The 20ft horn had been built in 1959 to develop the technology for transmitting and receiving radio signals from the first communication satellites launched into orbit around the Earth. The first test was with Echo 1, a kind of Stone Age satellite launched by Nasa. Effectively, it was a silvered inflatable beachball, 100ft in diameter, off which radio waves from the 20ft horn could be bounced and picked up (a radio horn can both transmit and receive radio waves). Echo 1 was followed by Telstar, the first modern communications satellite. Telstar did not simply bounce back radio waves transmitted from ⋙→

the ground, but boosted them in strength before retransmitting them. It was a global sensation. In 1962, the first television pictures were broadcast between America and Europe via Telstar. Pop records were even produced celebrating the satellite.

The AT&T tests were a great success, ushering in the age of communications satellites. By 1963, the engineers no longer needed the 20ft horn on Crawford Hill.

The company decided to employ some radio astronomers. After all, they were in the business of detecting faint radio signals in the sky, and so AT&T might conceivably benefit from giving the unused horn over to pure science. And, as it happened, this was not AT&T's first venture into astronomy. In the 1930s, it had employed Karl Jansky to identify the sources of troublesome radio interference. By picking up radio waves from the sun and a mysterious source that later turned out to be a giant black hole at the centre of our Milky Way, Jansky became the father of the science of radio astronomy.

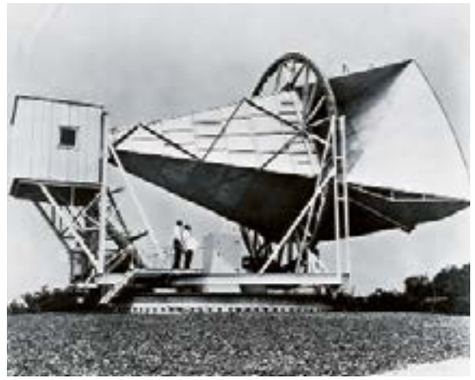
Arno Penzias, a dynamic New Yorker whose family had come to America as refugees from Nazi Germany, had arrived at Holmdel in 1962, at the age of 29. Robert Wilson, a taciturn 28-year-old, joined from Caltech, in California, in early 1964. That summer, the pair teamed up.

Wilson had the idea that our Milky Way galaxy, which is shaped pretty much like a flat CD, might be embedded in a spherical halo of extremely cold hydrogen gas. If so, the gas would be glowing with very faint radio waves. It turns out that everything glows with radio waves — trees, buildings, the sky, people and so on — and normally drowns out the kind of faint signal Wilson wanted to look for. However, the horn at Holmdel had the unique feature that, when its 20ft opening was pointed at any location in the sky, radio waves from all these spurious sources had extreme difficulty getting into it. Wilson's faint signal — basically, a hiss of static — would not therefore be overwhelmed.

Before moving to a frequency of radio waves where they expected to pick up the glow of the halo of the galaxy, Penzias and Wilson decided to test their experimental setup by observing at a frequency where they expected no such glow. If the signal they picked up was precisely zero, then they would be in business.

The only problem was that when the two astronomers pointed the horn at a patch of empty sky, instead of picking up no signal, they picked up a constant hiss of radio static. It was what would be emitted by an object at about –270C, or three degrees above absolute zero, the lowest temperature it is possible to reach.

At first, they thought the hiss of static might be coming from New York City, which was just over the horizon. But when they pointed their horn away from that



CAN YOU HEAR ME NOW? The Bell Labs radio horn at Holmdel, New Jersey, where Robert Wilson, left, and Arno Penzias discovered the radiation left over from the Big Bang

direction, the signal was still there. Next, they thought it might be coming from a source in the solar system; both the sun and Jupiter pump out radio waves. But, as the months wore on and the Earth travelled around the sun in its orbit, the location of any such source should have changed. The static, however, stubbornly remained. Next, Penzias and Wilson wondered whether the source of the static was a high-altitude nuclear bomb test a couple of years earlier, which had injected electrons into the outer reaches of the Earth's atmosphere. Such particles would be expected to emit radio waves. But the static did not decline over time as would have been anticipated if it was associated with the bomb blast.

Finally, Penzias and Wilson's gaze settled on two pigeons, which had made a nest inside the horn, at the tapered end. It might

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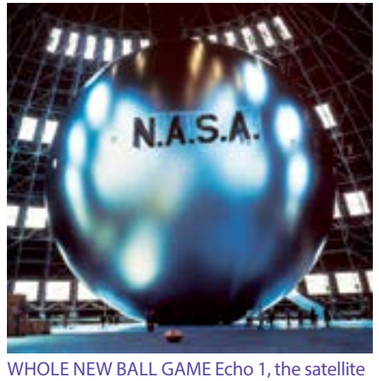


WHOLE NEW BALL GAME Echo 1, the satellite that the horn was built to communicate with

seem a daft place to make a home — after all, the nest had to be remade every time the horn was moved around to point at a different part of the sky. However, the winters in New Jersey are very cold, and the tapered end of the horn, where the pigeons had made their nest, was next to the refrigerator that cooled down the electronics of the radio receiver. Anyone who has been around the back of a refrigerator knows it is warm. So, in fact, the two pigeons had chosen a nice cosy spot to bring up their family.

In doing so, however, they had also coated the interior of the horn with what Penzias and Wilson, as scientists, described as a "white dielectric material", but which everyone else would have recognised as pigeon shit. And pigeon shit, in common with everything else, glows with radio waves. Could this be the source of the annoying hiss of radio static that for so many months had prevented Penzias and Wilson from doing any astronomy?

The two astronomers bought a Havahart humane baited trap at a nearby hardware store and caught the two pigeons. They then posted them (in the company mail!) to another AT&T site at Whippany, 35 miles across New Jersey, before putting on boots and overalls and, equipped with stiff brooms, climbing into the radio horn. Diligently, they scoured away all the white stuff inside. For good measure, they even put aluminium tape over all the rivets holding together the metal sheets from which the horn was constructed, just in case they too were contributing to the radio hiss.

Back in their everyday clothes, and full of hope they had finally solved their problem, Penzias and Wilson once again pointed the opening of the horn at the sky. But, to their dismay, the annoying hiss was still there.

By now, it was the spring of 1965, and they had managed to do absolutely no science since teaming up the previous summer. Just as they were succumbing to despair, however, Penzias made a fortuitous phone call to a physicist friend of his, Bernie Burke. The call was about another matter entirely, but, at the end of the conversation, Penzias could not help moaning about the annoying hiss of static they were picking up at Crawford Hill. Burke sat up. He had been to a recent talk by a researcher called Jim Peebles from Princeton University. From what he remembered, Peebles's boss, Bob Dicke, was supervising the building of a radio telescope to look for radio waves that have survived from a possible hot, dense phase of the early universe.

Immediately, Penzias phoned Princeton. Dicke was having a packed lunch with his team in his office. There was a short, technical exchange and, when Dicke put down the phone, he looked around the room, gravely: "Boys," he said. "We've been scooped!"

The next day, Dicke's group drove over to Holmdel, a mere 30 miles from Princeton. After examining the radio horn, and talking briefly with Penzias and Wilson, Dicke quickly realised that the two Bell Labs scientists had stumbled on exactly what the Princeton team was planning to look for.

Unlike the heat of, say, the fireball of a nuclear explosion, which dissipates into its surroundings, the heat of the Big Bang fireball had absolutely nowhere to go. It was bottled up in the universe, which, by definition, is all there is. Consequently, the heat "afterglow" of the Big Bang is still around today. Greatly cooled by the expansion of the universe in the past 13.82bn years, it appears not as visible light but as invisible radio waves. If you were to tune an old analogue TV between the stations, 1% of the "static" on the screen would be from the Big Bang. Before being intercepted by your TV aerial, it would have travelled across space for 13.82bn years, and the last thing it touched was the fireball of the Big Bang.

Remarkably, 99.9% of all the particles of light, or photons, in the universe are tied up in the afterglow of the Big Bang, with a mere 0.1% emitted by the stars and galaxies.

If you were to tune an old analogue TV between stations, 1% of the static on the screen would be from the Big Bang

(Here, "light" means both visible light and invisible radio waves.) If you had eyes that could see these radio waves, the whole universe would appear to be glowing brilliant white. It would be like being inside a giant lightbulb. The afterglow of the Big Bang is the single most striking feature of our universe. And yet it took until 1965 before it was discovered by Penzias and Wilson — and even then only by accident. (One of the reasons for this is that it is also the coldest thing pretty much anywhere in the universe.)

The "cosmic background radiation" comes from a time when the universe was a mere 380,000 years old. It truly is the oldest fossil in creation. Impressed on it is a "baby photo" of the universe at a critical moment when matter of the cooling Big Bang began to clump together under gravity. It was a process that would culminate in the birth of galaxies like the one in which you now live. The baby photo has proved to be a goldmine of scientific information. Every cosmic parameter you have ever heard of — for instance, the age of the universe being 13.82bn years — comes from the cosmic background. And cosmologists are still mining it. Imprinted on it are expected to be "gravitational waves" — ripples in the fabric of space-time from the first split second of the Big Bang — which almost certainly will show Einstein's theory of gravity to be wrong and point the way to new physics.

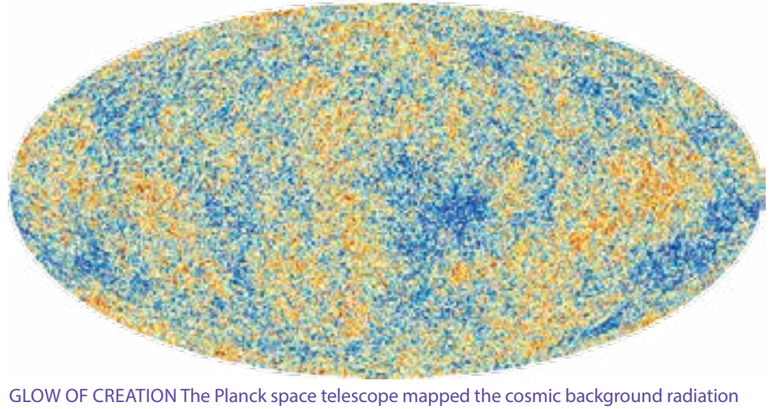
Bizarrely, it turned out that the cosmic background radiation had been both predicted and discovered before it was discovered — if that makes any sense. Seventeen years earlier, in 1948, the American physicists Ralph Alpher and Robert Herman had guessed that the heat of a "hot" Big Bang must be still around, and published their prediction in the British science journal Nature. Nobody had taken any notice. And, in 1938, Walter Adams, using what was then the biggest telescope in the world — a 100in instrument on Mount Wilson, north of Los Angeles — had noticed that, out in the cold of space, tiny dumbbell-shape molecules of cyanogen were spinning faster than they should. A Canadian astronomer, Andrew McKellar, suggested that they were being buffeted by something — radio waves at a few degrees above absolute zero. With the discovery of the cosmic background radiation, which permeates every pore of the universe, it became suddenly obvious what that "something" was.

The Nobel prize winner Steven Weinberg, in his bestselling popular-science book The First Three Minutes, pondered why the prediction of the cosmic background radiation had been utterly ignored. He concluded that, back in 1948, scientists literally could not believe that something as bonkers as the Big Bang could really be true. "The mistake of physicists," he said, "is not in taking their theories too seriously but in not taking them seriously enough."

Ironically, Penzias and Wilson were both adherents of the steady-state theory, proposed by the British cosmologist Fred Hoyle and two colleagues, in which the universe has existed for ever and had no hot dense beginning. They were, therefore, not happy about making a claim that what they had stumbled on came from the Big Bang. So they wrote a paper mentioning their annoying hiss of static, which they believed was an experimental result that would hold up whatever happened, but left all speculation about the identity of that hiss to an accompanying paper written by Dicke's team.

Penzias and Wilson did not in fact admit that the signal they had picked up had anything to do with the birth of the universe, and confirmed the Big Bang, for two whole years. Despite this, however, they won the 1978 Nobel prize for physics for the discovery of the relic afterglow of the Big Bang fireball.

And the pigeons? Well, they returned to the Holmdel horn — they were homing pigeons, after all — and, sadly, had to be shot. The only positive is that they died for science. Their droppings are invariably mentioned in astronomy books. Never in the history of science has something so profound been mistaken for something so mundane ■



GLOW OF CREATION The Planck space telescope mapped the cosmic background radiation

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