National Aeronautics and Space Administration

COSMIC TIMES

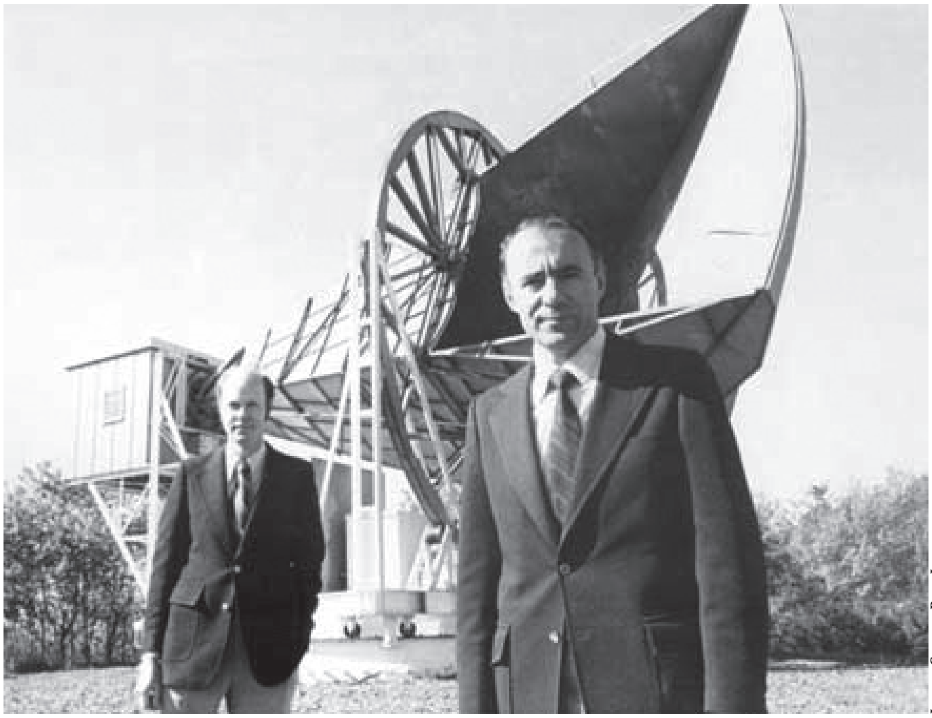
Early Edition

Age of the Universe: 10-25 Billion Years

1965

Size of the Universe: 25 Billion Light Years

MURMUR OF A Bang



Robert Wilson (left) and Arno Penzias stand in front of their antenna in Holmdel, New Jersey. They discovered a radiation signal that matches a signal astronomers expected if the universe began with a hot explosion called the "big bang." This discovery was made by accident as they tried to track down the source of unwanted noise in their receiver.

Astronomers have found a mysterious cosmic radio signal that is as old as the birth of the universe. This is the first direct evidence that the universe began with a Big Bang. It also gives us clues about how the universe might end.

The newly discovered radio signal is very faint. It is in the form of microwaves, which is a part of the electromagnetic spectrum. Microwaves are between radio waves and infrared light on the electromagnetic spectrum. These microwaves in space come from every direction of the universe, every hour of every day. This is the exact wavelength some scientists predicted they would find if the universe started in a Big Bang. The Big Bang, a giant explosion of hydrogen about seven billion years ago, would have been extremely hot and would have steadily cooled since then (everything warmer than "absolute zero" gives off some kind of electromagnetic radiation). If there was a Big Bang, then some of that radiation, detected as microwaves, would still be found in space today.

Two scientists, Arno Penzias and Robert Wilson, found what they call "cosmic background radiation" by accident. The two men work at Bell Laboratories and were trying to find out what was causing unwanted microwave signals that a 20-foot horn-antenna in Holmdel, N.J. was picking up.

When the Holmdel horn was aimed directly overhead (called the zenith), Penzias and Wilson found a microwave signal that

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matched the temperature of 6.7 degrees Kelvin. After subtracting microwave radiation that is found in Earth's atmosphere, and radiation from the antenna itself, they were still left with an unexplained microwave radiation that matched 3.7 degrees Kelvin. The antenna was aimed at empty space, so they had no explanation for the radiation. Empty space should be absolutely cold, "absolute zero," or zero degrees Kelvin. But it wasn't.

Luckily, just down the road from Bell Laboratories, at Princeton University, other scientists had the answer. Astronomer Robert Dicke and his team were building a telescope that could detect "cosmic background radiation." When they heard about the mysterious microwaves that Penzias and Wilson found, they knew it was just what they were looking for. The two teams discussed the find, then announced the discovery in a pair of letters that were published in the July issue of "Astrophysical Journal."

Robert Dicke and his team wrote about the cause of the cosmic background radiation. The very hot, very dense fireball of matter and energy that existed during the early universe would have been about 10 billion degrees Kelvin, he said. The extremely hot beginning of the universe, he said, would explain the heat that still remains in space today.

IMAGE CREDIT: AIP EMILIO SEGRE VISUAL ARCHIVES, PHYSICS TODAY COLLECTION

Robert Dicke

While this is an amazing discovery, some astronomers were not surprised. After all, in the late 1940s, George Gamow, Ralph Alpher, and Robert Herman already said there had been a "Big Bang" and that the heat from it should still be detectable in space. In 1949, Alpher and Herman recalculated some of Garnow's earlier calculations and predicted that this heat, this cosmic background radiation, would now have a temperature of "a few degrees Kelvin." It looks like they were right.

But Alpher and Herman were also partially wrong. They thought they would not be able to detect the cosmic radiation background because of starlight and radiation from other objects in space. But this is not so. It looks like the Big Bang has cooled off in a very specific way that channels the energy into specific wavelengths of radiation. Dicke and his team suspected this, so they were planning on looking for microwave radiation. This is also why they knew, right away, that Penzias and Wilson's unexplained microwave radiation was a huge discovery.

The discovery of cosmic microwave radiation was exciting for some scientists who study the universe, but not for others. Cosmic radiation background supports the Big Bang Theory, but causes big problems for the

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Big Hiss
Missed by Others

One of the biggest surprises that came from the new discovery of the Big Bang's background radiation is how many times other people have missed the radiation.

Just last year, Russian scientists Andrei Doroshkevic and Igor Novikov published a study on the physics of the Big Bang. They guessed that if the bang had happened, then there would be leftover heat between one and ten degrees Kelvin. They even said sky temperature measurements could be used from 1961 measurements taken from Edward Ohm to find this remaining heat. In an ironic twist, Ohm gathered his information from the Holmdel Horn antenna. This is the same antenna astronomer Robert Dicke and his team, along with Arno Penzias and Robert Wilson recently used to find the 3.5 degrees Kelvin cosmic radiation background left behind from the Big Bang. But Doroshkevic and Novikov didn't know that the radiation readings from Ohm's measurements were from space. Because of Ohm, they thought it was from the antenna itself.

Ohm had identified in his data what seemed to be 3.3 degrees Kelvin background radiation. He figured it was from the antenna. Because Penzias and Wilson had the job of subtracting away the antenna's own microwave radiation, they were able to say that the faint radiation really did come from space.

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QUASARS: *Express Trains* to Netherworlds

Astronomers have found a quasar racing towards the edge of the known universe at 450 million miles an hour. That speed is two-thirds the speed of light! This and other newly discovered quasars aren't just fast—they are really bright, too. Because they are visible to us Earthlings means that they have to be extremely bright. The speed of quasars and their brightness makes them very mysterious since no one really even knows what quasars are.

Radio astronomers have seen quasars for years. Five years ago astronomers matched one of these quasars, or quasi-stellar objects, with an object seen with telescopes using visible light instead of radio signals. But it wasn't until two years ago that astronomers Jesse Greenstein and Maarten Schmidt were able to see quasar 3C 273's colors.

The visible spectrum shows astronomers what elements the light-giving object contains. They found amazing things in this quasar. The color spectrum shifted towards the red end of the spectrum. This was kind of like a train's whistle dropping in tone as the train moves away from us quickly. The quasar, like a high speed train, was moving away from us very quickly. However, with quasar 3C 273, this "red-shift" showed more than just speed. Its speed was 16 percent of the speed of light. That is more than 100 million miles per hour!

The speed record holder is quasar BSO-1. Marteen Schmidt and Allan Sandage used the same technique for BSO-1 as they did for 3C 273. But, no one can even explain what BSO-1 is yet.

Sandage did say, though, that quasars give astronomers hints about the size and shape of the universe.

They know that quasars are probably NOT coded messages from a super-civilization. Russian astronomer Nikolai Kardashev suggested that early theory. US astronomers say that is probably not true. Any civilization that could send something that bright and that fast would have to send the messages with the power of 10,000 billion suns. That power—10,000 billion suns—is the amount of energy a quasar contains.

But the message might be from the universe itself. Astronomers are looking for more quasars and measuring their distance from us. Using the 200-inch Mount Palomar telescope, they want to see some of these quasars whose light is from 15 billion years ago, which is how long it would take their light to reach us if they are moving to the edge of the known universe. If the light from 15 billion years ago is reaching earth now, it would be from the early universe.♦

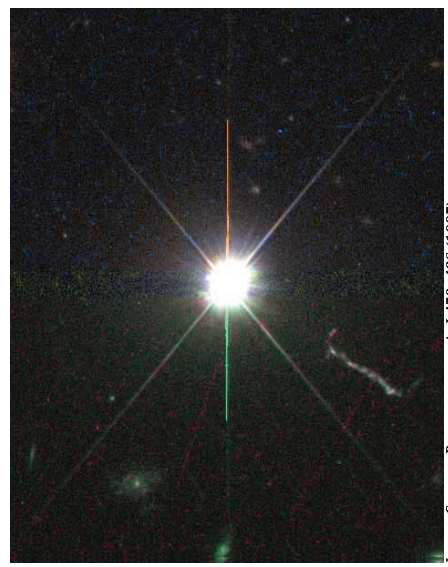

IMAGE CREDIT: BACHALL ET AL., APJ 450, 486 (1995)

Quasar 3C 273

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Steady State Theory of the Universe. The Steady State Theory, which many astronomers have favored over the Big Bang Theory, says that the universe is expanding because new particles are spontaneously created in empty space. But because this theory has no explanation for cosmic background radiation, the discovery weakens Steady State Theory.

The Big Bang Theory implies two different fates for the universe. Dicke and his team say that either the universe will expand and cool forever, an "open universe," or the universe is a "closed universe." If it is a closed universe, the gravity of all of the matter in the universe will pull back together and collapse into another hot ball. All matter will break into its basic building blocks, then explode again in another big bang. We will have another new universe. The closed universe idea is similar to the Steady State Theory because neither one has a beginning or an end. The Big Bang Theory has no way of figuring out what existed before the last big bang and no way of stopping us from being crushed into another hot ball before the next big bang.♦

Supernovae Leave Behind Cosmic X-Ray Generators

Two years ago, astronomers discovered that the universe is full of X-rays. Now they are starting to find very small sources even more accurately. And the machines they are using look nothing like the machines in your doctor's office!

One X-ray source astronomers found is the Crab Nebula — it is the remains of a star that exploded almost 900 years ago. The remains of a star are often called a supernova remnant. Another X-ray source, Ophiuchus XR-1, seems to be in the same direction as another past supernova. If you drew a map of all X-ray sources, then compared it to another map of supernova remnants, the two maps would look almost the same. Astronomers don't know why there is X-ray radiation from these sources that are far, far away from the Sun (where we get many X-rays from). But if Ophiuchus XR-1 really does come from a supernova remnant, as astronomers predict, then they can compare the two X-ray sources to try to answer some questions.

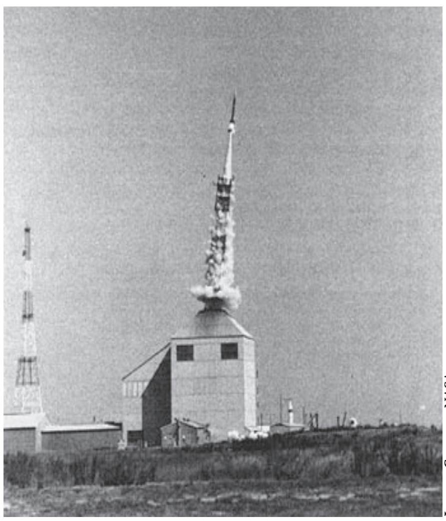

IMAGE CREDIT: NASA

A rocket launches from Wallops Island in Virginia. This rocket is similar to ones used to find X-ray sources such as Scorpius X-1 and, more recently, the Crab Nebula and Ophiuchus XR-1.

Locating these two X-ray sources was not easy. X-rays cannot get through the Earth's atmosphere. The trick was to get X-ray instruments enough time in space, on rockets, to allow them to find the distant sources. Because of this, X-ray astronomy is difficult and expensive. Each rocket launch only allows five minutes of time to observe. This difficulty is not all bad, however; because the Earth's atmosphere blocks X-rays, life is protected from these deadly rays that sometimes flare from the Sun.

Because each rocket flight only gives X-ray astronomers five minutes of study, the discoveries of the X-ray sources at the Crab Nebula and Ophiuchus XR-1 took three years of research. During that time, astronomers were looking for other X-ray sources besides our Sun. Even though our Sun doesn't put out a lot of X-rays, we can easily detect those because it's the closest source in our sky. So the first research rocket launch in 1962 was designed to use its five minutes to look at the Moon. Riccardo Giacconi and his team at the American Science and Engineering Group expected to discover Moon minerals fluorescing, or giving off light, after they were hit with heavy particles (known as "solar wind") from the Sun. But they were wrong.

Instead, astronomers found something even more unexpected and amazing. They found X-rays coming from every direction. They found an especially intense X-ray source coming from the direction of the constellation Scorpius. They named this area Sco X-1. This source is different from the Crab Nebula, where the X-ray source seems to come from objects. Sco X-1 has not been tracked to any known object. At this point, it is a space mystery.

Someday astronomers hope they can place one of their instruments in a stable orbit above the earth so they can spend even more time looking at the X-ray universe. Until then, they will be limited to observing X-rays in five minute periods while their instruments are strapped to a rocket. ♦

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Two other astronomers just missed the radiation as well. Ten years ago, at the Nançay Radio Observatory, Emile Le Roux reported microwave background radiation of 3 degrees Kelvin, plus or minus 2 degrees. Then in 1957 it was Tigran Shmaonov who almost made the discovery. He reported measuring background temperature of 4 degrees Kelvin, plus or minus 3 degrees.

Neither Le Roux nor Shmaonov connected their observations to the predictions of the Big Bang Theory. The predictions existed as early as 1948, but the astronomers didn't connect the theory with their discoveries. It just didn't make sense to them. Penzias and Wilson might have had the same problem if the Princeton University team, just down the street from them, did not see the background radiation as the same radiation predicted by the Big Bang Theory. ♦

Galaxies Still Misbehaving

Galaxies are not heavy enough. That's what astronomers are saying. When astronomers compare the amount of light coming from galaxies with how much they "weigh," the numbers don't work out right. Even the latest "weigh-in" does not match. Spiral galaxy NGC 3521 has the mass, or "weight," of 80 billion suns. And spiral galaxy NGC 972 has a mass of 12 billion suns. But there is more light coming from the galaxies than that. They should "weigh" more. And astronomers don't know why they don't.

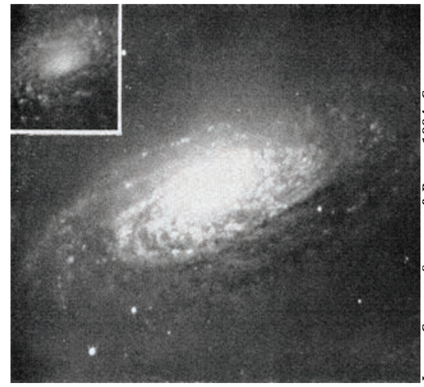
To measure the amount of starlight coming from the two galaxies, astronomers carefully measured their total brightness, or luminosity. They record these on photographic plates. They also look at how the stars in each galaxy spread out from the center to the edges. The way the stars spread out is different for every galaxy.

They measure the mass of the galaxy using the same technique they used long ago to figure out the mass of the Sun. If you have a small-massed object (small compared to the Sun or larger object!) orbiting the large-massed object, and you know how fast the object is orbiting, then you can figure out the large object's mass. You can use the same technique for galaxies. This time you use the stars that are orbiting the galaxy's center.

Astronomers can't find out how fast stars are orbiting in galaxies by using stopwatches or telescopes because the movements are too small for that. Instead, they look at small areas of starlight in the galaxy, then break the starlight down into the color spectrum (much like astronomers do when studying quasars). This rainbow of colors that make up starlight contain lines of color that shift based on how fast the stars are moving. The speed can then be used to determine the mass of the galaxy they are a part of.

To compare numbers of mass and amount of light in a galaxy, astronomers come up with a "mass-to-light ratio." This is based on the mass and light (luminosity) of our own Sun, since we know the mass and the amount of light from our Sun. Our Sun's mass-to-light ratio is one. The mass is "one solar mass" and the luminosity is "one solar luminosity." A one-to-one ratio is equal to one. If another galaxy or object has a ratio more than one, then that implies it has more mass than light, which means it "weighs" more than it should.

The NGC 3521 galaxy was studied with the 82-inch telescope at McDonald Observatory at the University of Texas. When they studied the galaxy, they found a mass-to-light ratio of 4 or more. This means the galaxy weighs 4 times more than it should, based on how much light it gives off. The mass of the other galaxy



Sprial galaxy NGC 3521; inset is galaxy NGC 972.

they studied was much closer—NGC 972 had a 1.2 ratio. Teams of researchers led by Margaret Burbridge at the University of California at San Diego reported these results in recent issues of the *Astrophysical Journal*.

These two galaxies are not unique. Other researchers are also finding mismatched mass-to-light ratios. No one has a good explanation for this.

But astronomers today are doing better than astronomers in 1933. Fritz Zwicky at CalTech measured the amount of light from the entire Coma cluster of galaxies (instead of small light samples like they did with NGC 3521 and NGC 972). Then he measured the speeds of the galaxies as they orbited the cluster. This gave him the mass. He came up with a mass-to-light ratio of about 500. That means 99% of the matter is hidden, or not giving off light! At the moment, most astronomers just ignore such extreme numbers since they are probably just flukes. ♦