THE BIG BANG

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The title of this paper conveys to most of you what is now the the most popular concept among astronomers of how our universe began, an event which we would most easily understand as a great explosion. It happened some 18 to 20 billion years ago.

How do they know this? What evidence could exist at present for such an event which, it is claimed, occurred at the instant of creation itself. The concept of an expanding universe was implied in the general theory of relativity published by Albert Einstein in 1916. Einstein himself had a personal distaste for the notion, much preferring the idea of a stable cosmos, and did not pursue the implication. It was some 10 years after publication of the theory when Edward Hubble discovered that all observed galaxies in the sky are, in fact, moving away from ours, and the farthest galaxies at the greatest speeds. This observation, by itself, did not establish the idea of an initial explosion. After all, there could possibly be a central source of this matter which, beyond the range of our observation, was continually spewing it out at enormous velocities, and could have been doing this forever--no beginning, no ending--rather, a "continuous creation," and it was this theory which held sway until just a few years ago.

The 1978 Nobel prize in physics was awarded to two men who were the first to discover radiation still existing from the so-called "big bang." They were Arno Penzias and Robert Wilson, of the Bell Laboratories, who admitted their discovery was pure accident.

It was no accident for a group at Princeton University, some 30 miles away from the Bell antenna. In 1965, Professor Robert Dicke conceived the idea that if such a stupendous, nuclear-type detonation had occurred some 20 billion years ago, then some of its heat radiation should persist even now at very low temperatures, temperatures which could be registered on modern sensitive instruments. His colleague, James Peebles, was placed in charge of the procedure.

Heat radiation is familiar to all of us, but we only infrequently think of it as an electromagnetic radiation, having the same speed and somewhat similar frequency to that of visible light.

I have a chart here of the entire range of electromagnetic transmission. Notice the very small portion of which is visible to us as light. See how much larger is the area of radiant heat, or infrared radiation. Infrared means less-than red, the red being the red portion of the whole spectrum of visible light. Red light waves are some 150 times shorter, from crest to crest, than the waves of infrared. One can experience considerable heat without seeing it: consider a tub of hot water in a dark room.

Princeton's Prof. Peebles made his calculations and saw that he would be searching for a very low level of temperature, about 3 degrees Kelvin. Recall that the Kelvin scale's zero is 273 degrees below zero degrees Centigrade, which is the freezing point of water. So Peebles was looking for radiation 270 degrees Centigrade below the freezing point of water. This is 3 degrees above a point which can be demonstrated only mathematically, for at absolute zero there would be no kinetic energy in the molecules being measured.

Peeble's group felt that their's was the only effort being made to detect this so-called "whisper from space," and when the professor was invited to a physics seminar at John Hopkins, he voluntarily talked of the planned experiment. One of the listeners was an MIT astronomer who knew about the Bell Laboratory work and who later learned that the Bell Lab researchers could not understand the signals they were receiving. The MIT man brought the two groups together. There was immediate excitement, because it was realized that the~~ir~~ Bell antenna, tuned to this low level of infrared was seeing farther than anyone had seen before. The radiation came from all directions, no matter where the antenna was aimed, and was uniform in intensity, as would be the case in temperature radiation. It was the same day versus night, thus it could not be the sun. It was the same winter versus summer; it could not be from only our solar system. It was the same whether the antenna was aimed at the center of our galaxy, or in the opposite direction; thus it could not be a property of our galaxy alone. This radiation was permeating all space.

The equipment used by the Bell Lab people had picked up their signal in the 7 centimeter range; the Princeton receiver was tuned for a slightly longer wave length. These points were plotted graphically, along with a third point supplied later by the radio observatory at Cambridge, England. What was being sought was the whole spectrum of this temperature, so that it could be evaluated quantitatively. Radiation from a source of steady temperature will describe a fixed curve as the frequency, or wave length, of the receivor is varied. This is illustrated on the accompanying sketch.

Each steady temperature has its distinctime curve. This curve ~~is~~ approximates the one for 3 degrees, with allowances for my memory and the short period of display on the television screen. I have added the three points first recorded by the researchers. They knew they were dealing with a very low temperature, but they could not define it absolutely until the whole curve had been received. To go up over the hump of the curve meant detecting millimeter-length waves instead of the centimer-lengths first discovered. These shorter wave lengths were being blocked by the water droplets in our atmosphere. The researchers first tried rockets to get above the atmosphere, but their instruments were confused by the residual heat from the rocket engine. Balloons gave them usable data. In 1977, a University of California group brought in a tape delineating the entire curve from its balloon flight 25 miles up.

Now having fixed the shape of the curve as that of 3 degree temperature, it was a straightforward calculation to show that this much energy, permeating all observable space, is 99 percent of all the radiation in space. Our own sun, all the other stars, and including the super-energy quasars do not radiate 1 percent as much as the 3 degrees which fills all the vast blackness between the little white specks out there.

To get an idea of where this vast energy is coming from, we must understand that basic tool of astronomy used by Edward Hubble, as mentioned earlier. Recall that Hubble noticed that the light from stars observed on different occasions had shifted toward the red end of the spectrum, the light thus showing a longer wave length. The longer wave length means that the star is moving away from the observer, an application of the Doppler effect.

Doppler, you'll remember from your high school physics, found that the pitch of a sound wave goes lower (longer wave length) as the source of the sound is moving away, or higher (shorter wave length) if the source is moving closer. This is because the speed of the movement makes for a relative change in frequency, the waves being stretched apart or pressed together, as far as the observer is concerned. The speed of the source can be determined by measuring the change in pitch. It works the same whether the source or the observer is moving, or both moving, as long as there is a relative difference in their speeds.

This physical principle applies also to light waves. For the higher frequencies of light waves, the speeds must be relatively greater to be as noticeable. Hubble found that the most distant stars had the most noticeable shift toward the red, thus were moving away at the greatest speed.

On a musical scale, the farthest galaxies our telescopes can see have a red shift of about one octave lower than the close ones. But the shift of the infrared heat we've been discussing is on the order of 6 octaves, or a thousand times greater than that of the close stars.

Thus, by Hubble's thesis, the source of the heat is much farther away and moving out faster than anything we had known about. Its redness, having been shifted a thousand fold, has been cooled a thousand fold by the time it reaches us. The temperature way out there at the source is not 3 degrees, but 3,000 degrees. Now, finally, we're getting close to the very beginning. Here's the version of Phillip Morrison, professor of astronomy at MIT:

"We can imagine that region...because it's not so hard to realize something like it in the laboratory. Had you been there, it would have been like living inside a sunlit cloud, bright everywhere...As the young universe expanded, that bland plasma slowly grew cooler and cooler--4,000 degrees, 3,500 degrees, 3,000 degrees. At that point, the temperature is not high enough to break apart ~~the~~ atoms of hydrogen, so the atoms form, each electron finding a proton to join in a tight dance as familiar hydrogen atoms. When that happens, the electron mist is no longer opaque. Hydrogen is transparent. The radiation is then set free from matter; it travels through this stuff as unimpeded as the light from a desk lamp falls on the desk, and it's been glowing separate from matter ever since that time. So now the black space is filled with radiation, and the shining points mark the condensation of matter."

"Nature has been generous in showing us the 3 degree temperature... It comes from a single time, the time when the electrons and protons combined to make transparent hydrogen. That time is marked with the single temperature...As that temperature travels away through space it is successively reddened by the red shift to longer and longer wave lengths. These longer wave lengths shift the energy peak to lower and lower energies, so that the measured temperature becomes smaller and smaller, gradually with time. Had we measured a hundred million years ago, we would have found a little more than 3 degrees. If our descendants measure a hundred million years from now, they will find a little less than 3 degrees."

In 1977 and 78, the radiation lab at Berkeley began using a new tool in its study of this cosmic heat radiation--an old U-2 spy plane which could operate around 13 miles high, above most of our atmosphere. The plane was fitted with two antennas, placed back to back, and rotatable, so that any imperfection in a single antenna would be canceled when the other antenna was rotated into the first one's position. After about a year of flights, in which the entire sky was scanned, a significant pattern emerged. We quote Prof. Richard Miller:

"There was a most intense region, in the direction of the constellation of Leo, and very significantly, the least intense region was 180 degrees away in the constellation Aquarius...The variations between these regions was very smooth and uniform. This gave us a very ready interpretation of what was causing it. It was due to the motion of the earth through the background radiation."

Invoking the Doppler effect again, we see ourselves as moving observers. The radiation looking behind us is a little colder; ahead of us, a little hotter. And by about one part in a thousand, we learn by measuring the difference between these two radiations. So that you and I, and Hopkinsville, and all our solar system is moving in the direction of the constellation Leo, at about 200 miles per second.

We learned from Einstein that all motion is relative, but this motion is related to the grandest reference marker one can imagine. It is related to the average motion of all matter in the universe, the source of our temperature radiation. It is the closest thing to absolute motion that we can think of measuring.

So if we know the direction in which we are going, and the speed at which we are going there, and our approximate age--what then about our future? Will we be going like this forever and ever? Will the whole universe continue always expanding, or will it slow down and stop, perhaps even begin to contract under the influence of its own total gravity to a size which would precipitate yet another explosion, or perhaps even to contract and vanish into the vortex of a gigantic "black hole" of unimaginable gravity and next appear in a different universe of anti-matter, a universe of opposite and negative values. Because this is a challenge, the research is underway to produce evidence of trends, clues to the full answer.

One approach is to measure the density of the universe and calculate whether this amount of mass can generate the gravity necessary to slow down the expansion at its present rate of speed. One can compute the masses of the obvious components in a specified volume of space by noting the gravitational attraction of these components on neighboring objects. Such measurements generally yield a density more than three times too small to close the universe: however, this factor of three is small enough to be within the range of experimental error, according to those who have made the measurements. Also, there may be undiscovered forms of matter in the area studied--such things as nonluminous stars, the elusive particles called neutrinos, and the ageas of space gravel.

In this connection, a satellite recently found previously unknown amounts of a hot, gas-like material scattered in space. Another problem: how can we take a given volume of space and say that the number of stars, and their distribution there, is typical or the average of a heterogeneous total universe?

Astonomers will in time have more sensitive probes, more sophisticated methods, and may then be able to give us as clear a picture of our eventual ending as we now have of our beginning, that almost incomprehensible display of energy which we smugly term "the big bang."