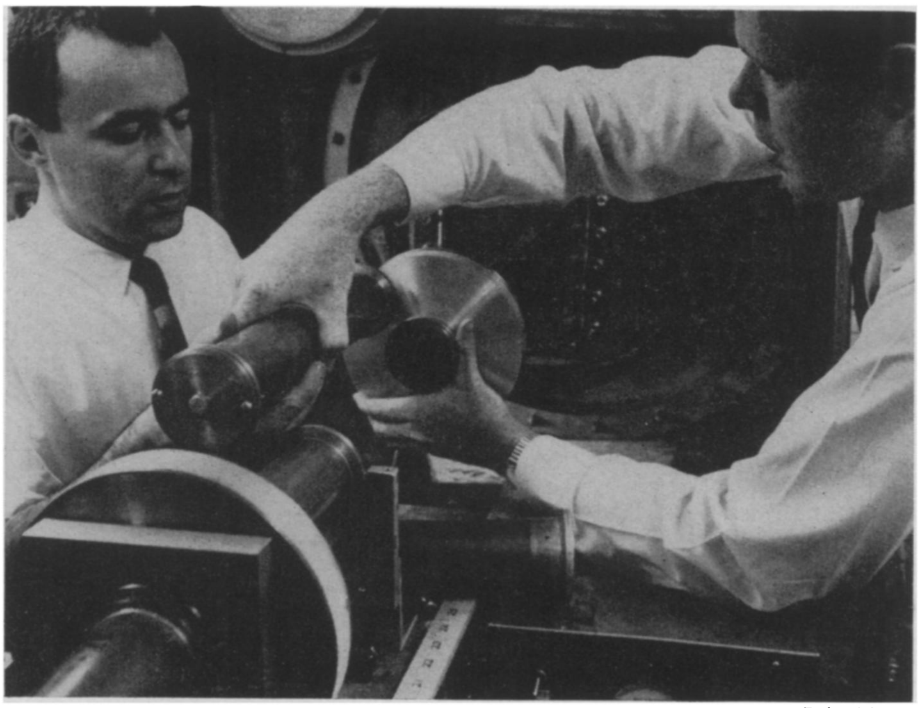
Remnants of the primeval fireball believed aglow

Big Bang theorists take relic radiation as proof

by Dietrick E. Thomsen



Robert Isear

Drs. Wilson and Penzias examine equipment used to detect black body radiation.

For the last 50 years cosmologists have known that they have to deal with an expanding universe. Many theories of the universe's evolution and history have been proposed in the light of this fact, and controversy over them has been continuous.

Until recently observation—the basis of most sciences—has had little to contribute to the argument because the effects that would distinguish among the theories were unobservable. However, radio astronomers in the last few years appear to have hit on one of the few observables in the business. They have identified in space radiation of the sort that would be expected from a black body at temperatures three degrees above absolute zero.

This level of blackbody radiation is predicted by the so-called big bang theory of cosmology, which postulates a universe supposed to have expanded from a small, extremely dense beginning and to be getting thinner and thinner as it grows. Finding the radiation, supposed to be a relic of physical conditions at the time of the primordial fireball, has given proponents of the theory almost a certainty that they are right, but the proponents of a radically different set of theories—the steady-state models—are not ready to give up. They continue to try to shake the confidence of their opponents.

The expansion of the universe began as a theoretical prediction by Dr. Willem de Sitter, who found in 1917 that one of the possible solutions of Einstein's general relativity called for it. Observational evidence that there was indeed an expansion going on came in the next decade from studies of the velocities of distant galaxies by Dr. Edwin Hubble and others, but whether it fitted de Sitter's model was not determinable; the field was open for theorists.

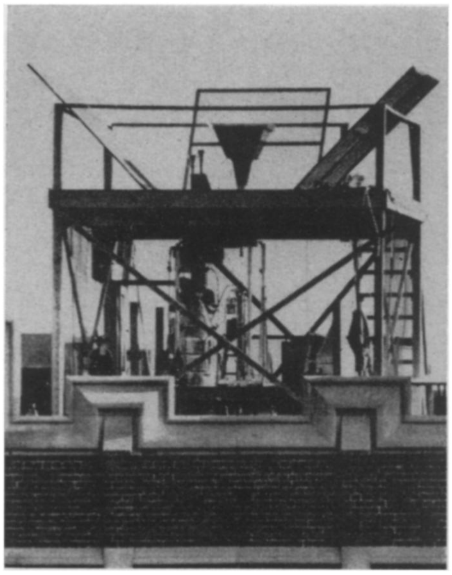
This expansion, if it has always been going on, raises serious problems of beginning and end in cosmological theories. If one follows time backward, the universe gets smaller and smaller until in the beginning everything is concentrated in a geometrical point. Going toward the future the universe gets ever more attenuated.

These ideas, especially the problem of infinite density at one end and infinite expansion at the other, were difficult for many scientists to accept, and some tried to get around them by postulating various combinations of static and expanding or pulsating universes.

A more radical way of getting around the density difficulties was to throw away the notion, implicit or explicit in other models, that the amount of matter and energy in the universe was fixed and constant once and for all. Doing this led to the steady-state or continuous-creation theories associated with the names of Profs. Hermann Bondi, Thomas Gold and Fred Hoyle.

Though Profs. Gold and Bondi differ from Prof. Hoyle, both theories are based on the notion that as the universe expands, matter is continually created out of nothing. This notion is shocking to many people, but, Prof. Bondi asks in his book, *Cosmology* (Cambridge University Press, 1961): ". . . why is it more of a hypothesis to say that creation is taking place now than that it took place in the past?" The continuous creation maintains the density of the universe at a constant value. As the universe gets bigger, more matter appears; in the past when the universe was smaller, there was less matter.

At about the time — 1948 — that Profs. Bondi and Gold came up with their steady-state theory, Drs. George Gamow, R. A. Alpher and R. C. Herman took a close look at the physical conditions that would have existed if the universe began in a point or a very small volume. They evolved a theory that has since become known as the



Princeton

Antenna at Princeton: old message.

big bang or cosmic fireball concept.

They found that if the matter and energy now in the universe were concentrated into a very small volume it would have been very hot; 10 billion degrees C. is the figure usually given. At these temperatures organized matter would not exist: electromagnetic radiation would dominate the situation. They found further that this radiation would be thermal or blackbody radiation; that is, it would have the characteristics of the radiation that comes from a hypothetically perfect radiator when only thermal motions are contributing to its generation.

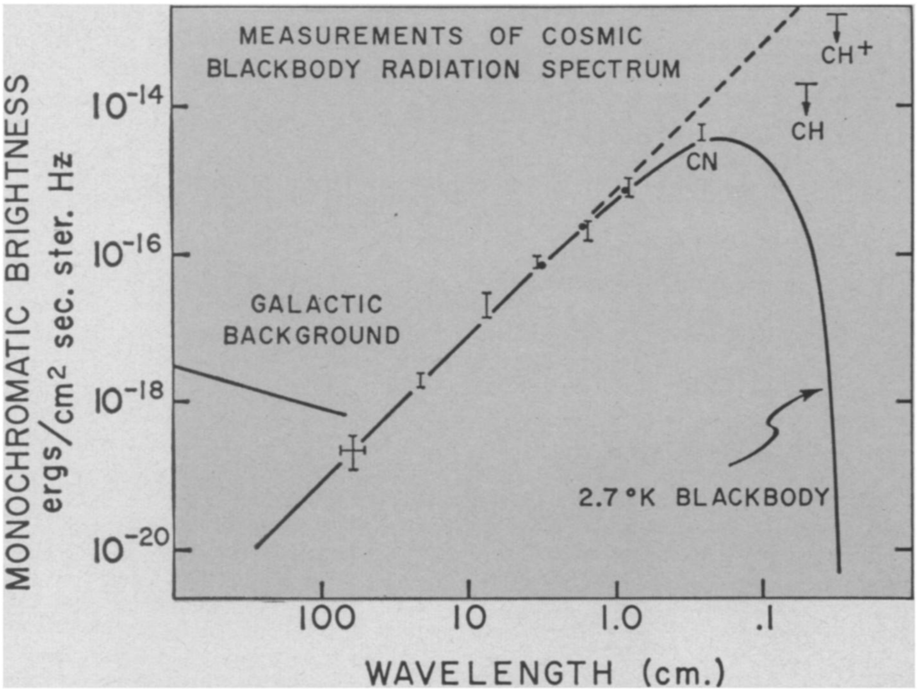
The spectrum of a black body shows a characteristic pattern of variation of brightness with wavelength. The shape of the pattern is the same no matter what the temperature of the emitter, but the wavelength band it covers shifts with temperature: When the body is cool, it emits in the radio range, shifting its emissions into the infrared, visible, ultraviolet and X-ray regions as it gets warmer.

As the universe expanded, it would have cooled. Most of the original radiation would have been converted to matter, but some of the radiation would have stayed as such, cooled by now to a temperature less than 10 degrees above absolute zero, at which it would appear roughly as centimeter-band radio waves.

The idea got a good deal of publicity when it was presented, but then it fell into a kind of limbo. Prof. Robert H. Dicke of Princeton University suggested a similar blackbody condition in a theoretical study of a pulsating universe, but he forgot that he had done so until some students and colleagues reminded him of it years later.

It was in 1964 that the reminder took place and Prof. Dicke suggested that the cooled-off blackbody radiation might be looked for. A group of Princeton physicists prepared to look, aided by a microwave radiometer that Prof. Dicke had invented in 1945—this he had not forgotten—which used a technique of switching back and forth between the signal and a super-cooled reference to record faint signals that were in danger of being masked by receiver noise caused by heating in the circuits.

While the Princeton cosmologists were at this work, they received word that Drs. Arno A. Penzias and Robert W. Wilson of the Bell Telephone Laboratories in Holmdel, N.J., had found a signal at 7.5 centimeters wavelength that fit a blackbody spectrum of about three degrees above absolute zero.



Graph of the blackbody radiation supports the backers of the cosmic fireball.

(Absolute zero is minus 273.16 degrees C.) Shortly thereafter, Drs. Peter G. Roll and D. T. Wilkinson of the Princeton group found a signal at 3.2 cm that fit the same spectrum. As Prof. Wilkinson said recently while reviewing progress for the members of the American Physical Society, all this could have been done 15 years earlier than it was if the right people had talked to each other, read the right papers and made the proper mental connections.

But once the investigation was started, it was pursued with great vigor. Many observers in different parts of the world went to work to find other points of the spectrum. Up to now many points have been found ranging from about one-meter wavelength down to about eight millimeters; all that have so far been found fit the spectrum of a black body that is now figured to about 2.7 degrees K. (The Kelvin scale starts at absolute zero.)

The growing certainty of the blackbody radiation had led, for a while, to a general belief that steady-state theories had been pretty well discredited. But their proponents, especially Prof. Hoyle and his colleagues, have counterattacked in a series of recent papers, principally in NATURE, dating back from March 30.

The steady-state theories suffer from insusceptibility to observation. It would take millions of years to be sure that the density of the universe is indeed constant—the motions are too slow to reveal in a shorter time period, whether it changes or not. The appearance of the new matter that the theory calls for is also impossible to observe. On the average, according to Prof. Bondi, the mass of one hydrogen atom is created in one liter of volume every 500 billion years. Nobody has bothered to calculate the chances of seeing one pop up.

The steady-state proponents have therefore concentrated on attempts to demolish the observational case for the cosmic blackbody. Since they cannot deny the existence of the radiation, they have tried to find other factors responsible for it. They have suggested interstellar dust grains, cosmic rays and heating of gas clouds by radiation from infrared stars. Success in attributing all or any part of the radiation to such causes would shake the fireball theory.

At the moment there is no firm evidence that any of these are at work, and the proponents of the fireball are not in the least daunted. They are moving on to the job of providing a detailed history of the universe under their theories.

If you believe the fireball theory, says Prof. P. J. E. Peebles of Princeton, who has been very active in work on this theory, you have a new handle on the evolution of the universe. A number of people are at work determining such things as at what stage various kinds of matter formed, when and how galaxies formed, and whether clusters of galaxies associate in superclusters.

And Prof. Wilkinson points out: One good practical use of the cosmic fireball is that it gives jobs to a lot of cosmologists.