

Penzias A A & Wilson R W. A measurement of excess antenna temperature at 4080 Mc/s. *Astrophysical J.* 142:419-21, 1965.
[Bell Telephone Labs., Inc., Crawford Hill, Holmdel, NJ]

Radiometric measurements at 7.3 cm show the brightness temperature of the sky to be unexpectedly high. The results of a series of tests appear to exclude terrestrial, atmospheric, solar system, and galactic origins of this phenomenon. This radiation appears to be a cooling remnant of the hot explosive origin of the universe. [The SCI® indicates that this paper has been cited over 310 times since 1965.]

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"Bell Labs' superb communications-related technology has also provided powerful tools for basic science. In the fall of 1963, with the completion of the research portions of the Echo and Telstar communications satellite projects, the Lab's 20-foot horn reflector antenna became available for radio astronomy. Robert Wilson and I set out to refit this instrument for our planned program of observations, a series of measurements aimed at providing precise determinations of the wavelength dependence of a number of astronomical radio sources in the microwave portion of the radio spectrum. Of these, our galaxy, the Milky Way, provided the most challenging observational problems. Its radio emission is a sharply decreasing function of frequency with a barely detectable intensity at microwave wavelengths. More important however is the fact that our observations are made from inside the galaxy. The normal radio astronomical techniques of alternately observing a source and an adjacent region of blank sky, recording the difference in receiver output, cannot be used. Instead the comparison must be made with a source of microwave noise whose intensity is accurately known.

"In our case this source of reference noise was a transmission line termination immersed in liquid helium. My design philosophy was to make it as good as possible from an electrical

standpoint and worry about cryogenic design afterwards. The resulting accuracy was much better than we thought we needed, but more than amply rewarded our extra effort by throwing the unexpectedly high brightness temperature of the sky away from the band of the Milky Way into unignorable sharp relief.

"In determining this brightness, we had to allow for noise contributions from the atmosphere, the ground around the antenna, the lossy components in the antenna itself, and miscellaneous items such as the droppings of a single-minded pair of pigeons.

"We were left with a source of noise which persisted day-to-night and summer-to-winter some two orders of magnitude larger than what one might reasonably expect from our galaxy or any other combination of known radio sources.

"Our perplexity was ended when a colleague called our attention to a preprint by P.J.E. Peebles indicating that microwave radiation could be an observable consequence of the explosive origin of the universe. We contacted R.H. Dicke, who had suggested Peebles's investigation and was in fact setting out to look for such radiation,¹ and arranged to publish back-to-back papers in the *Astrophysical journal*. While we were grateful for the comfort of at least one explanation, we had little reason to believe that it would be the final answer, and wanted to call our result to the attention of other astronomers.

"Despite the best efforts of ingenious theoreticians, this explanation has proven to be the durable one. Unknown to us at the time, it was contained in the earlier work of George Gamow² and predicted by Ralph Alpher and Robert Herman.³ The existence of the three degrees provides the foundation of the nearly universal acceptance of the 'Big-Bang' theory of the origin of the universe; the perjurious origin of this name in an allbut-forgotten scientific debate notwithstanding, this term has found its way into everyday usage, including the product of a popular T-shirt company some few weeks before the 1978 Nobel prize in physics was announced. Recent work in the field has been prepared by S. Weinberg."⁴

1. Dicke R H, Peebles FJE, Roll P G & Wilkinson D T. Cosmic black-body radiation. *Astrophysical J.* 142:414-19, 1965.
2. Gamow G. Expanding universe and the origin of elements. *Phys. Rev.* 70:572-3, 1946.
3. Alpher R A & Herman R C. Remarks on the evolution of the expanding universe. *Phys. Rev.* 75:1089-95, 1949.
4. Weinberg S. *The first three minutes*. New York: Basic Books, 1977. 188 p.