NOBEL RECOGNITION OF COSMOLOGY

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Although astronomy once occupied the pride of place in physics at the time of Galileo and Newton, it had been relegated to the status of a poor relation at the turn of the present century. In the renaissance of astronomy over the last five decades, thanks to improved observational devices and inputs from theoretical physics, the subject is regaining its lost popularity. Even so, of all the branches of astronomy and astrophysics, cosmology is still viewed with suspicion (and derision?) as being a highly speculative subject.

Against this background, the astronomers in general and cosmologists in particular should welcome the award of the 1978 Physics Nobel Prize for a discovery which is of importance *only* because of its cosmological significance. The scientists responsible for this discovery, Arno A. Penzias and Robert W. Wilson, share the prize with the Russian low temperature physicist Peter Kapitza.

Both Penzias and Wilson work at the Bell Telephone Laboratories at Holmdel, N. J., U.S.A. Penzias, the Director of Radio Research Laboratory, was born on April 26, 1933 in Munich, Germany. During the Nazi rule, the Penzias family shifted to America. After graduating in 1954 in the City College of New York, Arno Penzias served as a radar officer in the U.S. Signal Corps and then took his Ph.D. degree from the Columbia University in 1962. He joined the Bell Labs in 1961. Wilson, who heads the Radio Physics Research Department was born in Houston, Texas in 1936. Having graduated from Rice University in 1957, he went to the California Institute of Technology where he took his Ph.D. in 1962. Having spent a year as a post-doctoral fellow at the Owens Valley Radio Observatory of Caltech, Wilson joined the Bell Labs in 1963.

For cosmologists, the pair Penzias and Wilson became household names when their paper entitled 'A Measurement of Excess Antenna Temperature at 4080 Mc/s' appeared in the Astrophysical Journal in 1965 (**142**, 419). To understand the significance of this 'excess' temperature for cosmology, it is necessary to go back nearly two decades before this discovery was made.

In the mid-1940s, George Gamow and his collaborators Ralph A. Alpher and Robert Herman had proposed the concept of what is known as primordial nucleosynsis. In this concept it is assumed that in the early stages of the big bang universe, there was plenty of radiation around at high temperatures. The radiation temperature of the universe drops steadily as it expands, in inverse proportion to the scale factor. Thus the radiation temperature was $\sim 10^{10}$ °K at ~ 1 second and $\sim 10^{9}$ °K at ~ 100 seconds after the big bang. Gamow *et al* proposed that in the first few seconds of this hot big bang, the temperature was high enough to synthesize nuclei of atoms from the basic building blocks of neutrons, protons etc. Although in the early stages there was interaction between matter and radiation, subsequently they got decoupled. The radiation did retain, however, its thermalized nature even in its decoupled form, although the temperature of the black body spectrum decreased.

At that time, Gamow *et al* did not make any precise guesses for the present day radiation temperature (A figure of ~ 5 °K was in fact mentioned by R. A. Alpher, and R. Herman, (*Nature*, **162**, 774, 1948). It was however, expected that the relic radiation would be in the microwave region.

The discovery of the isotropic radiation at 7.35 cm by Penzias and Wilson, with a temperature of 3.5° ± 1°K was therefore a striking confirmation of this big bang picture. However, the story is not so simple as that.

Owing to a strange series of circumstances, Gamow's early prediction seems to have been more or less 'forgotten' in the early 1960's. Several research workers including Ya. B. Zeldovich (Moscow), F. Hoyle and R. J. Tayler (Cambridge) and P. J. E. Peebles (Princeton) had redone Gamow's primordial nucleosynthesis calculations with more sophisticated inputs from nuclear physics and cosmology. I personally recall in early 1964 an excited telephone call from Fred Hoyle when he stated that his calculations with Roger Tayler had convinced him that 'the matter in the universe has passed through a high temperature phase in the past.' Hoyle was referring to the observed abundance of Helium which seemed too high to be made entirely in stellar nucleosynthesis. Gamow's primordial nucleosynthesis offered the solution to the helium problem.

Peebles at Princeton had also reached a similar conslusion. The Princeton group went one step further, however. R. H. Dicke at the Palmer Physical Laboratory of Princeton University realized that it was a practical proposition to look for the relic radiation and he set his colleagues P. G. Roll and D. T. Wilkinson to devise an instrument to make such a measurement.

Penzias and Wilson, on the other hand were engaged in an atogether different project when they made their discovery. Their primary object was to measure the galactic continuum radiaton at 21 cm, when a 20-foot horn reflector antenna became available at Holmdel. However, before conducting the survey at 21 cm, Penzias and Wilson decided to verify the calculated low noise characteristic of the antenna at the shorter wavelength of 7.3 cm where the galactic contribution at high latitudes was expected to be small.

It was measurement with this 7.3 cm system in the horn that revealed the excess antenna temperature—*i.e.*, an isotropic radiation without any apparent source.

When Penzias and Wilson discovered this excess antenna temperature, they were unaware of the early work of Gamow or the experiment planned at Princeton. However, through astronomical grapevine, the word of their discovery got round to Princeton where Peebles and Dicke could provide a cosmological explanation. The paper from the Princeton group immediately precedes the paper of Penzias and Wilson (op. cit.) and provides the the cosmological perspective (*Astrophys. J.*, **142**, 414, 1965). The result of the measurement of Roll and Wilkinson at 3.2 cm was announced a few months later (*Phys. Rev. Letts.* **16**, 405, 1966).

Since then many measurements have been made at several wavelengths and the fit is shown on the cover photograph to a black-body curve of 2.7°K. The measurements on the short wavelength side of the peak have to be made above the Earth's atmosphere. The observations here are not so precise but probably not inconsistent with the black body spectrum.

In an age of quick communications it is surprising that the Princeton group should have been unaware of Gamow's prediction. From hindsight it is possible to say that the experiment which Penzias and Wilson performed was technically feasible even a decade earlier. Why did no one bother to do it in the 1950s ?

A possible explanation is that Gamow's work did not receive the serious consideration it deserved. This was partly due to the overall derision showed by the physics community to cosmology as being a speculative field. It was also partly due to the fact that Gamow's primordial nucleosynthesis could not produce heavier nuclei like Carbon, Oxygen etc. The work of E. M. Burbidge, G. R. Burbidge, W. A. Fowler and F. Hoyle (*Rev. Mod. Phys.*, **29**, 547, 1957) had shown how well the nuclei could be made in stars; and so Gamow's theory had fallen in slight disrepute.

Whatever be the post mortem of these events, one thing is certain. Cosmology henceforth will be taken more seriously by astronomers and physicists : this is the message of the 1978 physics prize. Perhaps in the same spirit the cosmologists should examine the big bang explanation more critically. There are several nagging questions which still remain to be answered. Is it a coincidence that the energy density of this radiation is comparable to several other energy densities encountered in astrophysics (e.g., cosmic rays, starlight, magnetic field in the Galaxy) which have no relevance to big bang? How did this background radiation manage to achieve such fine scale isotropy ? Why is the motion of our Galaxy against this background altogether different from that needed to account for the Rubin-Ford effect ?

It is to be hoped that the Nobel award does not mark the end of this fascinating field but inspires a beginning of fresh investigations.

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