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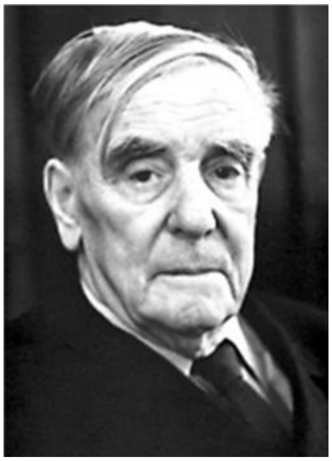
Nobel Prize in Physics 1978



Pyotr Leonidovich Kapitsa

Arno Allan Penzias

Robert Woodrow Wilson

The Nobel Prize in Physics 1978 was divided, one half awarded to Pyotr Leonidovich Kapitsa *"for his basic inventions and discoveries in the area of low-temperature physics"*, the other half jointly to Arno Allan Penzias and Robert Woodrow Wilson *"for their discovery of cosmic microwave background radiation"*.

Information about winners:

Piotr Leontevitch Kapitsa,

Institute of Physical Problems, USSR Academy of Sciences, Moscow,

Dr **Arno A. Penzias** and Dr **Robert W. Wilson**,

Bell Telephone Laboratories, Holmdel, New Jersey, USA,

RESEARCH INFORMATION:

Low-temperature physics

All objects and matter consist of small particles - atoms and molecules - that are in constant motion. The temperature of the matter or body is dependent on the intensity of this so-called 'heat movement'. When the movement is halted, the temperature of the body drops to the 'absolute zero point' at minus 273° Celsius.

Low-temperature physics deals with the properties of materials at temperatures immediately above the absolute zero point. It has been shown that at these temperatures many kinds of materials acquire radically different properties, which are of interest to physicists and often technically valuable. Many metals and alloys, for instance, become what is known as superconductive.

The first Nobel Prize in this area was given in 1913 to Kamerling-Onnes, of Leiden University, The Netherlands, for 'his investigations on the properties of matter at low temperatures, which led inter alla to the production of liquid helium'. This substance has since become one of the most useful means for attaining low temperatures.

In 1934, Kapitsa constructed a new device for producing liquid helium, which cooled the gas by periodic expansions. For the first time, a machine had been made which could produce liquid helium in large quantities without previous cooling with liquid hydrogen. This heralded a new epoch in the field of low-temperature physics.

In the 1920s, it had been found that when liquid helium was exposed to a temperature of less than 2.3 degrees above absolute zero, it was changed into an unusual form, which was named He II, or 'helium two'. By 1938, Kapitsa was able-to show that He II had such great internal mobility and negligible or vanishing viscosity, that it could better be characterized as a 'superfluid'. During the next few years, Kapitsa's experiments on the properties of He II indicated that it is in a macroscopic 'quantum state', and that He II is therefore a 'quantum fluid' with zero entropy, i.e., that it has a perfect atomic order.

As a result of his remarkable experimental and technical abilities, Kapitsa has played a leading role in low-temperature physics for a number of decades. He has also shown an amazing capacity to organize and to lead work: he established laboratories for the study of low-temperatures in both Cambridge, United Kingdom and Moscow. One of his associates was Lev D. Landau who in 1962 was awarded the Nobel Prize in physics for his theoretical studies on liquid helium. Kapitsa's discoveries, ideas and new techniques have been basic to the modern expansion of the science of low-temperature physics.

Mysterious background radiation

It has been known for a relatively long time that various astronomical objects emit radiation in the form of radio waves. Radioastronomy has grown in significance and is now a very important complement to classical optical astronomy. The radiation is emitted in various ways; for example, hydrogen clouds in the Galaxy radiate when excited, and cosmic ray electrons radiate when spiralling in the weak magnetic fields of interstellar space. Various objects, such as single stars, galaxies and - quasars, have been found to emit radio waves. In order to study these radio sources, it is, of course, necessary that their radiation show up over the general background radiation. The composition and origin of this background were for a long time not well understood; it was assumed to consist of the integrated radiation from a great number of sources, both galactic and extragalactic.

The study of cosmic microwave radiation, and especially of the weak background radiation, obviously requires the use of a very sensitive receiver. Such an apparatus was built in the beginning of the 1960s at Bell Telephone Laboratories in the USA. It was originally used for radio communications with the satellites Echo and Telstar. When this instrument became available for research, the two radio astronomers, Arno Penzias and Robert Wilson, decided to use it for the study of microwave background radiation. It was very well suited for this purpose: the instrument noise, i.e., the radiation created by the instrument itself, was very low; furthermore, it was tuned to a wavelength of 7 centimeters. It was already known that the intensity of cosmic microwaves decreases with decreasing wavelength; hence, the intensity at 7 centimeters would be expected to be quite low. However, to their surprise, Penzias and Wilson found a comparatively high intensity. They suspected at first that this radiation must originate either in the instrument or in the atmosphere. However, by painstaking testing, they showed that it came from outer space and that its intensity was the same in all directions. Hence, their measurements allowed the surprising conclusion that the universe is filled uniformly with microwave radiation.

These two researchers made no suggestions about the origin of this mysterious radiation. When their discovery became known, however, it was found that speculations had already been made about the existence of a weak, microwave background radiation.

The starting-point for these speculations had been a number of attempts, made during the 1940s, to explain the synthesis of chemical elements. A theory developed by the American physicist Gamow and his associates suggested that this synthesis took place at the beginning of the existence of the universe. It is known from studies of the spectra of stars and galaxies that the universe is at present expanding uniformly. This means that at a certain point, 15 billion years ago, the universe was very compact; it is thus tempting to assume that the universe was created by a cosmic explosion, or 'big bang', although other explanations are possible. This 'big bang' theory implies the occurrence of very high temperatures, of about 10 billion degrees. Only at those temperatures can various nuclear reactions take place such that chemical elements could be built up from the elementary particles assumed to be present from the very beginning. It also implies the release of a large amount of radiation, whose spectrum extends from the X-ray region, through visible light, to radio waves. After this hypothetical explosion, the temperature would decrease rapidly (the whole 'creation' is assumed to have been completed in a few minutes). The question then remains of what would have happened to the debris of the explosion: matter, consisting of hydrogen, helium and various other light elements, would have expanded as a hot cloud of gas which would gradually have cooled down to form condensations, which developed into galaxies and stars. But what about the radiation? Since the universe is virtually transparent to radiation of these wavelengths, nothing would really have happened to it: the radiation would expand in universe at the same rate as the universe is expanding. The question is whether it still exists and, if so, whether it can be detected. The difficulty here is that because of the expansion of the universe, the wavelength of the radiation has decreased, in the same way that light from distant galaxies is 'red-shifted' Instead of the 'hard' radiation that would have been emitted during the 'big bang', the radiation that might be detected now would correspond to that emitted by a body with a temperature of 3 degrees above absolute zero. No visible light is emitted at such a low temperature, and the radiation emitted falls : entirely within the microwave region, with a maximum intensity of about 0.1 centimeters. It was because of these difficulties that the

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early predictions were forgotten: it was assumed that it would be impossible to detect such weak radiation in the cosmic noise

When Penzias and Wilson discovered cosmic microwave background radiation, it was reasonable to suspect that it was fossil radiation from the 'big bang'. Support for this interpretation came from a number of investigations of the shape of the spectrum, which soon showed that it was indeed that which would be expected for a body with a temperature of 3 degrees. This provided solid support for the view that background radiation is the fossil remains of the 'big bang'; other interpretations are possible, however, even if they lack detailed theoretical backgrounds. The discovery of Penzias and Wilson was a fundamental one: it has made it possible to obtain information about cosmic processes that took place a very long time ago, at the time of the creation of the universe.

Recently, investigation of this radiation has been extended. Due to the fact that it fills the entire universe and interacts with interstellar and intergalactic matter, it can be used as a measuring probe. During the last few years it has been found that this radiation is not quite uniform and that its intensity has a certain directional dependence; this can be interpreted as an effect of the motion of the earth and of the solar system relative to the radiation field, and its variation can be used to measure that motion. Since the distribution of the intensity of the radiation reflects the distribution of matter in the universe, the possibility is opened up of defining absolute motion in space. Thus, the discovery of cosmic microwave background radiation by Penzias and Wilson has marked an important stage in the science of cosmogony.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1978/press.html