CHAPTER I
INTRODUCTION

1:1 HISTORY

As it is known to-day cosmic radiation originates from high energy particles coming from outside the earth. It was first discovered through its power of ionization, revealed by the slow discharge of effectively insulated electrometers in hermetically closed containers with dry air. These phenomena were studied by Geitel and Wilson (1) independently in the year 1900. Later, in 1902 Rutherford, Cook, Mclennon and Burton (2) showed that the ionization was roughly the same when the gas containers were protected by comparatively thick layers of lead, and decreased when it was protected by a sufficiently thick layer. Thus, one of the properties of the ionizing radiation must be high penetrating power.

But, at that time it was generally assumed that the ionization was due to radioactive sources on the surface of the earth, until C.T.R. Wilson suggested that it could be due to an unknown radiation penetrating the atmosphere from outer space. Gockel in 1910 observed this effect by sending a balloon up to 4,000 meters above the sea level, and found that the intensity of the radiation increases with increasing altitude. The same studies were made by Hess and Kolhorster in 1913 which confirmed Gockel's results. Therefore it was concluded that the unknown rays were of extra-terrestrial origin. This conclusion was confirmed again later by Millikan (1923-1924), Hoffman (1925), Bchounck (1926), and at last it was accepted in the year 1926 and the rays have been called "COSMIC RAYS" ever since.

1:2 THE ORIGIN OF COSMIC RAYS

Before the discovery of cosmic rays, γ-rays from radioactive elements constituted the most penetrating radiation known. This caused some scientists to propose that the unknown radiation mentioned above consisted of γ-rays of ultra-high frequencies. In 1929, with the advance of cloud chamber techniques, Skobelzyn found that at sea level, the unknown radiation consists of a mixture of various charged particles and γ-quanta; the main component being electrons.

In 1933, from the studies of C.D. Anderson as well as Blackett, it became known also that the mixture of particles constitutes a secondary radiation released by nuclear reactions in the atmosphere. The cosmic radiation thus consists of two separate types, primary and secondary radiation. The primary cosmic radiation enters the atmosphere from outer space, and the secondary radiation is produced from nuclear reactions between the primary rays and the various nuclei in the atmosphere.

In 1935, Street and Woodward discovered that the cosmic radiation can be divided into two components. They are the soft component and the hard component (3). The soft component is of low energy and cannot pass through 10 centimeters thickness of lead, but the hard component is of higher energy and penetrating power and cannot be easily absorbed.

At present it appears reasonable to define primary cosmic rays as a radiation of particles with high specific energy entering the atmosphere from outer space. The origin of the primary cosmic rays constitutes a problem which is still far from being solved in a satisfactory way.

The primary cosmic rays are characterized by such high kinetic energies per nucleon that a very effective acceleration process has to form part of the production mechanism. Possible acceleration processes in the universe are thus of first importance. The locality of the acceleration process depends partly on the process itself. Discussions concerning various origin theories involve four separate problems, ie. injection, acceleration, location and storage of cosmic ray particles. All of them have to be answered in a satisfactory way by any theory concerning the origin of cosmic rays.

Many origin theories have been proposed and discussed during the last 30 years. The location of the source of cosmic rays has caught much of the interest. Table 1.1 contains a list of papers on origin theories, arranged according to the proposed location of the source. The table has been compiled without any pretension of completeness. It has to be accepted as a fact that despite 30 years of research, the problem concerning the origin of cosmic rays has not as yet been settled.

Table 1.1*

Theories	Scientists
Interplanetary and solar origin	W.F.G. Swann (1933) M.A. Auvillier (1934) D.H. Menzed and W.W. Salisbury (1948) R.D. Richtmeyer and E. Teller (1949) H. Alfven (1949, 1950, 1954, 1959)
Origin in Supernovae	W. Baade and F. Zwicky (1934) D. Terhaar (1950) J.S. Shklowsky (1953, 1954) S.A. Colgate and M.H. Johnson (1960) S.A. Colgate, W.H. Grasberger and R.H. Wite (1962) Y. Ono and S. Sakashita (1962)
Universal origin (betatron acceleration and magnetic pumping)	W.F.G. Swann (1954) H. Alfven (1959)
Origin interstellar space	E. Fermi (1949) C.Y. Fan (1951) V.L. Ginzburg (1953) L. Bierman (1953) E. Fermi (1954) S. Chandrasekhar and E. Fermi(1954) P. Morrison, S. Albert, B. Rossi(1954) L. Davis (1956)
Intergalactic or extragalactic origin	L. Bierman and E. Bagge (1949) E. Bagge (1950) E. Teller (1954) J. Heidmann (1955) G. Cocconi (1956) F.J.M. Farley (1956)

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* Table from A.E. Sandstrom, "COSMIC RAY PHYSICS," p391, 1965.

However, two distinct sources are known, i.e. the sun, from direct observations, and the supernovae, because of a high degree of probability. As our sun produces cosmic rays of 10 to 15 Gev and at rare occasions even more than 25 Gev., such a production is to be expected also from similar stars. It is conceivable that in each instance there exists a certain probability of escape of particles from the immediate vicinity of the stars. Consequently, there will be particles in interstellar space which have energies exceeding what is needed for an effective injection into an acceleration process. The isotropic balance has to be ascribed to the time of storage of the accelerated particles as well as the number of sources of injection, to which the supernovae also contribute.

1:3 EVIDENCE OF NEUTRONS IN COSMIC RADIATION

Nuclear collisions produce not only high-energy secondary particles but also substantial numbers of protons, neutrons and α particles with energies of only the order of millions of electron volts. Protons and α particles of such low energies are very rapidly absorbed through ionization losses. As a result, they never occur naturally in any great abundance. But neutrons, of course, do not lose energy by ionization. In successive collisions with nuclei, they gradually slow down and eventually become easy prey to nuclear absorption.

Neutrons were found in the cosmic rays accidentally when Goldshmit Elearmont, Muirhead and other scientists were studying star production in photographic emulsions in the years 1928 and 1929. And later, Cool, Fowler, Street and Sard also confirmed the evidence of neutrons in cosmic rays by cloud chamber techniques.

After Amaldi and Fermi (4,5) discovered the method of neutron thermalization in 1936 - 1937, many scientists used various experimental techniques and worked at different altitudes to measure the neutron intensities of cosmic rays. Among the physicists who made important contributions to this subject, the leading ones were Serge Korff of New York University and John A. Simpson of the University of Chicago.

1:4 NEUTRON MONITOR DEVELOPMENT

The atmospheric neutrons are detected by a $B^{10}F_3$-proportional counter with either the atmosphere as the neutron energy moderating medium (for slow neutron measurement), or by using a local condensed moderating material such as paraffin or carbon surrounding the detector (for fast neutron measurement). Both methods have been used to investigate the neutron intensity since 1936 (4,5). But the first method has difficulties with the changes in air moderator characteristics. The latter kind reduces or eliminates all the difficulties mentioned.

After J.C. Sterns 1938 (6) had reported the evidence of neutrons in heavy particle showers, the neutron production in heavy material was investigated by many scientists.

Neutrons produced from condensed materials are called "Local production neutrons". The local neutron production in elements is a function of atomic weight. The average number of neutrons emitted by this nuclear disintegration is called the multiplicity, the ratio of neutron multiplicity from lead to carbon being about, 8:1, was determined by V. Tongiorgi in 1949 (7) C.G. Montgomery and A.R. Tobey 1949(8).

In 1939, S.A. Koff and W.E. Danforth (9) introduced the gaseous boron-trifluoride filled neutron counters. This boron-trifluoride counter gives high sensitivity with thermal neutrons.

From the studies of S.B. Treiman and W.Fonger in 1952 (10) of the optimum thickness of the lead producer, J.A. Simpson in 1953 (11) designed and constructed the first neutron monitor to measure the intensity-time variation of cosmic radiation.

After that, Neher (12,13) put the pile on a balloon while Meyer and Simpson (14,15) put the pile in an aeroplane to measure the intensity of cosmic radiation in the upper atmosphere.

During the International Geophysical Year (I.G.Y. from July 1, 1957 to December 31, 1958), J.A. Simpson's neutron monitor (16) was chosen to be the I.G.Y. standard pile, and was constructed in many stations all over the world to measure the intensity variation of cosmic rays.

In 1959, several boron-trifluoride proportional counters of unusually large size (6 in. in diameter and 68 in. long) were made. With the good performance of these big counters, a series of measurements was carried out in 1960. In 1961 at Deep River, Steljes and Carmichael built a lead-paraffin monitor (17) accommodating 24 big counters, and in 1962, they tried to use polyethylene instead of paraffin. The NM-64 neutron monitor specifications of the lead-polyethylene monitor were sent to 200 addresses in 30 countries from Chalk River. The completely constructed NM-64 neutron monitor at Chalk River Nuclear Laboratory in 1964 (17) by C.G. Hatton and H. Carmichael is called "BP 28 Chalk River Neutron Counters."

Nowadays there are almost one hundred neutron piles distributed all over the world. The study of cosmic rays in Thailand, however is of special interest, because of high rigidity cut-off in this region.