Chapter 13

PROSPECTS FOR THE FUTURE

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Cosmic ray physics is not a closed science, but has been developing in close association with the progress of various fields in physics.

These various fields complicatedly entangled in physics may be considered something like the "wefts" and "warps" of a fabric. If such a similarlity would be applicable to the character of physics, the fields in cosmic ray research might be supposed as the "wefts" capable of connecting various fields in physics with each other. From the historical point of view, it is clear that cosmic ray physics has never become one of the main streams in physics like the "warps", but has always played important roles as the "wefts" in many stages of the history of physics since the discovery of cosmic rays.

The research fields in cosmic ray physics were mainly divided into two distinctive disciplines up to the middle of the 1950s; in fact, cosmic rays themselves were classified to be primary and secondary cosmic rays in accordance with the interests in cosmic ray research. It should, however, be noticed that the secondary cosmic rays are the components secondarily yielded from the interactions of the "primary" cosmic rays with the atmospheric nuclei near the top of the atmosphere. Although the origin of the primary cosmic rays was not well known before the end of the 1950s, new particles like positrons, mesons and many others were discovered from the experimental studies on secondary cosmic rays during those years, since high energy particles were contained in these cosmic rays which were never produced by the accelerators available in those years. It can be said, therefore, that the physics of elementary particles was first born as a branch of cosmic ray research.

The origin of the primary cosmic rays had been searched for since their discovery, but these particles were also considered an important probe to explore the space beyond the earth's atmosphere, i.e., the interplanetary space. The temporal change in the cosmic ray intensity on the earth is, in fact, produced by the modulation of cosmic rays between the earth and the space beyond the solar system.

In the meantime, the cosmic ray research has gradually become to intrude into the fields of astrophysics. As have been described in the earlier chapters of this book, the research results such as the energy spectrum and the chemical composition of cosmic rays, the cosmic electrons, and the traces of cosmic rays remaining in the cosmic matter such as meteorites play important roles in the research on astrophysics.

Generally speaking, the main subjects of cosmic ray astrophysics aim not only to search for the origin of cosmic rays, i.e., the acceleration and propagation of cosmic rays in the cosmic space, but also to investigate various astrophysical phenomena such as the physical state of the interstellar gases and magnetic fields, supernova remnants, the galactic structure and of extragalactic objects.

Scientists devoted to cosmic ray research have been differentiated in accordance with the research means and methods proper to each field in cosmic ray physics. Such differentiation has become more marked with time since the discovery of cosmic rays. During the years of the 1950s, when many new particles were discovered, a number of scientists in the world, including Japan, shifted their research subjects to those in high-energy physics. With the development of space probes such as artificial satellites, balloons and rockets, many physicists had begun to apply their ideas and methods in applied physics to the research in astronomy, in particular, the new fields such as X-ray and gamma-ray astronomy. Such a tendency is well observed in the scientists in U.S.A. and Japan. The methods of research on the cosmic ray modulation have also largely changed since the direct observations in interplanetary space with deep space probes have become possible.

Taking into account the current trends in cosmic ray research, some discussions were informally done about the division of the international cosmic ray conferences which were held every two years since 1953 on behalf of the IUPAP. According to these informal discussions, in order to achieve their purposes, these conferences had to be separated into the two divisions of high-energy physics and cosmic ray astrophysics, including solar-terrestrial physics. However, the current situation has not been shifted in accordance with such discussions. As is observed in the studies of extensive air showers or the chemical composition of cosmic rays, for instance, it seems impossible to classify formally these studies into either particle physics or astrophysics, since they have to be done with the knowledge of both high-energy physics and astrophysics. In consequence, there still remain some difficulties in trying to sever the "wefts" as the threads connecting various fields in cosmic ray research from each other, despite the fact that the purposes of these fields have already differentiated largely.

The subjects related to cosmic ray research would, therefore, remain as the dominant means in many fields in physics in the future. As recognizing strongly that many objectives in cosmic ray research are never considered as those of physics by themselves, cosmic ray research should, however, proceed so as to harmonize with the other fields in physics. In so doing, new methods used in the other fields should be taken into account in cosmic ray research. In order to summarize the view very personal to the author himself, a schematic diagram as shown in Fig. 13.1 has been made of the possible relation of cosmic ray physics with many other fields and topics in current physics. This should be thought of as my "personal" view, but has been ventured here as material to understand the complex relations among many research fields in physics, though it seem almost impossible to draw this kind of diagram from a fair point of view. In this diagram, the mutual distances indicate the closeness between subjects. In other words, the nearer these distances are, the closer become their

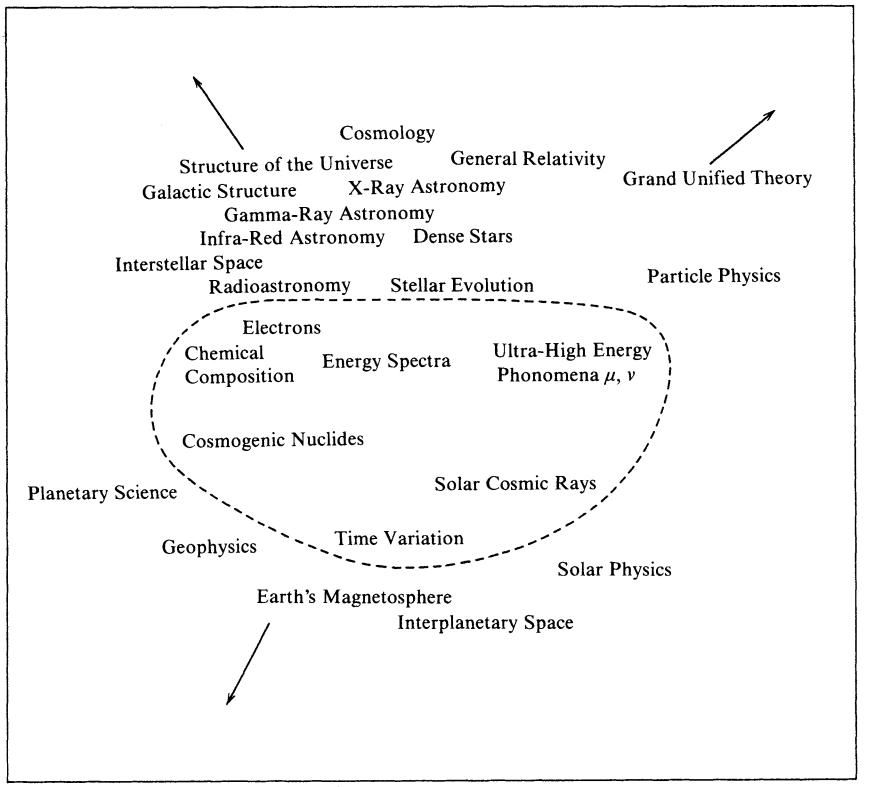

Fig. 13.1. A personal diagram to show the relations among various phenomena seen in the nature.

relations. The area surrounded by the dotted line corresponds to that which belongs to cosmic ray physics at the present moment. Because it does not seem valid to synthesize the complex relations among many fields into a view acceptable to everybody, this diagram should be considered only as giving a bird's-eye view from my personal view point. The current trends in cosmic ray research are, however, indicated with three arrows.

It should, furthermore, be noted that plasma physics also plays an important role as the "warps" in many fields in cosmic ray research. Really speaking, this branch of physics is closely connected with the research on the space beyond the earth, the sun, the interstellar space, supernova remnants, the space around highly dense stars and the large-scale structure of the universe. The plasmas constituted of particles of high energy, equivalent to ultra-high temperature, have not yet become one of the subjects in plasma physics, but the research on such plasmas would seem to be an important research field in the near future in relation to the research on cosmic rays.