SYMPOSIUM ON FUNDAMENTAL PROBLEMS IN THE THEORY OF STELLAR EVOLUTION — INTRODUCTORY REMARKS

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It is about twenty years since Professor C. Hayashi and his collaborators wrote a paper in 1962 on "Evolution of the Stars" in the Supplement series of *Progress of Theoretical Physics*. It seems proper to begin this Symposium with these words, because Friday, July 25 of this Symposium marks Professor Hayashi's sixtieth birthday and because it is hosted by the Research Institute for Fundamental Physics from which the Journal *Progress of Theoretical Physics* is issued.

In the twenty years since this paper, there has been much progress in this field of astrophysics. On the one hand observations in X-ray, ultraviolet, infrared and radio wave lengths have uncovered a variety of celestial bodies in different circumstances. Among them, we can now see a neutron star directly by means of the Einstein Observatory, and infrared and radio observations as well as ultraviolet observation have revealed physical characteristics of interstellar gas and protostars. Thus, now we can observe stars from their birth through their death. On the other hand, progress in theory has also been significant. In a sense Hayashi et al.'s paper in 1962 marked the transition to the computer age. As computers have become relatively common and increased in speed a great many theoretical models have been constructed. Here, however, we must examine for ourselves how such models have contributed to advance our understanding of nature.

The structure of astrophysics and the theory of stellar evolution, in particular, are characterized with three steps. In the first step, we have *local* physics in the sense that the physical processes taking place locally at given temperature and density must be known. In the second step the local physics is inserted into models of celestial bodies where selfgravitation plays an essential role. In the third step, the resultant global behavior of the models is compared with observations.

The second step, in particular is characteristic of astrophysics in the sense that it treats the aspect which are less familiar in ordinary laboratory physics but are inherent to celestial bodies. First

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of all, the system is governed essentially by selfgravitation leading to a non-local nature and to spatial gradients in physical parameters, and by non-linear interactions with the range of forces equal to the size of the system. Because of this the system should be thermodynamically dissipative and open. Such a system behaves, to some degree, out of common sense. For example, the effective gravothermal heat capacity of the star is negative and the isothermal temperature distribution corresponds to a local minimum of entropy rather than local maximum in most cases. The nature of such a system is a motive force of evolution which characterizes astrophysical systems. Here we should ask how and, in particular, why they evolve, why are they both now and initially out of thermal equilibrium etc.

In order for models to be called *Theory*, they should enable us to understand not only their individual nature but also the general characteristics of such systems. For example the responses of the model to changes in physical parameters or in physical assumptions or approximations should be understood without adding further detailed numerical computations. Such generalizations are rather difficult, particularly in the second step, but we have to try to find such generalizations.

Though many computations and model constructions have been done recently, I personally think that the things in the second step still remain obscure. We are apt to say that we take into account all detailed physics as accurately as possible, but in many cases we are talking only about the local physics in the first step. Too much physics in detail sometimes causes complexities and may even obscure the essential physics acting in the second step. In many instances physics in the second step has not even acquired its citizenship. In such cases we only have a huge pile of numerical results and a description of the final results for a single special case. Only computers might know the physics involved in the second step, and we have a big response table between the input to and the output from the black box. This is something like the tale of blindmen stroking an elephant.

In order to remove such pit falls and to look into the black box, two things are important. First, we have to recognize the importance of idealized models which can be constructed by neglecting relatively unimportant factors. Second, we have to perform numerical experiments rather than construct detailed models. Such an approach is common in the field of physics and used to be common in astrophysics before the computer age. Recently, however, it is apt to be ignored in favour of detailed modeling.

Such aspects are becoming more and more important because we are now proceeding to extend our scope of studies which include the effects of rotation, magnetic fields, two and three dimensional configurations etc. These studies are too complicated to be understood from a pile of numerical results. In the early sixties when Hayashi et al.'s paper was written such aspects were primarily taken into consideration because of the shortage of computing facilities. Now computers have become much more powerful but our subjects of research have become still more complicated and difficult. In this sense our relative situation is similar to that just before the computer age.

This is one of the reasons motivating the Symposium on *Fundamental* Problems in the Theory of Stellar Evolution. At this Symposium we hope to have much discussion concerning bold assessments of known facts, interrelations between them and strategy to surmount a barrier standing in front of the coming phase in the stellar evolution theory.