CONCLUDING REMARKS - II

D. Sugimoto
College of Arts and Sciences, University of Tokyo

In the Opening Remarks Dr. Kudritzki asked what tricks were used in calculating stellar structure. Though many fine models and discussions have been presented, answer has not been given yet to this question. The theory of stellar structure consists of two very much different kinds of building blocks. One is the local physics such as equation of state, opacity, nuclear reaction rate, and so on. They are determined only locally when the values of temperature and density at a point are given, i.e., they are irrelevant to the conditions whether they are considered in the stellar interior or not. Another is the physics of self-gravitating systems in which the global spatial structures are discussed. Characteristics of astrophysics are often said to lie in the fact that it covers much wider parameter ranges than in laboratories. This, however, grasps only one side of the problem, i.e., only local physics. Those which are not encountered in laboratory physics lie mainly in the global physics. It shows characteristics out of common sense; examples are negative specific heat and associated gravothermal catastrophe which are related with the gravitational contraction of the stars, formation of core-halo structures which is observed not only in red giant stars but also many celestial objects, and tendencies dividing a system into two subsystems one with high energy and/or high entropy and the other with low energy in the deep potential well and/or low entropy as seen in supernova explosion of type II and formation of jet in various objects. They behave contrary to the general trend, i.e., against equipartition and thermal equilibration.

For these phenomena numerical models are constructed. Usually, however, one discusses in detail the local physics as the fundamental assumptions, and then jumps into presenting numerical model. The logical connection between them are not clear at all. To make it worse people are apt to be fond of more detailed models. Though it is easy for computers to take less essential effects into account, they often obscure important physical processes. In the traditional physics, on the contrary, idealization was intentionally done to extract essentials. In astronomy, of course, standard models in which everything is taken into computation are

https://doi.org/10.1017/S0252921100094434 Published online by Cambridge University Press

necessary to compare with observations. However, this does not deny the necessity of idealized models. Anyway, more efforts seem necessary in the side of global physics characteristic to self-gravitating systems.

Things which make it more difficult are some natures of non-linear systems. Let me give an example. In relation with the supernova 1987A the size of the progenitor star and its evolutionary implications were discussed in this colloquium. Some said that the star spended pre-supernova stages as a blue supergiant for the low metalicity as in the Large Magellanic Cloud. Others paid attention to the existence of red supergiants in LMC. Theoretically, the blue star can not swell to a red giant in a short time as in the presupernova stages because of too long time scale of heat transport in its envelope. Dr. Woosley gave a talk concerning the possible envelope mass. It lies in the range which Dr. Wheeler excluded in his talk. This contradiction might arise because the former took account of thermal disequilibrium of the envelope during rapid evolution, while the latter assumed thermal equilibrium envelope. One might think the apparent contradiction could thus be understood.

However, the situation is not so simple when the heat transport is coupled with stellar structure. Here, I would give another example. It is a problem of X-ray bursting neutron star. The X-ray burst proceeds in tens of second and it might be much shorter as compared with the time scale of heat transport in the envelope of the neutron star. During the burst the X-ray luminosity of the neutron star becomes very close to the Eddington luminosity and the outer layers of the envelope are pushed up by the radiation coming from the interior. Then the neutron star is puffed up and the time scale of heat transport becomes shorter and shorter. Finally, the envelope solution with steady mass flow in thermal equilibrium becomes a good approximation and such situation is also observationally confirmed. Before this has become understood, a specialist tried to calculate such expansion of the envelope all the way as an initial value problem by means of stellar evolution code, but it was found impracticable.

Here, we see limitations of straight-forward approach of modeling as well as peculiar behaviors of non-linear systems which sometimes show very strong or even practically unstable response even to the slightest change in the initial conditions. Such a hyperbolic instabilities are recently discussed for non-linear systems in relation with their chaotic behaviors. Since the self-gravitating systems are one of the typical non-linear systems in the sense that the whole system interacts coherently even between the most distant points because of long-range nature of the gravitational interaction. Thus, another approach seems also necessary which aims at some general understanding on the global behaviors in celestial objects.

https://doi.org/10.1017/S0252921100094434 Published online by Cambridge University Press