COMMENTS AND IMPRESSIONS

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I will give no summaries or substantive remarks, partly because Roger Tayler has already done so and largely because I have been away from the field of stellar evolution for a long time. However I will give some personal impressions of a "prodigal son returned to the field" — or "how do things look 15 or 20 years after Professor Hayashi's pioneering work".

(A) PHYSICS INPUT AND MATHEMATICAL TECHNIQUES

(1) Rotation and Magnetic Fields: My first impressions are "A for Effort, but not necessarily for Achievement". Twenty years ago angular momentum and magnetic fields were simply ignored — not because they are unimportant but because they are difficult. They are still difficult today, but at least they are being tackled. I am particularly happy to see a "Two-pronged attack" — actual "honest and detailed" calculations on a few topics on the one hand, the establishment of semi-quantitative features for many topics on the other. Dissemination of expertise is still a bottleneck, but the Proceedings of this Symposium will help.

(2) Computer Codes for Evolutionary Calculations: One's first naive impression is that this area was much further advanced 15 years ago than today: Computational techniques were adequate then for one-demensional calculations (based on the unwarranted assumption of spherical symmetry), whereas current techniques are not fully adequate for more realistic calculations. Although a start has been made in this direction, a more systematic comparison of different techniques would be reassuring - to show that the computational schemes neither suppress real phenomena nor create phantom ones. There is an interesting parallel with the methodology of fundamental turbulence theory: Neither analytical nor numerical methods alone can solve a number of problems of principle (the determinacy of circulation modes, the non-Gaussian behavior of "intermittancy", etc.). The mixture, used there, of systematic numerical experiments with abstract theory may give some

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useful hints by analogy.

(3) Physics of Dust Grains: I have a warning and/or question about dust grains in the formation period of the solar system. The warning relates to our ignorance of the dust grains in the interstellar medium from which the early solar system contracted. For instance, it is not clear whether collisions between dustgrains result in sticking or shattering or evaporation. Even for particles made of ordinary Materials there is surprisingly little experimental data. Furthermore, the solid-state structure of interstellar dust grains is likely to be quite unusual, because of radiation damage (U.V. and cosmic rays) and of chemical processing by radicals. My question to solar system theorists is: which of various uncertainties in the grain physics are really important. There are few groups working in experimental laboratory — astrophysics (astrochemistry), but some progress might be possible on the one or two key questions.

(4) The Solar Neutrino Problem: There is generally little interaction between work on solar physics and stellar evolution. In particular, I hope that stellar theorists will revisit the solar neutrino puzzle in the near future. It is likely that a second solar neutrino experiment will be carried out in a few years, employing a Gallium-detector. The two experiments are sensitive to different uncertainties and progress should be possible. However, it is important that different stellar theorists, with different views on the present solar neutrino puzzle, make very specific predictions for the Ga-experiment before it is carried out.

(B) ASTRONOMICAL TOPICS

(1) The Initial Mass Function: There has been real progress in at least a qualitative understanding of the intermediate stages of star formation, just before the Hayashi track. The even earlier stages seem to be elusive still and it is not clear what determines the distribution of masses to which individual stars settle down. In other words, a genuine a priori calculation of the Initial Mass Function (IMF) has not succeeded yet, although not for lack of trying. That's a pity, especially since the other two points I will make are closely connected to the IMF.

(2) The Extreme "Ends" of the Main Sequence: Main sequence stars of the lowest and highest masses are still somewhat shrouded in mystery, partly because observations are difficult and partly because the rate of massloss is appreciable but not well known. Theoretically it is not clear if we really understand the mechanism of massloss and observationally it is not clear if we know the IMF. These two uncertainties are connected, even if the luminosity function ψ is known observationally: If a star loses an appreciable fraction of its mass in a much shorter period than the main sequence lifetime, then the IMF derived by the standard methods from ψ is a gross underestimate.

I stress the uncertainty in the massloss rate, because of

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recent indirect indications that it might be particularly large: (a) Infrared observations of dense molecular cloud complexes seem to require the frequent release of energy, packaged in relatively "small chunks". Supernovae come in "large chunks", but massive young stars are still likely to be involved. Although there is no direct evidence the following hypothesis is a possibility: The IMF may extend to larger masses than previously thought, but these stars lose mass rapidly and intermittently. Appreciable chunks of energy could be released during this evolution "down the main sequence" towards ordinary O-stars and these supermassive stars are difficult to find outside of molecular clouds because of their short lifetime. (b) X-ray observations from the Einstein satellite indicate a surprisingly large number of X-ray flares from cool M-dwarfs. Although there is no direct observational data, massloss is likely to accompany flares. The fact that cool M-dwarfs burn nuclear fuel in their deep interior and are convective from there all the way to the surface raises a theoretical challenge: Does convenction provide a close enough coupling between nuclear reactions and the surface, so that new modes of dynamical instability come into play?

(3) "Stellar Population III": In the stellar theory literature this phrase usually means stars in "Standard" regions of a galaxy, but formed early out of material with a very low abundance Z of heavier elements. I reserve the phrase "stellar population III" for an even more mysterious class of objects: We now have good evidence from rotation curves of spiral galaxies, that most galaxies have an "almost invisible" halo extending very far out. Even if massive neutrinos exist, they are not able to provide the mass for such a halo, but stars of very low mass and/or the neutronstar (or black hole) remnants of very massive stars have a sufficiently large mass-to-light ratio. One challenge to the theorist lies in the fact that the mass-density in these halos is very low but the total mass is very large. Another puzzle is that the gas in galaxy clusters, which was probably ejected from these galaxy haloes, has almost solar values for the abundance Z. This stellar population III, which contains more total mass than stellar populations I and II put together, presents a sufficiently large challenge that I hope Professor Hayashi will turn his brilliant talents into this direction!