GENERAL DISCUSSION

Kwok: If the chairman would permit me I would like to make a comment on the effects of mass loss in the red phase of stellar evolution. We have recently been investigating metallicity as a parameter of stellar evolution. It has been shown that radiation pressure on grains is not a feasible mechanism if the metallicity of the star is below 10% of that of solar value (Kwok, Ap.J. 198, 583). If radiation pressure on grains is in fact the mass loss mechanism for the red phase, this implies that Pop II stars will not be able to lose mass. This is in fact consistent with the absence of gas in globular clusters. Recently it has been suggested that (Kwok et al., Ap.J. 211, L125) planetary nebulae do not represent a separate mass loss phase but instead are the result of sweeping up matter ejected during the red phase. If this is true then the underabundance of planetary nebulae in globular clusters can also be easily explained. From a study of sulphur abundances in planetary nebulae, Barker (Ap.J. 221, 145) also concludes that planetary nebulae are produced by a predominantly metal-rich population. In conclusion metallicity may be an important parameter for it may imply that only low mass Pop II stars can become white dwarfs and any star more massive than ~ 2 M_0 will become a supernova.

Vanbeveren: I want to ask a question to the people who are doing evolutionary calculations in the red giant phase: as there exists a very extended atmosphere at the red giant phase and if we can expact excessive mass loss rates as has been assumed by Chiosi, I wonder how one can possibly treat atmospheres with a hydrostatic approximation?

Sreenivasan: At present there exist four "prescriptions" for removing mass in an evolutionary scheme : (1) due to McCrea; (2) Lucy-Solomon; (3) Lamers, van den Heuvel and Petterson and (4) Castor, Abbott and Klein. The first two depend upon luminosity and increase with it, the third goes through a maximum and comes down while the fourth remains at a fairly constant rate up to log T_{eff} ~ 4.0. In addition to this variation, one has two parameters k and α in the fourth recipe, which allows for different rates and although one can say that a good correspondence exists for k = 0.076 and α = 0.90 or 0.83 in some parts of the HR diagram, such is not the case in other parts. It is therefore necessary to use different combinations of k and α at different stages. It is important to have observational guidance to produce acceptable models of evolutionary sequences, e.g. those of Niemela concerning firm indications of mass and spectral classifications for the WR stars: WN or WC. This enables one to discriminate between the different "scenarios" of

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formation of WR stars - single versus binaries. I am happy to know that WC stars of 17-20 M_o exist in binary systems and similarly WN stars of higher masses, and that not all WR stars are 10 M_o objects!

Hyland: I should like to address a question to Susan Lamb. In supernova events a considerable mass of interstellar gas is swept up by the expanding shock front, which would suggest that the (N/H) and (He/H) abundances which you observe in the Cas A supernova remnant may be lower limits. 1) Have you estimated the mass of gas swept up in the Cas A SNR and 2) what are the upper limits of (N/H) and (He/H) which you can derive from your computations?

Lamb: The Cas A supernova occurred about 300 years ago and it is thus a very young S.N. remnant. This small age together with high densities in the "fast-moving knots" suggest that very little interstellar material has been swept up so far. Thus one can make a meaningful comparison between the abundances in the S.N. remnant and stellar models. The maximum ^{14}N/H ratios that are predicted by the model calculations are ~ 10 if mass loss is allowed. If mass is conserved the maximum value that this ratio can attain is ~ 5.

Rahe: Question to Dr. Lamb: Do your calculations give any information on isotope abundances, such as the ^{12}C/^{13}C ratio, in the matter lost?

Lamb: I have not calculated isotope abundances, such as ^{12}C and ^{13}C, for these models. However, these can be calculated from the models at a later time.

Leung: I would like to comment on an earlier point about mass lost during the red-star phase. Pretty well all late-type supergiants are variable (semi-regular variables). They have a typical periodicity of several hundreds of days, and with other much longer modulation periods, typically of 10 times longer. There must be a driving force to feed this instability. Thus, the mass loss rate will be affected somehow. The red giants are also unstable, as long period variables.

Abbott: Since we know an accurate rate of mass loss for at least one star, ζ Pup, I would favor those evolutionary calculations whose rate of mass loss formula agreed with that of ζ Pup. For de Loore et al. this implies N ~ 150 to 200 while for Chiosi et al. this implies α ~ .85.

Morton: Certainly it is desirable to extend the types of stars for which the mass loss rate and ionisation level have been determined. Several O type main sequence and giant stars are available with Copernicus to obtain the line profiles of CIII, NV, OIV, SiIV etc, and IUE could provide the CIV profile. It would be good to analyse some stars using the Copernicus high resolution scans, which are not subject to large background corrections and are less confused by interstellar lines.

Conti: I think we may have a good estimate of mass loss rates in Of stars (e.g. ζ Pup) where optical emission lines are seen, but we have only upper limits for O stars. These stars may have substantial mass loss rates, as evidented by their UV spectra. A detailed analysis of 9 Sgr, an Of star, is badly needed and will help this problem considerably.

van den Heuvel: Can anyone explain to me why some authors get massive stars into the right hand part of the HR diagram and other authors don't? I have not yet heard a satisfactory explanation for this here.

Chiosi: As for constant mass evolution we know that amongst the others one of the leading parameters determining the position in the HR diagram of models in the core burning phase is the detailed shape of the H profile and its correlation with the H burning shell. Any modification of the H profile due either to intermediate or external mixing or both may therefore significantly change the location in the HR diagram. Similar arguments seem to be still valid also for losing mass sequences and allow us to qualitatively understand why core He-burning models get redder as the mass loss rate increases, and might also explain why slightly different rates give substantially different locations of the models in the HR diagram.

de Loore: This is an interesting point as it could explain the fact that in the right red upper part of the HRD stars are lacking. I feel that it is due to the treatment of convection by Susan Lamb, which means excessive mixing, in the large number of shells used in the computations. It is not exactly the same as semi-convection; in her treatment more mixing is used.

Lamb: The physical nature of so called semi-convection is not understood, and therefore it is impossible to know if one is modelling this phenomena correctly. If important details of the evolution of massive stars are found to depend heavily on the precise gradient in the mean molecular weight left behind in the star after the main sequence phase of semi-convection, then we will have a large uncertainty in the evolutionary calculations.

Dearborn: In the regions that Susan wants to expose in order to obtain the large ^{14}N overabundance, the $^{12}C/^{13}C$ ratio would be near its equilibrium abundance of 3. There would however be very little carbon of any form as it was used to create the ^{14}N overabundance.