EFFECTS OF A STOCHASTIC INITIAL MASS FUNCTION ON THE UPPER MAIN SEQUENCE BAND

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Introduction

The theoretical (M_b versus Log T_e) HR diagram for the brightest galactic OB stars shows an upper boundary for the luminosity, which is characterized by a decreasing luminosity with decreasing effective temperature (Humphreys and Davidson, 1979). The existence of this limit was interpreted by Chiosi et al. (1978) as due to the effect of mass loss by stellar wind on the evolution of most massive stars in core H-burning phase. In fact, evolutionary models calculated at constant mass cover a wider and wider range in effective temperature as the initial mass increases during the main sequence phase. On the contrary, sufficiently high mass-loss rates make the evolutionary sequences of most massive stars ($M\ 60 \gtrsim M_{\odot}$) shrink toward the zero age main sequence whenever, due to mass loss, CNO processed material is brought to the surface (Chiosi et al., 1978; de Loore et al., 1978; Maeder, 1980). In such a case the main sequence band is found to coincide with the observational one if mass-loss rates of the order of $10^{-6}\ M_{\odot}/yr$ during the whole main sequence phase are used. As a consequence of this, the experimental upper boundary for the luminosity has been regarded as a way to constrain the mass-loss rate within the range of observational uncertainty.

However, recent data (Conti and Garmany, 1980; Abbott et al., 1980; Gathier et al., 1981; Lamers, 1980) suggest rates of mass loss from those stars that imply a much lower mass removal during the whole main sequence phase than for the previous cases (Chiosi, 1981; Lamers, 1980). Such a low mass loss does not affect the behaviour of the evolutionary sequences which look like the conservative ones. It seems therefore that the most recent data on the rate of mass loss are in conflict with the observed distribution of very luminous OB stars in the HR diagram. The aim of this paper is to point out that such an upper boundary is related more to the existence of fluctuations on the initial mass function than

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to the effect of substantial mass loss during the core H-burning phase.

The composite HR diagram

As it is well known, an observative HR diagram is populated according to the lifetime spent by stars in any given evolutionary phase. In this respect the main sequence band is the region with the highest probability of being populated, but, owing to the fact that the first stages of central H-burning are much slower than the later ones, a thin band near the zero age main sequence is more likely to be occupied by stars. In addition to this, the distribution of young stars is also controlled by the star formation process, which is customarily described in terms of initial mass function $\Phi(m)$ and birth rate $\psi(t)$. The number of stars formed in the mass interval m, m+dm and time interval t, t+dt is $\Phi(m)\psi(t)dm\,dt$. The initial mass function $\Phi(m)$ is often approximated by a power law of the mass, $\Phi(m)=Am^{-(1+x)}$, whereas much more complicated relations are used for $\psi(t)$, which however are not of interest here. Current values for x are in the range 1.35 to 2 (Salpeter, 1955; and Lequeux, 1979; respectively), whereas $\psi(t)$ in the solar vicinity is estimated to be in the range 3 to 7 $M_\odot/pc^2/10^9$ys (Miller and Scalo, 1980).
With the above formulation we implicitly assume that, in each generation, stars are born instantaneously and continuously distributed in mass intervals according to the above relation. This assumption, while fairly holding in the range of low mass stars, might fail for the most massive objects whereby, due to the very low number of stars involved and their short lifetime, the intrinsic stochastic nature of star forming processes can sensibly affect the final distribution of stars in the HR diagram. To this purpose we take into account the possibility of random fluctuations of the initial mass function around the average value given by $\Phi(m)$ and allow for a temporal dispersion Δt within each stellar generation. We tentatively assume $\Delta t \simeq 10^6$ys, whereas a Monte Carlo tecnique is used to perturb $\Phi(m)$. We start considering the observational HR diagram as a superposition of several generations of stars with different initial mass, evolutionary stage (age) and chemical composition (this effect however is not considered here). To account for the stochastic nature of star forming process we associate a random number λ, in the range 0 to 1, to each value of m in such a way that the average trend given by $\Phi(m)$ is reproduced. Along each isochrone a number N of stars is randomly distributed in such a way that $Nd\lambda=Am^{-x}d$ is the number of stars in each mass interval m, m+dm. Upon integration, we derive the relationship between the random number λ and mass m

$$m = \left[m_\ell^{1-x} + \lambda \, \frac{1-x}{A} \, N\right]^{1/1-x}$$

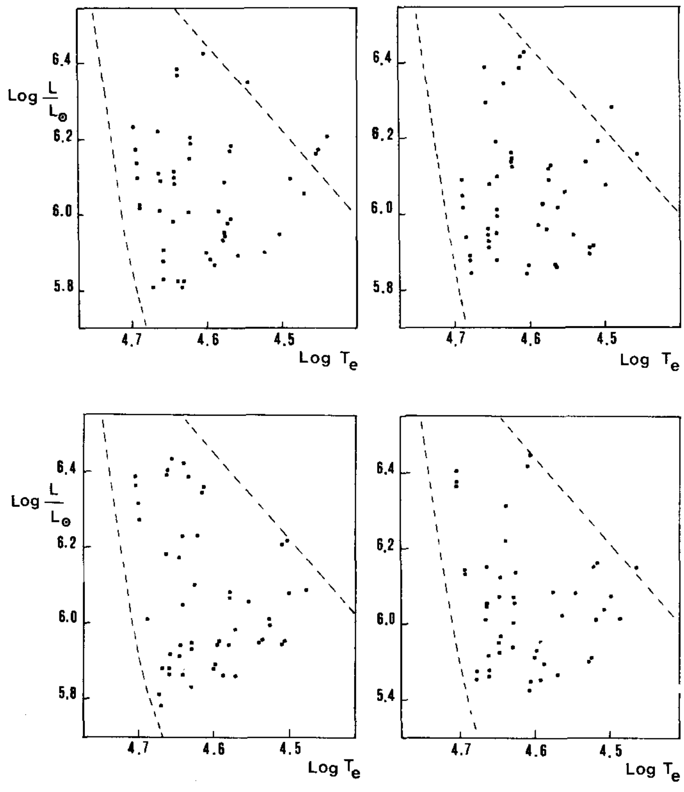

Fig. 1 - Expected distributions of OB stars in the HR diagram

m_ℓ being the minimum mass of interest here ($m_\ell \simeq 60\ M_\odot$). The constant A is fixed by the request of matching the total number of stars in the observational HR diagram, and $\Phi(m)$ is normalized to unity over the whole mass interval. The range of masses considered here is 60 $M_\odot$ to 150 $M_\odot$, the upper limit being imposed by stability considerations (Appenzeller, 1970). The slope x of the initial mass function is taken from Lequeux (1979), x=2. The following set of isochrones has been used in the numerical experiments

1.00 1.5 1.8 2. 2.4 2.5 2.7 3. 3.4

where ages are given in units of 10^6ys.

Fig. 1 shows four rapresentative diagrams taken from a much larger number of numerical experiments; the upper luminosity boundary as given by Humphreys and Davidson (1979) is also shown for purposes of comparison.

Conclusions

From these numerical experiments we may derive the following conclusions:

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i) the predicted distribution of stars in the HR diagram is consistent with the observations, as very few stars fall beyond the observed upper boundary, even with a very modest loss of mass during core H-burning.
ii) different luminosity boundaries seem to be suggested by the numerical experiments, which however do not imply different evolutionary backgrounds.
iii) the upper main sequence band is severely affected by the occurrence of stochastic effects in the process of star formation, due to the very low number of stars involved.
iv) the existence of such boundary for the luminosity of earliest OB type stars cannot be safely used to infer evidences about the occurrence of substantial mass loss during the core H-burning phase.

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