THE DISTRIBUTION IN LUMINOSITY OF OB STARS AND EVOLUTIONARY TIMESCALES

F. Bisiacchi, L. Carrasco, R. Costero, C. Firmani and J.F. Rayo
Instituto de Astronomía, Universidad Nacional Autónoma de México

We have obtained the observed fraction of supergiant (luminosity classes I and II), giant (III) and dwarf (IV-V) stars of spectral types B2 and earlier. The stellar sample used was formed with all the stars with bi-dimensional spectral classification listed in the Catalogue of Galactic O stars by Cruz-González et al. (1974), the unpublished compilation of B0 and B0.5 stars by J.F. Rayo, and the B1-B2 stars listed by Morgan et al. (1955). The latter sample is by far the least complete one. The results are listed in Table I, together with the total number of stars (in parenthesis) considered in each spectral interval. A prominent conclusion is drawn from the table: The fractions remain approximately constant all over the spectral range considered.

TABLE I

Observed Fraction of Stars by Luminosity Class for Different Spectral Types

Sp.T. / Class	O3-O5.5 (22)	O6-O7.5 (90)	O8-O8.5 (60)	O9-O9.5 (276)	B0 (544)	B0.5 (752)	B1-B2.5 (462)	O3-B2.5 (1744)
I-II	0.23	0.20	0.28	0.32	0.26	0.28	0.31	0.28
III	0.18	0.26	0.17	0.22	0.26	0.23	0.19	0.24
IV-V	0.59	0.54	0.55	0.45	0.48	0.49	0.50	0.49

The observed relative fractions cannot be explained by the classical evolutionary models of massive stars without mass loss. Adopting the mass function by Prentice and ter Haar (1969) and the luminosity calibration by Conti and Alschuler (1971), the predicted fraction of supergiant to dwarf, late O- and early B-type stars is smaller by at least an order of magnitude than the observed one. The disagreement is mainly due to the failure of the classical models to produce low enough surface gravities during the core hydrogen burning phase. However, models where mass loss

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is considered (e.g. the ones presented by Chiosi and coworkers, and by de Loore and his group in this symposium) do extend the core hydrogen burning phase into the region of the log g, log Teff plane where supergiant stars lie, particularly those with the highest mass loss rates.

Adopting the mass function mentioned above, the surface gravity and effective temperature calibrations for the O-type stars by Conti (1973) and those for the B-type stars by Morton and Adams (1968), we have computed the expected fractions of supergiant, giant and dwarf stars from the models by Chiosi et al. (1978) with α = 0.96 (the highest mass loss used in the paper). The resulting fractions are, respectively, 0.24, 0.28 and 0.48 for the O9-B0 spectral range and 0.36, 0.27 and 0.36 for the B0-B1 one. In deriving these numbers we have assumed equal timescales for segments of equal length of the track (in the log g, log Teff plane) for a star of a given initial mass.

The above estimated fractions are in reasonable agreement with the observed ones. However, these models fail in predicting a roughly constant value for the relative fractions as observed for the whole O3 to B2 spectral range. Models with even higher values of α might be able to reach better agreement with the observed fractions for the hottest stars. An alternative explanation for the large fraction of supergiants observed could be the possible presence of hot UB-bright stars in the galacatic disk (Carrasco et al., 1976). In the log g, log Teff plane the evolutionary tracks for UV-bright stars by Pacyński (1971) and Gingold (1974) are almost parallel to those by Chiosi et al. (1978) for massive star with high mass loss rates, and the evolution takes place at almost constant pace with log Teff. Hence, the difference between the fractions of supergiants predicted for the UV-bright stars and those for massive stars will depend largely on the masses of the progenitors of the former stars, their mass function and the mass lost during both red giant branches previous to the UV-bright stage. Adopting the total mass lost for solar-type stars as a function of initial mass given by Fusi-Pecci and Renzini (1975,1976), we found that the fraction of supergiants among the UV-bright stars is comparable to the one observed for OB stars in general.

We conclude that the observed fractions of supergiants, giants and dwarfs for OB stars can be explained by the evolutionary models of massive stars with mass loss and/or the presence of hot UV-bright stars in the galactic disk.

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DISCUSSION FOLLOWING BISIACCHI, CARRASCO, COSTERO, FIRMANI and RAYO

Ovenden: This paper is clearly very important, and its conclusions must be taken seriously. Taking them seriously consists, in part, of asking if other explanations are possible. Regarding the velocity residual histograms, it must be remembered that the residuals are found relative to an assumed global galactic rotational velocity field. Is there a possibility that the adopted model field is wrong? One possibility is that dynamical effects of spiral arms must be included. We cannot do this well at present.
Also, the stars involved have life-times less than the phase-mixing time for galactic orbits ($\sim 10^8$ years), so that the velocity distribution might show relics of the dynamical processes involved in star formation. Finally, I would like to emphasize that since early-type stars play an important role in the investigation of the kinematics of the galaxy, this investigation is very important for the study of stellar kinematics.

Carrasco: Yes, I agree this point requires further investigation.

Garmany: I would like to mention that in our study of the brighter O-stars, we have studied the radial velocities of a number of run-away O-stars, and so far have found indications for variations only in α Cam, unlike the predictions made by Beckenstein and Bowers. In addition, I would like to ask how our discovery of a Balmer gradient in several run-away stars (Bohannan and Garmany, Ap.J., 1978, 223, 908) affects your conclusions.

Carrasco: There may be some run-away stars which are actually not Pop II, low mass stars, but this would only add to our sample some stars and then our estimates of the number of run-aways of Pop II are only upper limits. No theory about the origin of run-aways via ejection and/or velocity gradient can explain the asymmetric drift derived by us.

van den Heuvel: From the UV spectrum there is a simple way to distinguish between low-mass, low-radius halo O-type stars and population I O-stars, as the terminal wind velocity is always a few times the escape velocity V_{esc}. V_{esc} is given by $\sqrt{2.g.R}$ where g is the surface gravity and R is the stellar radius. A spectral type gives us g and T_{eff}, so g is the same in both cases. The halo O-stars are expected to have a 50 to 100 times smaller radius than the population I O-stars, so one expects their wind outflow velocities to be some 7 to 10 times lower. With IUE such a difference must be easy to see.

Carrasco: Yes, in fact we have written a proposal to observe this effect with the IUE. However one should not expect effects on the terminal velocities as high as factors of 7 to 10, since the radii of the UV bright stars may be comparable to 1 R_o, if so then the factors to observe may be only of about 1.5 to 3.

Heap: Can you say what the typical luminosity and mass of these high-velocities stars are?

Carrasco : Typical luminosities should fall in the $L = 10^3 L_o$ to $10^4 L_o$ range, while the masses should be in the 0.5 to 1.4 M_o range.

Heap: How do you account for so many Pop II OB stars needed by your interpretation of run-aways?

Carrasco: They are not many, in fact our estimates of the number density of run-aways are in good agreement with both the theoretical evolutionary time scales of UV-bright stars by Gingold and the number of this kind of objects observed in globular clusters.