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Test of Evolutionary Models for Stellar Population Studies

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Abstract. Using the Andersen (1991) data on the mass, absolute visual magnitude, the effective surface temperature and the bolometric corrections, new calibrations for the mass vs. absolute visual magnitude and for the bolometric correction vs. effective surface temperature have been derived. Comparison between the latest evolutionary models with the empirical data has been made to test the evolutionary models for the purpose of stellar population studies.

Key words: Mass-luminosity relation—evolutionary models—bolometric correction.

1. Introduction

A well-known empirical relationship exists between the absolute visual magnitude M_v and the colour or the photospheric effective temperature T_{eff} for the populous main sequence stars. Relationship between mass m of a star and its M_v could not be derived in absence of the direct knowledge of the mass of a star. Only when we have a binary system of stars, the orbit of individual component stars around their common centre of mass can be measured which can reveal mass of the individual components. By 1980, Popper had determined mass and the visual luminosity of nearly a hundred stars which could have been used for the mass luminosity calibration of the main sequence stars in the solar neighbourhood. Cester *et al.* (1983) and Grenier *et al.* (1985) enlarged this catalogue which was used by Rana (1987) for deriving the initial mass function of stars, IMF in short. Basu & Rana (1992) included Liebert & Drobst (1987) for their latest revision of the IMF. More recently, Andersen (1991), hereafter referred to as A91, has compiled the masses, radii, surface temperature and absolute visual magnitude for 45 binary systems (90 single stars). Because the A91 data is primarily concerned with the intermediate and high mass stars, we complement the low mass stars from Basu & Rana (1992) in order to cover the whole range of stellar masses.

On the theoretical side, there is a tremendous improvement in the treatment of opacity in computation of stellar evolutionary models. For instance, Claret & Gimenez (1992) and Maeder and his coworkers (refer Schaller *et al.* 1992, hereafter referred to as SSMM) have computed new theoretical grid of evolutionary stellar models which take into account the updated opacity tables due to Rogers & Iglesias (1992) and Kurucz (1992).

The calibration between observed quantities has been discussed in section 2. We also compare the empirical data with theoretical evolutionary models in order to evaluate the evolutionary status of stars in A91 and to test the consistency of evolutionary models with the observations.

2. Results and discussion

The input data in the current study comes from various sources in order to produce reliable empirical relationships between mass and absolute visual magnitude for the construction of IMF, and between bolometric corrections and effective temperature for the deduction of luminosity vs effective temperature (required for comparing the theoretical HR-diagram with the observational one).

The data for the first relationship were taken from Basu & Rana (1992) and Andersen (1991), where M_v's were binned according to M_v in steps of unity. A smooth relationship was derived by using the spline fitting with a constraint that solar values are reproduced by the modeled line. In Table 1 we provide M_v as a function of log m, use of this result for the construction of IMF will be discussed in a separate paper.

As we expect for the $M_v > 15$ the effective temperature of the stars falls considerably below 3000 K and therefore the visual band will allow very little light to come out as a result of which a small decrease in mass will tend to show a very large decrease in M_v . This is well demonstrated in Fig. 1. As compared to previous calibrations used by Scalo (1986), similarly on the high luminosity end the star would gradually approach the Eddington luminosity i.e. $L \propto m$ instead of $L \propto m^3$. This implies that fast flattening of the $M_v - m$ relationship beyond log $m > 1.5$, and this trend is also obvious in Fig. 1. However, in the mass range $0.1 <$ log $m < 10$ the slope of the M_v – log m relationship has several undulatory features which were not apparent in the semiempirical studies so far. This has got a direct bearing on the estimation of the present day mass function from the luminosity function. Though A91 data already use bolometric correction from Popper (1980) to convert absolute magnitude to luminosity of stars, here we trace back this parameter from the observed quantities,

Table 1. Mass-luminosity relationship.

log m	M_v	log m	M_v
– 1.2	17.50	0.2	2.69
– 1.1	15.90	0.3	1.85
– 1.0	14.73	0.4	1.11
– 0.9	13.93	0.5	0.41
– 0.8	13.32	0.6	– 0.29
– 0.7	12.71	0.7	– 0.98
– 0.6	11.96	0.8	– 1.65
– 0.5	11.05	0.9	– 2.28
– 0.4	10.00	1.0	– 2.86
– 0.3	8.84	1.1	– 3.38
– 0.2	7.57	1.2	– 3.83
– 0.1	6.22	1.3	– 4.24
0.0	4.85	1.4	– 4.62
0.1	3.67	1.5	– 4.97

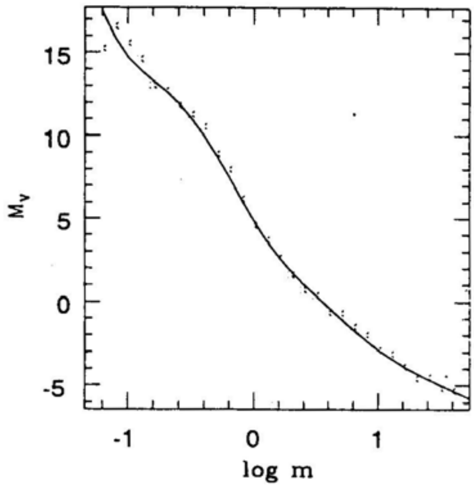

Figure 1. The absolute magnitudes of the binned data is shown as a function of the logarithm of the masses in A91. The solid line represents the calibration derived from the data (see text for detail).

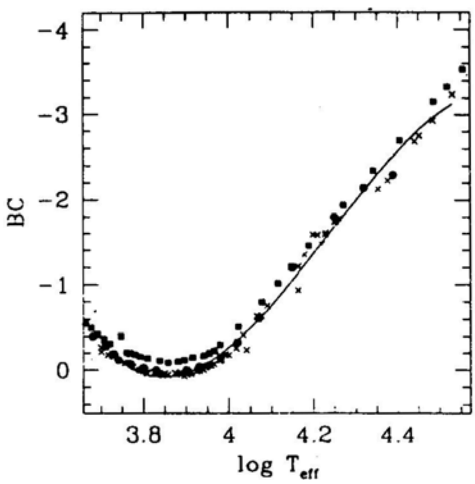

Figure 2. The bolometric corrections of stars in A91 is plotted against the logarithm of the effective temperatures. The solid line corresponds to the calibration derived. The filled squares and filled hexagons are the points from the calibrations of Schmidt–Kaler (1982) and Böhm–Vitense (1992) respectively.

luminosity and absolute magnitude (assuming $M_{bol,\odot}$ = 4.69). In Fig. 2 we plot BC as a function of log T_{eff} for stars in A91. A smooth relationship in the form of best fit polynomial of order five was followed to calibrate BC in terms of log T_{eff} . For comparison we plot also other existing calibrations from Schmidt–Kaler (1982) and Böhm–Vitense (1992) for main-sequence stars. In Table *2*, we provide the calibration of BC as a function of log T_{eff} together with other calibrations mapped into log T_{eff} in steps of 0.1.

Table 2. Bolometric correction in mag as a function of log T_{eff} for luminosity class V from three different sources.

log T_{eff}	BC[a]	BC[b]	BC[c]
3.70	– 0.39	– 0.31	– 0.33
3.75	– 0.35	– 0.08	– 0.09
3.80	– 0.15	– 0.03	– 0.04
3.85	– 0.09	0.00	– 0.08
3.90	– 0.13	0.00	– 0.03
3.95	– 0.19	– 0.07	– 0.08
4.00	– 0.41	– 0.23	– 0.26
4.05	– 0.65	– 0.49	– 0.49
4.10	– 0.93	– 0.82	– 0.76
4.15	– 1.23	– 1.20	– 1.05
4.20	– 1.53	– 1.52	– 1.36
4.25	– 1.82	– 1.80	– 1.68
4.30	– 2.11	– 2.07	– 1.99
4.35	– 2.40	– 2.23	– 2.29
4.40	– 2.67	– 2.31:	– 2.58
4.45	– 2.96	– 2.30:	– 2.82
4.50	– 3.23	– 2.46:	– 3.03

[a] Schmidt–Kaler 1982.
[b] Böhm–Vitense 1992.
[c] This paper.

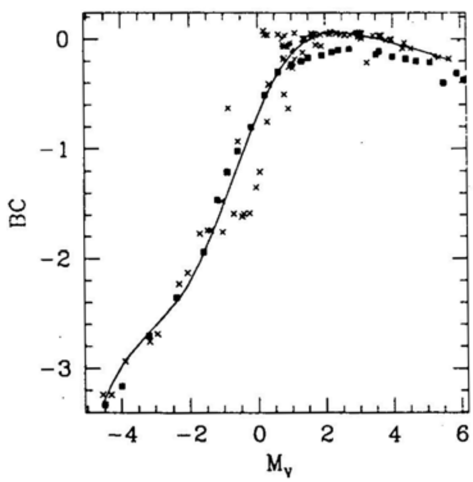

Figure 3. The bolometric corrections of the A91 is shown as a function of the absolute visual magnitude together with points from other calibrations as in Fig. 2. The solid line is the calibrated line from the A91 sample.

In Fig. 3 we plot BC as a function of *Mv*, the region $-1.5 < M_v < 2.2$ corresponding to log *m* on the other side of 0.8 ± 0.1 falls in the well-known Balmer discontinuity region, A very wide dispersion in this region is attributed to the presence of Balmer discontinuity.

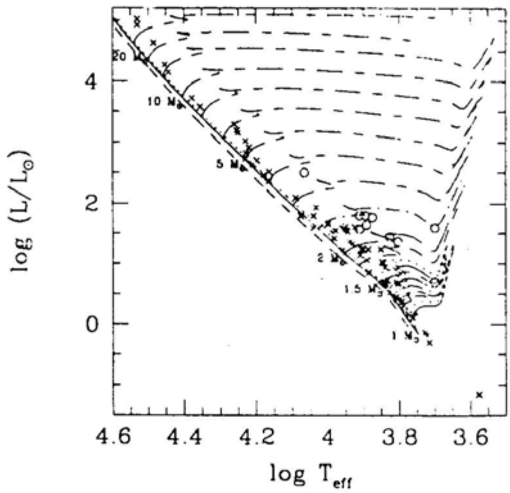

Figure 4a. Theoretical HR diagram of Claret, A., Gimenez, A. (1992) evolutionary models for solar metallicity with ZAMS for three metallicity (Z = 0.01, 0.02, and 0.03). Crosses indicate stars in A91 of luminosity classes V, while circles represent other luminosity classes.

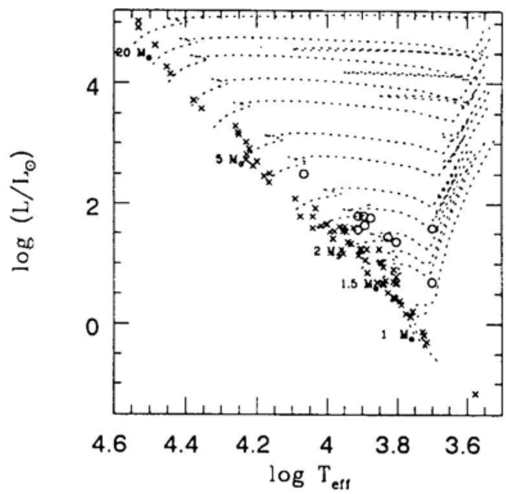

Figure 4b. Same as Fig. 4a, but for the SSMM models.

Fig. 4a essentially confirms the findings of Andersen (1992), who has shown that Claret models reproduce not only the masses of binary stars on the evolutionary frame, but also that $T_{\rm eff}$ of primary and secondary components are in agreement. However, here we have compared evolutionary models of Schaller *et al.* (1992) against the empirical data. There is not much difference in the distribution, as evidenced from Fig. 4a and 4b that most of A91 stars are distributed between zero age main sequence (ZAMS) and theoretical age main sequence (TAMS) which is further confirmed from luminosity classes of these stars. Those stars with luminosity classes less than V (which are quite few) fall away from TAMS and are in the late stages of evolution. More observational data will be required to ascertain the consistency of evolutionary models in evolutionary phases not covered by the A91.

It is advantageous to use the latter SSMM models, since they are exhaustive in masses which are useful for population synthesis.

In conclusion, a reliable calibration of the mass and absolute visual magnitude of single stars (detached binaries), and bolometric correction as a function of effective temperature and visual magnitude are derived. A comparison has also been made between the absolute luminosity and effective temperature (HR diagram) between the observed data points with the latest evolutionary models justifying the consistency of SSMM models with correct identification of the luminosity class.

References

Andersen, J. 1992, in *Inside the Stars, IAU Coll. 137,* Ed. Werner W. Weiss & Annie Baglin, p. 347.

Andersen, J. 1991, *Astr. Astrophys. Rev.,* **3**, 91.

Basu, S., Rana, N. C. 1992, *Astrophys. J.,***393**, 373.

Böhm-Vitense 1992, *Stellar Astrophysics* (Cambridge: Cambridge University Press).

Cester, B., Ferluga, S., Boehm, C. 1983, *Astrophys. Space Sci.,* **96**, 125.

Claret, A., Girnenez, A. 1992, *Astr. Astrophys. Suppl. Ser.,* **96**, 225.

Grenier, S., Gomez, A. E., Jaschek, C, Jaschek, M., Heck, A.1985, *Astr. Astrophys.,* **145**, 331.

Kurucz, R. L. 1992, in *Stellar Atmosphere: Beyond classical model,* Ed. L. Crivelleeri, I. Hubeny & D. G. Hummer, NATO ASI Series (Dordrecht: Kluwer).

Liebert, J., Drobst, R. 1987, *A. Rev. Astr. Astrophys.,* **25**, 473.

Popper, D. M. 1980, *A. Rev. Astr. Astrophys.,* **18**, 115.

Rana, N. C. 1987, *Astr. Astrophys.,* **184**, 104.

Rogers, F. J., Iglesias, C. A. 1992, *Astrophys. J. Suppl. Ser.,* **79**, 507.

Scalo, J. M. 1986, *Fund. Cosmic Phys.* 11, 1.

Schalter, G., Schaerer, D., Menet, G., Maeder, A. 1992, *Astr. Astrophys. Suppl. Ser.,* **96**, 269.

Schmidt Kaler, T. H. 1982, Physical parameters of the stars, in *Landolt–Bornstein New Series, Vol 2b, astronomy and astrophysics Stars and star clusters* Eds. K Schaifers & H. H. Voigt, (New York: Springer–Verlag).