COMPARISONS BETWEEN OBSERVATIONAL COLOR-MAGNITUDE DIAGRAMS AND SYNTHETIC CLUSTER DIAGRAMS FOR YOUNG STAR CLUSTERS IN THE MAGELLANIC CLOUDS

Stephen A. Becker[1], Grant J. Mathews[2], and Wendee M. Brunish[1]
[1]Los Alamos National Laboratory
[2]Lawrence Livermore National Laboratory

Young star clusters (<3 x 10^8 yr) in the Magellanic Clouds (MC) can be used to test the current status of the theory of stellar evolution as applied to intermediate and massive stars. The color-magnitude diagram of many young clusters in the MC shows, unlike the case of clusters in our Galaxy, large numbers of stars in both the main sequence and post main sequence evolutionary phases. Using a grid of stellar evolution models, synthetic cluster H-R diagrams are constructed and compared to observed color-magnitude diagrams to determine the age, age spread, and composition for any given cluster. In addition, for those cases where the data is of high quality, detailed comparisons between theory and observation can provide a diagnostic of the accuracy of the stellar evolution models. Initial indications of these comparisons suggest that the theoretical models should be altered to include: a larger value for the mixing length parameter (α), a larger rate of mass loss during the asymptotic giant branch (AGB) phase, and possibly convective overshoot during the core burning phases.

1. INTRODUCTION

Our grid of stellar evolution models spans the range of $3 \leq M_*/M_\odot \leq 40$ in mass, and $0.20 < Y < 0.36$ and $0.001 < Z < 0.03$ in composition (see Becker and Iben 1979, 1980; Becker 1981, Brunish and Truran 1982 a,b; and Becker and Brunish 1983). A detailed description of our method of constructing synthetic cluster diagrams is given in Becker and Mathews (1983). The conversions of Kurucz (1979) and Flower (1977) are used to convert luminosity into absolute visual magnitude and temperature into B-V. For composition determinations, we have elected to link Y and Z together via the Lequeux et al. (1979) relation:

$$Y = (0.228 \pm 0.004) + (2.83 \pm 0.60)Z$$

although we do have the ability to vary Y and Z independent of each other.

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 83–87.

https://doi.org/10.1017/S0074180900030588 Published online by Cambridge University Press

2. COMPARISONS BETWEEN THEORY AND OBSERVATION

In Figures 1 a-b synthetic cluster diagrams are plotted for two different compositions for six different ages. In both cases, one can see that the location of the bluest core He burning giants (i.e., those located at the tip of the blue loop) provides a very sensitive age indicator. This behavior can be used in many cases to obtain an initial estimate of the age and composition of a cluster based on the location of its blue loop tip. In Figure 2 this procedure has been applied to six clusters in the LMC and one cluster in the SMC.

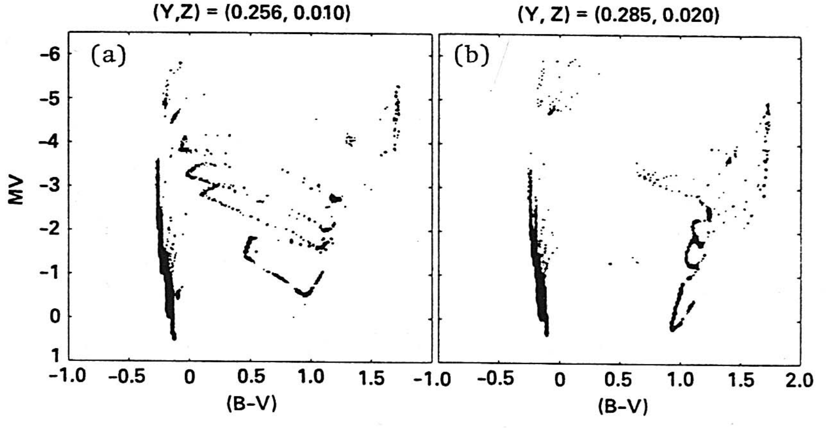

Figure 1. Synthetic H-R diagrams as a function of age (15, 30, 60, 90, 120, 240 x 10^6 yr) for two different chemical compositions.

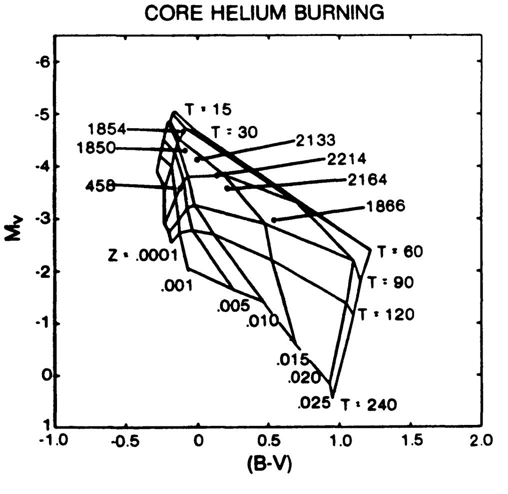

Figure 2. The location of the blue loop tip as a function of age (in 10^6 yr) and composition (Y is obtained from Lequeux et al. 1979). NGC 458 is in the SMC, the other clusters are in the LMC.

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Using these estimates as a guide, whole cluster fits between synthetic H-R diagrams and color-magnitude diagrams can then be constructed. This procedure is necessary in order to obtain the most information possible, i.e., the age, age spread, and composition of a given cluster as well as feedback on the accuracy of the stellar evolution models. For example, in Figures 3a-b and 4a-b, we compare the observations with our best theoretical fits for the cases of NGC 1866 and NGC 2214.

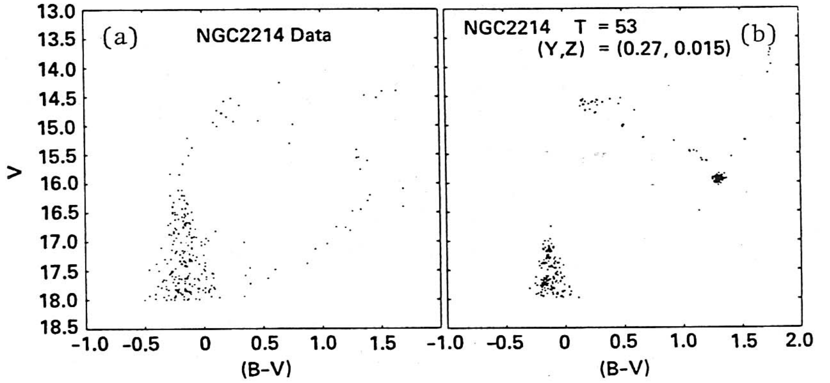

Figure 3. Comparison of the observed and theoretical H-R diagrams for the LMC cluster NGC 1866. The data is from Arp and Thackery (1967), Robertson (1974), Walker (1974) and Flower (1981).

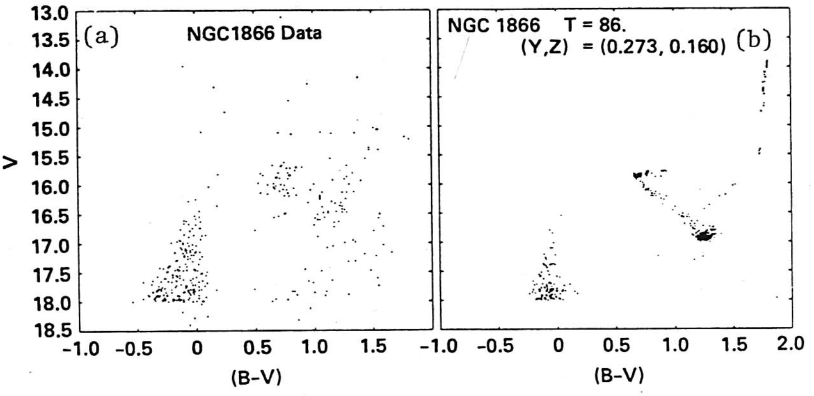

Figure 4. Comparison of the observed and theoretical H-R diagram for the LMC cluster NGC 2214. The data is from Robertson (1974).

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In Table 1 we summarize the results to date of our whole cluster fits with regard to their age and composition.

TABLE 1

Cluster	Age	Composition
NGC 1866	86×10^6 yr	(Y,Z) = (0.273, 0.016)
NGC 2214	53×10^6 yr	(Y,Z) = (0.27, 0.015)
NGC 1854	30×10^6 yr	(Y,Z) = (0.27, 0.015)
NGC 2100	10×10^6 yr	(Y,Z) = (0.28, 0.02)

Finally, observational feedback in the above cases suggests the following changes in the theoretical models: 1) based on the location of the red giant branch and the AGB, the value of α should be increased to ≈ 1.5; 2) based on the observed truncation at high luminosity of the AGB, the rate of mass loss for models in the AGB phase should be increased; and 3) based on the observed densities of stars located on the main sequence and the red giant region, some additional effect like convective overshoot (or perhaps rotation or binary evolution) needs to be considered. Work on other clusters in both the LMC and the SMC as well as on theoretical models is currently in progress.

REFERENCES

Arp, H.C., and Thackery,A 1967, Astrophys J. 149, pp. 73-89.
Becker, S.A. 1981, Astophys. J. Suppl. 45, pp. 475-505.
Becker, S.A., and Brunish, W. M. 1983, Astrophys. J. to be submitted.
Becker, S.A., and Iben, I. Jr. 1979, Astrophys. J. 232, pp. 831-853.
________. 1980, Astrophys. J. 237, pp. 111-129.
Becker, S.A., and Mathews, G.J. 1983, Astrophys. J. 270, pp. 155-168.
Brunish, W.M., and Truran, J. W. 1982a, Astrophys. J. 256, pp. 247-258.
________. 1982b, Astrophys. J. Suppl. 49, pp. 447-468.
Flower, P.J. 1977, Astron. Astrophys. 54, pp. 31-39.
________. 1981, Astrophys. J. (Letters) 249, pp. L11-L14.
Kurucz, R.L. 1979, Astrophys.. J. Suppl. 40, pp. 1-340
Lequeux, S., Pembert, M., Rayo, J. Serrano, A. and Torres-Pembert, S., 1979, Astron. Astrophys. 80, pp. 155-166.
Robertson, J. W. 1974, Astron. Astrophys. Suppl. 15, pp. 261-309.
Walker, M.F. 1974, Mon. Not. Roy. Astr. Soc. 169, pp. 199-209.

This work performed under the auspices of the U.S. Department of Energy Contract #W-7405-ENG. 36.

DISCUSSION

Richer: Do any of the clusters that you have looked at have carbon stars in them? If not, can you say anything about the ages of the clusters that do have carbon stars in them?

Becker: None of the clusters we are studying or are about to study have been observed to have carbon stars in them. It appears that clusters younger than about 3×10^8 years are unable to form them. This is consistent with my thermal pulse models in which models > 3 $M_\odot$ don't become carbon stars, but rather they evolve into N rich M supergiants on the AGB.

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