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# Testing Overshoot with Intermediate-age Magellanic Cloud Clusters

Jong-Hak Woo, Carme Gallart, Pierre Demarque

*Department of Astronomy, P. O. Box 208101, Yale University New Haven, CT 06520-8101*

Sukyoung Yi

*Oxford University, Astrophysics, Keble Road, Oxford, OX1 3RH*

Manuela Zoccali

*European Southern Observatory, Germany*

**Abstract.** We present synthetic color-magnitude diagrams (CMD) with different overshoot (OS) parameters for recently observed LMC clusters. Age is determined for each OS parameter by the $\Delta$(V-R) difference. A moderate OS is required for ages $\sim$2 Gyr. We are also able to constrain binary fraction and mass loss along the RGB.

## 1. Introduction

One of the fundamental parameters of stellar evolution theory, which directly changes the CMD of young and intermediate-age star clusters, is the amount of core overshoot. Observational studies of galactic open clusters with solar metallicity showed that a moderate amount of OS ($\alpha$ = 0.2) is essential to explain the observed gap near the turnoff (TO) in CMDs. We are investigating the OS parameter, binary fraction, and mass loss for 3 populous star clusters of LMC for which deep CMDs were obtained with FORS at the VLT.

Evolutionary tracks and isochrones with 3 different initial OS parameters ($\alpha$=0.1, 0.2, 0.3) are constructed with the Yale code (Yi et al. 2001). A detailed description of the CMD synthesis and analysis will follow (Woo et al. 2001).

## 2. Determining overshoot and age

The major role of core OS in stellar evolution is to supply hydrogen fuel from the OS region by mixing, and to lengthen the hydrogen core burning lifetime. This results in a much brighter TO and subgiant branch in isochrones. Therefore, if the amount of OS is larger, an older age is expected for a given observed CMD.

Since the OS parameter cannot be singly determined without an accurate age constraint, we determined plausible age along with each OS parameter. As the TO gets redder with increasing age, the color difference, $\Delta$(V-R) between the bottom of the RGB and the TO decreases. However, a larger OS isochrone

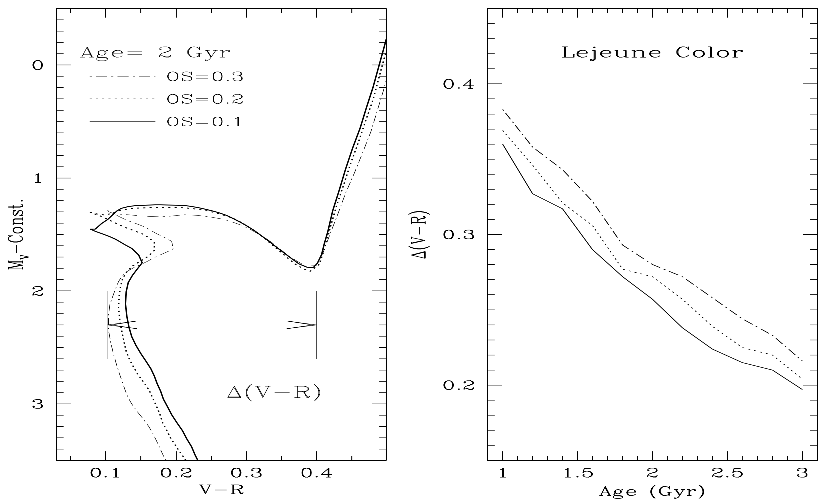


Figure 1. $\Delta$(V-R) dependence on the OS parameter. Z=0.004. The size of $\Delta$(V-R) between the bottome of the RGB and the TO decreases with increasing age. A larger OS parameter gives a larger age for an observed $\Delta$(V-R).

has a larger $\Delta$(V-R) since more massive stars are located near the TO for a given age (Fig. 1). This correlation directly constrains the cluster's age for each OS parameter. Table 1 shows 3 sets of isochrone solutions for each cluster obtained by the $\Delta$(V-R) method.

Table 1. Isochrone solutions for each cluster

| Cluster | Overshoot ($\alpha$) | Age |
|---|---|---|
| NGC 2173 | 0.1 | 1.3 Gyr |
| | 0.2 | 1.5 Gyr |
| | 0.3 | 1.8 Gyr |
| SL 556 | 0.1 | 1.9 Gyr |
| | 0.2 | 2.1 Gyr |
| | 0.3 | 2.4 Gyr |
| NGC 2155 | 0.1 | 2.7 Gyr |
| | 0.2 | 2.9 Gyr |

Isochrone fitting with each observed CMD shows that all solutions are reasonable within the observational error. With the determined age and OS parameter, we generated synthetic CMDs with the same distance modulus, reddening, and binary fraction. The distance modulus to the LMC is assumed to be 18.6, and Z=0.004 is used for all three clusters. We present synthetic CMDs of SL 556 in Fig. 2 & 3. The error and completeness simulations are carefully conducted according to Gallart et al. (1999).

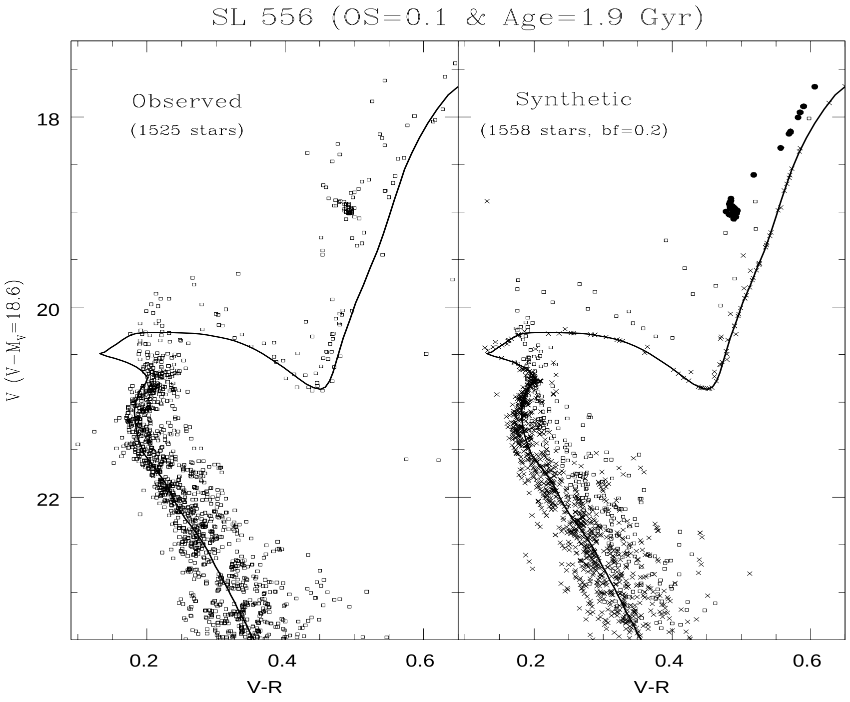


Figure 2. CMDs of SL 556. OS=0.1. Single (cross), binary (square), and red clump (solid circle) stars are denoted in the synthetic CMD.

## 3. Discussion

As in Galactic open clusters, a moderate amount of OS is required. OS $\geq 0.3$ seems unlikely since $\Delta$(V-R) between the TO and the tip of the red hook is too wide compared with the observed CMD.

Unresolved binary stars are located around the hook, where not many single stars are expected since the time scale of the core contraction phase is very short. We found that by comparing the number density of stars in the CMD, binary fraction can be determined. Once the binary fraction is derived, the color distribution of the stars around/above the hook can be used to determine the best soultion. Mass loss at the RGB tip is larger than expected from the Reimers formula ($\eta = 0.7$) in order to fit the location of red clump stars.

## References

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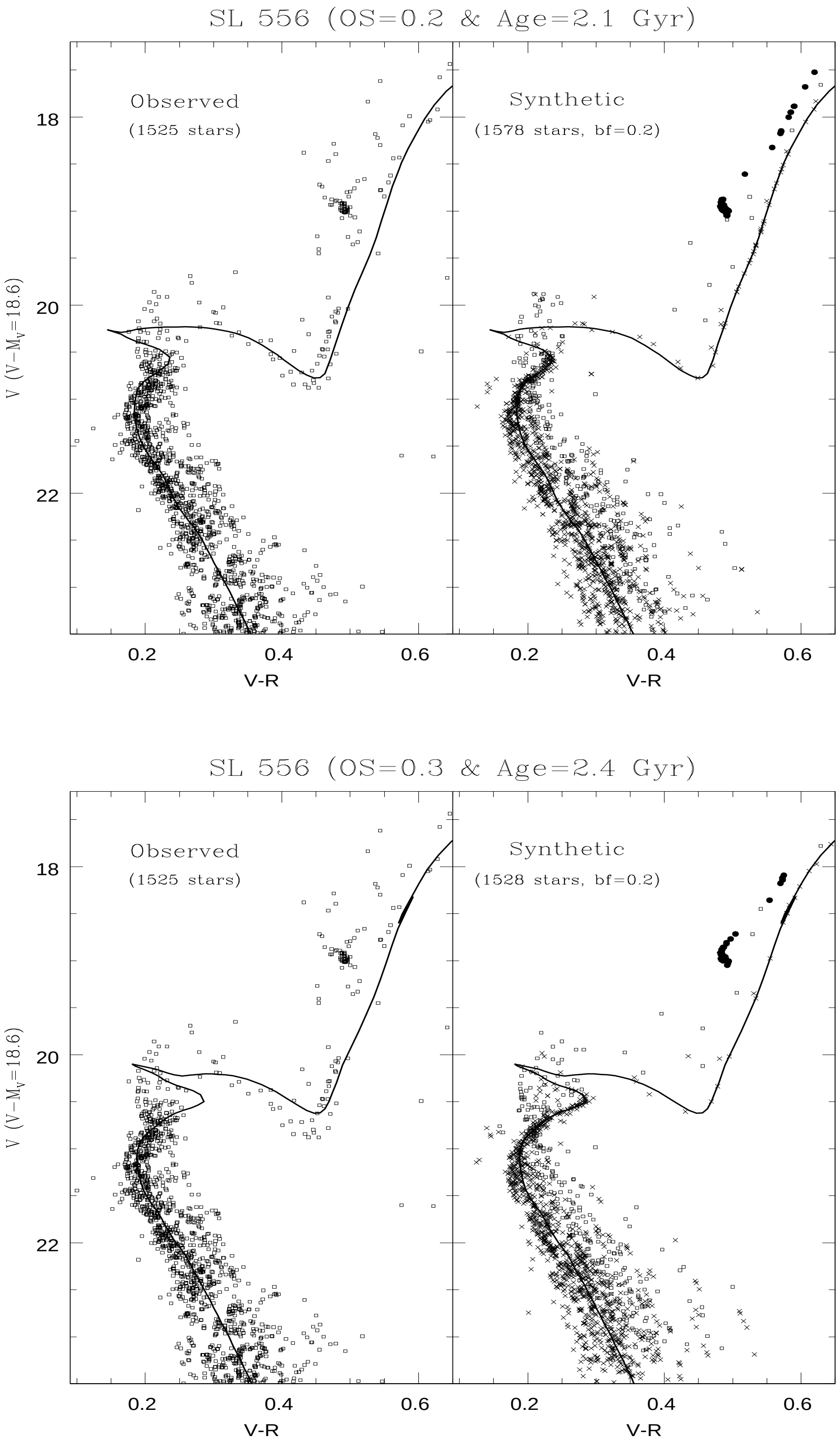


Figure 3. CMDs of SL 556. OS=0.2 (top), OS=0.3 (bottom)