The Art of Modelling Stars in the 21st Century
Proceedings IAU Symposium No. 252, 2008
L. Deng & K.L. Chan, eds.

doi:10.1017/S1743921308023211

The role of binary stars in stellar population synthesis

Zhongmu Li[1,2] and Zhanwen Han[1]

[1]National Astronomical Observatories/Yunnan Observatory, the Chinese Academy of Sciences, Kunming, 650011, China

[2]Graduate University of the Chinese Academy of Sciences
email: zhongmu.li@gmail.com

Abstract. More than about 50% stars are in binaries, but the effects of binary evolution were not taken into account in most previous stellar population synthesis studies. In fact, binaries can affect the integrated peculiarities such as spectral energy distributions (SEDs), colours, and line-strength indices of populations. With the effects of binary stars taken into account, some new results for stellar population studies will be shown. We discuss how binaries affect the colours and Lick indices of simple stellar populations, and the measurement of stellar ages and metallicities.

Keywords. Galaxies: stellar content, galaxies: evolution, galaxies: formation

---

1. Introduction

Evolutionary stellar population synthesis is a powerful method to study the stellar contents, and then the star formation histories of galaxies. It is widely used in astrophysics studies and is being updated day by day. Although most works (e.g., Thomas *et al.* 2005, Li *et al.* 2006) use spectral methods such as SED and line-index methods, photometric methods are also used by many works (e.g., Li *et al.* 2007, Li & Han 2007a, Li & Han 2007b) as it is shown that some colours can disentangle the well-known stellar age–metallicity degeneracy (e.g., Worthey 1994). However, most works take single-star stellar population (ssSSP) models (e.g., Fioc & Rocca-Volmerange 1997, Bruzual & Charlot 2003, Vazdekis *et al.* 2003, and Maraston 2005). This is actually different from the real case of galaxies and star clusters. Many works show that galaxies and star clusters contain a lot of binary stars, and the binary fraction seems larger than 50%. This suggests that binaries may play an important role in stellar population synthesis studies, and the role of binary stars should be taken into account. In fact, binary stars seem very important for stellar population synthesis studies, as they can reproduce the special stars, e.g., blue stragglers (e.g., Li & Han 2007c), and the UV-upturn of elliptical galaxies (e.g., Han *et al.* 2007). Binaries can also change the determinations (using both line-index or photometric methods) of the ages and metallicities of stellar populations. They are also important for galaxy formation and evolution studies. We introduce our work on the study of the role of binary stars in stellar population synthesis studies.

2. Stellar population model and methods used in the work

A rapid stellar population synthesis (RPS) model (Li & Han 2007c) is used in the work, because there is no more appropriate model. The model takes two different initial mass functions, i.e., the ones of Salpeter (1955) and Chabrier (2003), and it models both ssSSPs and binary-star stellar populations (bsSSPs) on the basis of a simple and easily used statistical isochrone database (see Li & Han 2007c), in which the rapid stellar evolution code of Hurley et al. (2002) (hereafter Hurley code) is used to evolve both single and binary stars. Most binary interactions are considered when using the Hurley code to evolve stars of bsSSPs. Except the metallicity, masses of two components, separation of two components, and eccentricity of each binary, other parameters are taken by the code naturally. As a whole, the systemic errors in the stellar population synthesis model is about 6%. For the work, 50% (the typical fraction in the Galaxy) binaries are assumed in each bsSSP. In order to investigate the effects caused only by binaries, we compare the integrated peculiarities of an ssSSPs to those of a bsSSP that has the same stellar age and metallicity as the ssSSP. The stellar-population parameters (age and metallicity) determined using theoretical ssSSPs are also compared with those determined by bsSSPs. This can help us to understand the differences between the estimates of stellar-population parameters when taking different stellar population models.

3. Main results

In our work, the effects of binaries on the colours and line-strength indices of stellar populations are tested, respectively. The effects on the estimates of two stellar-population parameters, i.e., age and metallicity, are also investigated. The main results are as follows.

1) When studying the effects of binaries on the colours of populations, it is found that binaries make the colours of populations bluer, compared to those of ssSSPs. In Fig. 1, the evolution of $(B-V)$ colour is shown, for both ssSSPs and bsSSPs. The results for other colours are not shown here, because other colours are shown similar results as $(B-V)$. When we try to find the reasons, special stars, especially the blue stragglers in stellar populations are found to be very important. They can significantly change the colours of populations as they are very luminous and blue, and contribute a lot to the light of stellar populations.

2) Binary stars can affect the line strength indices of stellar populations clearly. In Figs. 2 and 3, as examples, we compare the evolution of an age-sensitive index, Hβ, and a metallicity-sensitive, Mgb. We can see that binaries make Hβ index larger and Mgb index smaller when comparing to ssSSPs. In fact, binaries can also make other age-sensitive indices such as $H_{\delta A}$ and $H_{\gamma F}$ larger, while making other metallicity-sensitive indices such as iron indices smaller. The binary effects are mainly caused by the special stars generated by binary evolution, but the changes in surface element abundance that results from binary interactions can also contribute to them. As a whole, it suggests that ssSSP models can only measure stellar-population parameters different from the real ones because of the presence of binaries in galaxies and star clusters.

3) Because binaries change the integrated peculiarities of populations compared to ssSSPs, they affect the determination of stellar-population parameters. Our results show that ssSSPs determine less ages when taking a line-index method (using Hβ and [MgFe] indices), and determine lower metallicities (0.003 on average) when taking a photometric method (using $U-R$ and $R-K$ colours) for populations containing binaries. When taking two line-strength indices for work, the difference between stellar ages determined via bsSSPs and ssSSPs increases with increasing age or decreasing metallicity of populations. It can be as large as 6 Gyr for populations with ages near 15 Gyr and the metallicity of 0.004. A 3-D relation of the difference between ages determined by bsSSPs and ssSSPs

https://doi.org/10.1017/S1743921308023211 Published online by Cambridge University Press

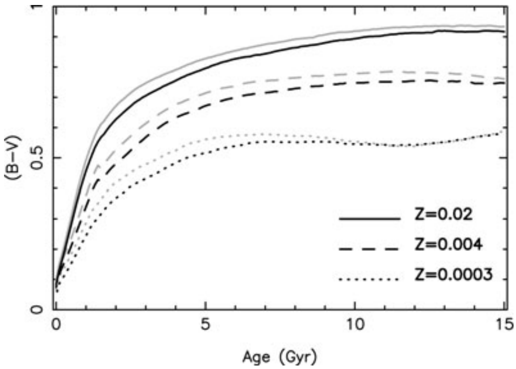

Figure 1. Comparisons of the evolution of $(B-V)$ colour of bsSSPs and ssSSPs. Solid, dashed, and dotted lines are for metallicities of 0.0003, 0.004, and 0.02, respectively. Black and gray lines are for bsSSPs and ssSSPs, respectively.

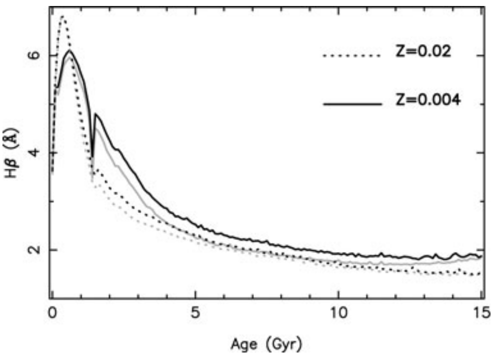

Figure 2. Comparisons of the evolution of Hβ index of bsSSPs and ssSSPs. Solid and dotted lines are for metallicities of 0.004 and 0.02, respectively. Black and gray lines are for bsSSPs and ssSSPs, respectively.

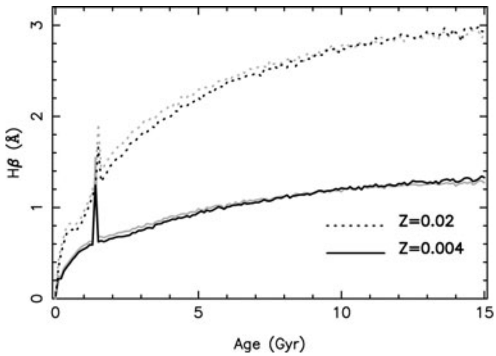

Figure 3. Comparisons of the evolution of Mgb index of bsSSPs and ssSSPs. Solid and dotted lines are for metallicities of 0.004 and 0.02, respectively. Black and gray lines are for bsSSPs and ssSSPs, respectively.

$(t_b - t_s)$, stellar age, and metallicity is shown in Fig. 4. In addition, it shows that ssSSP models and bsSSPs model can give similar results for stellar age determination.

4. Conclusion and disscussion

Binary stars play an important role in stellar population synthesis studies. They can make populations bluer, with larger age-sensitive indices and less metallicity-sensitive indices, for populations with different initial mass functions. When using bsSSP models instead of ssSSP models, larger stellar ages and metallicities will be obtained, via line-index and photometric methods, respectively. Although the results shown give us an image of the role of binary stars, it is far from well understanding the question. In fact, binary stars and new star formations have similar effects on stellar population studies. This makes it more difficult to get the accurate star formation histories of galaxies. In addition, the binary fraction in different galaxies or star clusters may be different. It seems necessary to measure the binary fraction of galaxies and then build stellar population models for different galaxies and star clusters.

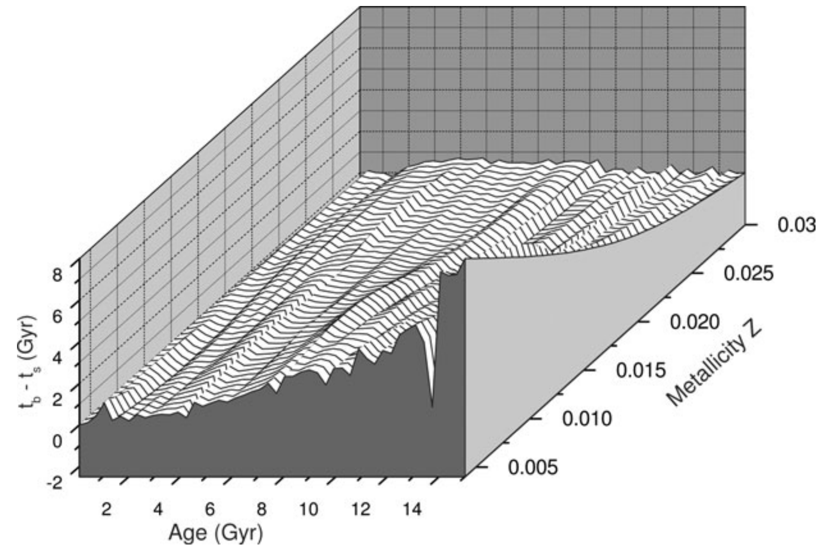

Figure 4. Comparisons of the isochrones of a pair of solar-metallicity ($Z = 0.02$) bsSSP and ssSSP. Black points show the isochrone of the ssSSP, and gray points show the isochrone of the bsSSP. Age and metallicity are the real parameters of populations, and for a population, "$t_b - t_s$" is obtained by subtract the age measured using ssSSPs from that measured using bsSSPs.

Acknowledgements

This work is supported by the Chinese National Science Foundation (Grant Nos. 10433030, 10521001 and 2007CB815406) and the Youth Foundation of Knowledge Innovation Project of the Chinese Academy of Sciences (07ACX51001).

References

Bruzual, G. & Charlot, S. 2003, MNRAS 344, 1000
Chabrier, G. 2003, ApJ 586, L133
Fioc, M. & Rocca-Volmerange, B. 1997, A&A 326, 950
Han, Z., Podsiadlowski, P., & Lynas-Gray, A. E. 2007, MNRAS 380, 1098
Hurley, J. R., Tout, C. A., & Pols O. R. 2002, MNRAS 329, 897
Li, Z. & Han, Z. 2007a, MNRAS 385, 1270
Li, Z. & Han, Z. 2007b, A&A 471, 795
Li, Z. & Han, Z. 2007c, MNRAS, in press, arXiv:0708.1204
Li, Z., Zhang, F., & Han, Z. 2006, ChJA&A 6, 669
Li, Z., Han, Z. & Zhang, F. 2007, A&A 464, 853
Maraston, C. 2005, MNRAS 362, 799
Salpeter, E. E. 1955, ApJ 121, 161
Thomas, D., Maraston, C., Bender, R., & Mendes de Oliveira, C. 2005, ApJ 621, 673
Vazdekis, A., Cenarro, A. J., Gorgas, J., Cardiel, N., & Peletier, R. F. 2003, MNRAS 340, 1317
Worthey, G. 1994, ApJS 95, 107

Discussion

F. Herwig: Could you explain what causes the spreading at the turn-off in the binary model compared to the single-star simulation. Is it just the super-position of slightly photometrically different binary components? Why does it extend further to the blue than the single-star isochrone?

Z.M. Li: I am not clear about the reason, but this is real. The results shown perhaps are affected by the discrimination of observation. I am not sure about this as I did not test it. I will check and give answers in the future. Thanks.

H.-G. Ludwig: What do we know about the binary fraction in external (perhaps Local Group) galaxies?

Z.M. Li: I think the binary fraction in different galaxies and star clusters is different and it is necessary to study further. The 50% fraction is very a widely used value.

C. Belczynski: You predict a large change in age estimate for old stellar populations (low mass stars). How big is this effect for very young populations ($\sim$ 4-5 Myr) containing massive stars (2-40 $M_{\odot}$)?

Z.M. Li: Not too much for young populations, as binaries contribute less to the light of young populations, relatively.

L. Deng: (1) Where are the photometric binaries in the CMD of M67? (2) How do you deal with the atmospheric models for remnants, such as Blue Stragglers if they are still binaries?

Z.M. Li: (1) I have no clear idea about this, because the data taken by our work was obtained by other people. This is actually not very important for our work. It needs to give more detailed investigation. (2) I did not take this point into account. It is very important to give further studies.

(F. Kupka: More a comment than a question: since you're using photometric indices in the IR to determine stellar properties, one problem we have in that wavelength region is the lack of atomic data to calculate reliable line blanketing and thus fluxes and finally, colours, from model atmospheres. As long as you only consider low Z values that may not matter. But to compute IR photometric indices for, say, a G or K type giant, we really need better atomic data.

Z.M. Li: It is absolutely right. Thank you.

E. Glebbeek: Remark: You point out binaries are important to consider when comparing CMDs of star clusters. They are important for another reason as well: they affect the cluster dynamics. Question: What sort of dynamical model did you use for the simulations you showed?

Z.M. Li: There is no dynamical model. The stellar evolution models shown are for stars evolving in isolation.

https://doi.org/10.1017/S1743921308023211 Published online by Cambridge University Press

N. Langer: Is the difference between your results for single stars and binaries not partly smaller than the error bar in your result for binaries due to uncertainties in binary evolution and population synthesis?

Z.M. Li: The difference is larger than the typical error in the Lick-index method, but it seems less than the uncertainty of photometric study. But the observational uncertainty depends on surveys. The changes caused by binaries are typically less than systematic errors of binary evolution because Hurly code gives rough evolution for stars.