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Blue straggler stars and other complications in star clusters

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Abstract. Blue straggler stars (BSSs), among other exotic native components in star clusters, are usually descendents of mass exchanging binaries, or the results of coalescence or even direct collisions. Being bluer and more luminous than the cluster's turn-off on the color-magnitude diagram (CMD), they are understood as rejuvenation of evolved stars due to dynamical processes, and can resemble core Hydrogen burning main sequence stars at their current locations. Also due to the locations on the CMD, BSSs contribute non-negligible extra light to the blue part of total integrated spectra of the host clusters compared to the single stellar population (SSP) model corresponding to the clusters' age and metallicity. In this talk, I will cover a few topics on BSSs and our recent work on stellar contents in star clusters.

Key words. Stars: blue stragglers – Stars: binaries: general – Galaxy: globular clusters general – Galaxy: open clusters and associations: general

1. Introduction

BSS as a native population in all type of stellar systems has been proved by various observations (Stryker 1993). The physical process of formation and evolution of individual BSSs has been understood quite clearly. The effects of such bright, blue (compared to the regular turn-off stars) and quite populous exotic objects on the host stellar systems still have not been understood satisfactorily, which becomes a challenge to widely used technique of population synthesis. When deriving fundamental physical properties of large composite systems as galaxies, non-negligible uncertainties are inevitable, as demonstrated using empirical cluster data (Xin et al. 2011) and theoretical binary synthesis (Zhang & Li 2005). A robust interpretation of various statistical properties of BSSs in different types of stellar systems is still missing.

BSSs in star clusters is a hot topic in this meeting, from our perspective, this work concentrates mostly on the following points:

1. BSS contribution to the integrated spectral properties of star clusters, and challenges to the SSP models.
2. Formation of BSS by mass transfer (MT) in primordial binary channel, and interpretations of BSS populations in star clusters;
3. Other observational facts that deviate from SSP models of star clusters.

2. SSP models with BSSs

BSSs are common and easily identified in the CMDs of star clusters. They are members of the host cluster and located above and blueward of the cluster's main-sequence turnoff (MSTO). The standard theory of single-star evolution cannot explain the presence of BSs in SSP CMDs, and thus the standard SSP models do not include contributions of BSSs. All currently accepted scenarios of BSS formation are related to stellar interactions. Coalescence in primordial binaries can launch BSSs to positions up to 2.5 magnitudes brighter than the MSTO (McCrea 1964; Chen & Han 2009). Mergers of binary-binary systems can produce possible BSSs with masses 4 times those of stars at the MSTO (Leonard & Linnell 1992). Given the high luminosities and common presence of BSSs in stellar systems (e.g., Ahumada & Lapasset 2007 for open clusters (OCs); Piotto et al. 2002 for globular clusters (GCs); Mapelli et al. 2009 for dwarf galaxies), we believe that we must consider the effects of BSSs in studies of stellar populations using population synthesis applied to unresolved observations. The key issue is how to accurately include BSS contributions in SSP models.

As the BSS content varies greatly among different stellar systems, it is not easy to measure the respective contribution of BSSs in SSPs of different ages and metallicities on purely theoretical basis. Therefore, building up BSS population characteristics empirically from the statistics of a large sample of star clusters could be more practical and reliable than relying on incomplete theoretical approaches.

Building up SSP models with BSSs has been done on the basis of individual clusters in our previous work (Deng et al. 1999; Xin & Deng 2005; Xin et al. 2007, 2008). Considering the integrated light of a SSP (star clusters), the contribution of BSS preferentially enhances the blue part of the spectra. Figure 1 shows the enhancement due to BSS for the case of NGC2682 (M67), the integrated spectral energy distribution (ISED) is systematically bluer. If still fit with SSP model without BSS, the resulting age and/or metallicity can be 50% off the true values.

3. BSS formation through mass transfer in binaries

The BSS content in star clusters does not have a single pattern, the total numbers and distributions with respect to the MSTO of the host clusters have a large range. The specific number can be measured with respect to either MS stars (Deng et al 1999, Xin et al. 2005, 2007) or the horizontal branch (Piotto et al. 2004). Some fuzzy correlations between the BSS content and the host cluster seem exist. However, as the formation process is ultimately linked to the dynamical properties of the specific host cluster, BSSs formed either from MT in binaries or collisions (coalescence) hardly show any robust tight correlation with cluster parameters. The discovery of two distinct sequences of BSSs in M30 (Ferraro et al. 2009) triggered theoretical studies about the formation channels. Our previous modeling work on MT BSSs in M67 was used to by the authors to infer possible scenario for the red sequence, and we later made a grid of MT binary models specifically aimed at explaining the sequences in M30. Figure 2 shows the evolutionary tracks of the individual component and the system of a primordial binary system with initial masses of $0.8M_{\odot}$+$0.5M_{\odot}$. The solid line is actually the observable track of the system. In our calculation, the detailed evolution of both components are followed (Tian et al. 2007; Lu et al. 2011; Xin et al. 2015).

4. Spectroscopic studies

The current models built for BSSs are generally OK in terms of understanding the formation and evolutionary scenarios of BSSs. But it is still difficult to make satisfactory and robust interpretations to observed number and distributions of BSSs in individual star clusters. Observationally, the location on the CMD and chemical compositions may provide clues to uncover hidden secrets about the formation, evolutionary history and the current properties of stars. To this aim, large spectroscopic surveys can help. LAMOST survey (Deng et al. 2012) has observed most of the northern sky with reasonable sampling rate. It was also

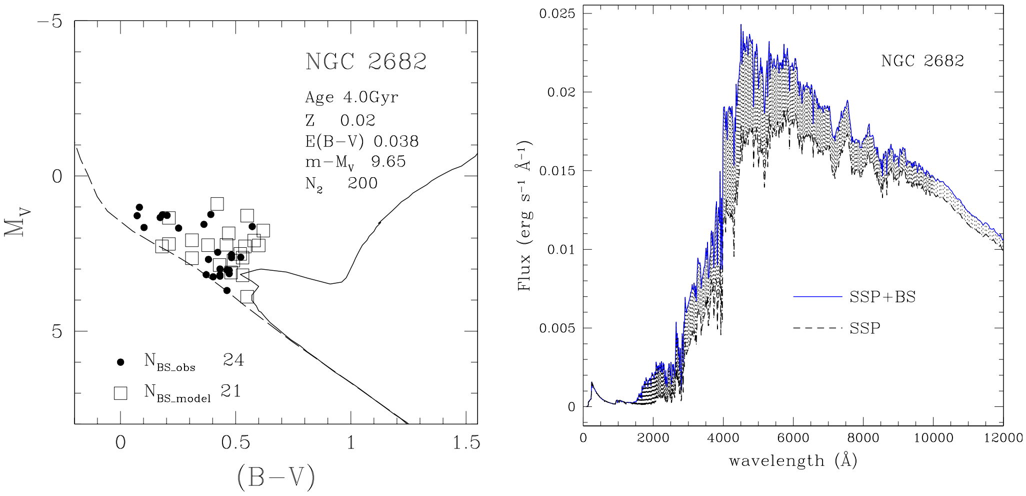

Fig. 1. The BSS members in open cluster NGC2682 (M67), while the other regular stars in the cluster are substitute by an isochrone that best fits the observations (the left panel). BSSs are preferentially enhancing (the shaded area) the blue part of the ISED of the cluster (the right panel).

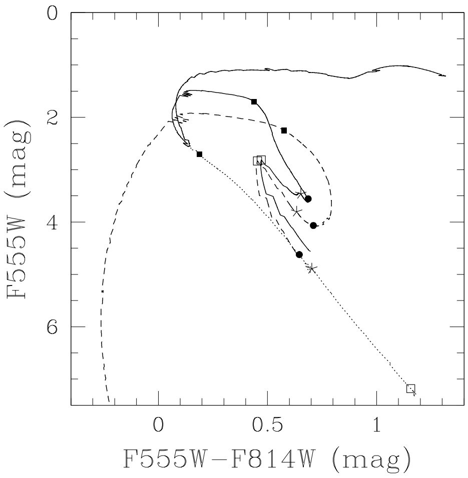

Fig. 2. Synthetic behaviors of a binary (0.8 $M_\odot$ + 0.5 $M_\odot$, initial orbital radius of 3$R_\odot$) in the CMD. The dashed line and the dotted line are the tracks of the primary and the secondary, respectively. The solid line is the synthetic track of the unresolved binary system.

planned to observe part of the Galactic OCs (Chen et al. 2012). LAMOST has a 20 square circular field of view, the fiber density is 200 per square degree. The resolution is R = 1800 at 500nm, similar to that of SDSS. OCs have much higher stellar density than LAMOST single visit observations (limiting magnitude g = 17), therefore, most OCs are sparsely sampled even with a few visits. Nevertheless, LAMOST still provides valuable data for OCs, especially radial velocity (σ~5KM/s) and chemical information. NGC2682 (M67), for example, has multiple visits with 57 bright members observed. Preliminary studies show that BSSs have different C/N that can trace MT process. The preliminary results also show that the under populated RGB of NGC2682 may still harbor split sequences. Figure 3 shows the chemical information of SGB and RGB stars based on data collected by DR2. Only a few member BSSs have good spectra until now, but similar difference between BSS and MS stars exists, more data will be collected for further analysis.

We have also made intensive studies of stellar content in star clusters, including one of the most BSS populated cluster Hodge 11 (Li, de Grijs & Deng, 2013), possible rotation induced eMSTO (Li, de Grijs & Deng 2014) and multiple populations in intermediate age massive clusters (Li, et al. 2016). These find-

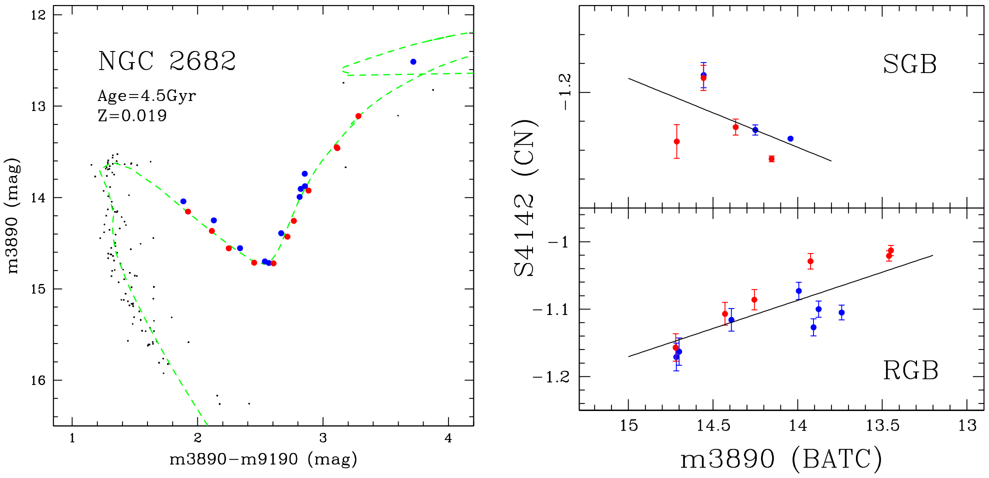

Fig. 3. Left panel: the CMD of NGC2682 (BATC filters, central wavelength marked). Right panel: CN band index S4142 versus m3890 magnitude. The photometric error is small than the widths of RGB or SGB, the blue and red points actually represent two sequences with distinct chemical compositions.

ings reveal that the stellar contents are far from simple, therefore more observations (spectroscopic especially) are indeed necessary.

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