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BS2fit: A NEW TOOL FOR ANALYSING SPECTRA AND COLOR-MAGNITUDE DIAGRAMS OF GALAXIES AND CLUSTERS

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ABSTRACT

We present a new tool for studying the spectral energy distributions (SEDs) and color-magnitude diagrams (CMDs) of galaxies and star clusters, BINARY STAR TO FIT (BS2fit). A key feature of this tool is that it takes the effects of binaries, stellar rotation and star formation history into account. It can be used to determine many parameters, including distance, extinction, binary fraction, rotational star fraction, and star formation history. Because more factors are included than in previous tools, BS2fit can potentially give new insight into the properties of galaxies and clusters. One can contact the authors for cooperation and helps via.

Key words: Galaxies;Star Clusters; Spectra; Photometry

1. IMPORTANCE OF SPECTRAL AND CMD STUDIES OF GALAXIES AND STAR CLUSTERS

Spectral and photometric data are two primary types of observations of galaxies and star clusters. They can help us to determine many important parameters and properties of such objects.

For some nearby star clusters or galaxies, we can observe individual stars to build clear CMDs. Detailed CMD studies can be used to analyze the parameters and properties in detail. Because such studies directly utilize the knowledge of stellar evolution, the result is relatively reliable, and many properties of clusters can be determined. This is helpful for further studies of clusters, e.g., statistical studies and simulations, and is the basis of spectral studies of distant objects. Therefore, accurate CMD studies play a fundamental role in stellar population studies of galaxies and star clusters.

However, for distant clusters and galaxies, it is difficult to obtain their CMDs. In this case we can use spectral methods to study such objects, a primary method for astrophysical studies. This type of method is based on spectral synthesis techniques, which is usually built up according to the CMD (or HR diagram) of stars in a galaxy or star cluster. A disadvantage is that the result usually retains a relatively large uncertainty as the effects of different parameters are degenerate.

2. NEW TOOL FOR SPECTRAL AND CMD STUDIES

Although there is a long history of spectral and CMD studies, most works utilize traditional stellar population models, in which the effects of stellar rotation, binarity, and star formation history were not simultaneously taken into account. In fact, binary and rotational stars are very common in both galaxies and star clusters. Such stars evolve differently from single non-rotational stars and make the CMDs and spectra of a stellar population different from the prediction of traditional single star population models. In addition, the stars of a galaxy or cluster are possibly formed in multiple bursts. The results of population studies can be obviously changed when this is taken into account. If the effects of stellar rotation, binarity, and star formation history are ignored, it is possible that incorrect results will be obtained. In order to make this research more accurate, it is necessary to use advanced stellar population models that have taken these factors into account. We have built up a model for future works, and developed a new tool for spectral and CMD studies of galaxies and star clusters. The new tool is called BINARY STAR TO FIT (BS2fit). It includes two parts; BS2fit for CMDs and BS2fit for SEDs. They can be used to analyze observed CMDs and spectra of star systems, respectively.

2.1. Basis of BS2fit

BS2fit is mainly built on the basis of binary star stellar population synthesis (bsSPS). One can read the papers of Zhang et al. (2004, 2005); Han et al. (2007); Li & Han (2008a,b); Brott et al. (2011); Li et al. (2012); Hernández-Pérez & Bruzual (2013); Li et al. (2013) for details of bsSPS. In addition, the effects of stellar rotation are also considered, following works such as Bastian & de Mink (2009) and Girardi et al. (2011).

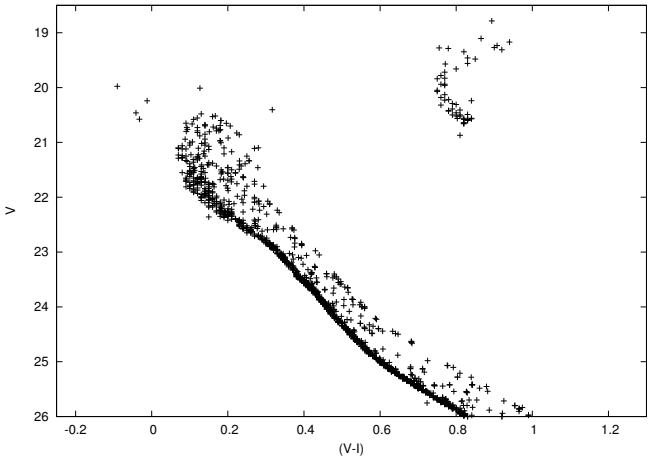

Figure 1. Example CMD of stellar population without observational errors. It includes observational features such as blue stragglers and extended main sequence turn off. This CMD is formed by single and binary stars, and rotational stars.

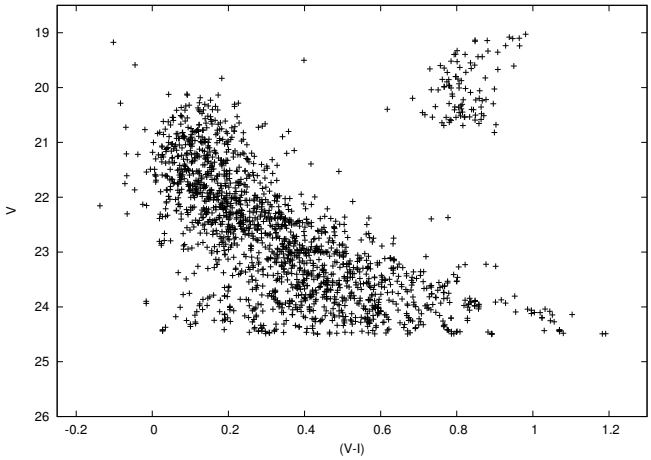

Figure 2. Similar to Figure. 1, but taking observational uncertainties into account.

2.2. *BS2fit for CMD*

BS2fit for CMD is specifically designed for CMD studies of galaxies and star clusters. This tool can reproduce individual CMD structures such as blue stragglers, red stragglers, broad main sequence, extended main sequence turn off, and extended red clump. It can be used to determine the distance modulus, color excess, stellar metallicity, stellar ages, star formation history, binary fraction, and rotational star fraction from an observed CMD. This is a powerful tool, because it determines seven properties simultaneously. Because it utilizes many CMD specifics, e.g., broadening of the main sequence, blue stragglers, and star fractions, the result are possibly more reliable than simpler models. Figure 1 shows an example CMD of a stellar population, which does not take observational errors into account, while Figure 2 shows one with errors.

2.3. *BS2fit for SED*

BS2fit for SED is specially designed for SED studies of galaxies and star clusters. This tool can be used to determine the redshift, stellar metallicity, ages, masses, and velocity dispersions of galaxies and star clusters based on an observed spectrum. A key feature of this tool is that it takes binaries into account. As binary evolution changes the UV spectra of old stellar populations noticiably, the inclusion of binaries can change many results from SED fitting, such as the star formation histories and stellar ages. More details of BS2fit for SED can be found in Li et al. (2013).

3. CONCLUSION

We introduce a powerful new tool for CMD and spectral studies of star clusters and galaxies. This new tool takes into account factors such as binary stars and stellar rotation into account. To do so, it uses stellar population models closer to real star clusters and galaxies, compared to those those based on single star population models. This tool may help scientists to derive more accurate information about star clusters and galaxies. However, although we have tried our best to develop this tool, and to make it easy to use, there are still issues due to the large size of stelar population data sets (about 500 Gigabytes). We are trying to solve this problem and hope to make the data sets much smaller in the future.

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