PAPER • OPEN ACCESS

Can the Full Spectrum Fitting Technique correctly detect Age Spreads in Young Star Clusters?

doi:10.1088/1742-6596/1258/1/012027

Can the Full Spectrum Fitting Technique correctly detect Age Spreads in Young Star Clusters?

Randa Asa'd and A. M. As'ad

American University of Sharjah, Sharjah, United Arab Emirates. P.O. Box 26666
Ministry of Education – Dubai - UAE

raasad@aus.edu

Abstract. Integrated spectra of star clusters have proven to be accurate tools for obtaining age, metallicity and reddening of extragalactic clusters for which resolved data is not available. In this work we investigate the possibility of recovering age spreads of young star clusters (in the range log (age/year) 6.8 to 7.2) using full-spectrum fitting approach and provide the preliminary results using model spectral combinations, in order to examine whether this approach can be used for identifying age-spreads for a grid with combinations of S/N, cluster age and population mass fraction.
Our preliminary results show that false age spreads might be obtained when fitting multiple ages using integrated spectra specially for the lower S/N. A more accurate experiment to determine how reliable is the recovery of the input parameters is needed.

1. Introduction

There have been many studies looking into integrated spectroscopy of young, intermediate age, and old star clusters the Large and Small Magellanic Clouds (LMC and SMC) because they offer a unique opportunity, due to their massive clusters (so stochastic sampling is not an issue), that can be studied through integrated spectroscopy as well as resolved stellar photometry. They have also been used to trace the chemical enrichment history of their host galaxies given their ability to provide accurate and detailed information about the age and metallicity of the clusters (Chilingarian & Asa'd 2018). However, there is a lack of coverage for the possible causes of the eMSTO phenomenon (age spreads and stellar rotation) using integrated spectra in the literature. In particular, it is unclear whether the eMSTO feature will have a strong effect on the derived age (and inferred age spread) of extragalactic clusters where only integrated properties are available. Cabrera-Ziri et al. (2014, 2016) have studied the integrated light spectra of two very massive clusters (NGC 34-1 and NGC 7252-W3) with ages between 100-500 Myr in order to search for evidence of multiple star-formation events within the clusters. The
authors found that both clusters are well described by an SSP, with no evidence for multiple epochs of star-formation. However, as both clusters are unresolved, it is not known whether they display the eMSTO phenomenon. In this work, we investigate the possibility of recovering age spreads of young star clusters using full spectrum fitting approach by develop a model grid of integrated spectra of two SSPs (representing age spreads) with their mass fractions being free parameters. We test how well the internal age spreads obtained from integrated spectra for intermediate age range (log age 6.8 to log age 7.2) can be resolved as a function of cluster age, population mass fraction, and spectrum S/N, by creating artificial clusters that are composed of two SSPs together, we then lowered the S/N and applied the fitting. We used values of S/N from 250 down to 25.

2. Data – Artificial Clusters

We create artificial clusters that are composed of two model SSPs, then lower the S/N to mimic real observations. We use values of S/N from 250 down to 25.

Different combinations of age and population mass ratio were selected from a grid to explore the ability of the method to correctly recover the input values across the parameter space for the age range from log age 6.8 to log age 7.2 for subsequent ages.

3. Method - Fitting Multiple Ages to Each Cluster

It is well established now that ages of star clusters can be obtained using the full integrated optical spectrum fitting (Santos et al. 2006; Koleva et al. 2008; Cid Fernandes & Gonzalez Delgado 2010; Asa'd et al. 2013). Our goal in this work is to investigate whether possible age spreads can be detected from using the full spectrum fitting. To emulate the age spread we create combinations of two fractions of SSP models (Choi et al. 2017) with LMC metallicity and Kroupa Universal IMF (Kroupa 2001). The range of ages used is from log age 6.8 to log age 9.5. The equation used for combining the two SSP models is:

$$f * (Age^{SSP1}) + (1 - f) * Age^{SSP2}$$

where Age^{SSP1} is the SSP of an arbitrary age and Age^{SSP2} is the additional SSP combined with the first age. f refers to the mass fraction contribution of Age^{SSP1}. The value of f is varied, running from 0 to 1 in steps of 0.01. A χ^2 minimization is then performed to obtain the best match between the 2-SSP models created using the equation above and the artificial clusters described in the previous section using the python program introduced in El-Mir & Asa'd (submitted).

4. Results and Discussion

As a first step we tested the fit for the trivial case where no noise was added. As expected, for all combination correct SSPs were distinguished. The results for the analysis done when S/N was lowered are listed in Table 1, from which we can note that for log age 6.8 the full spectral fitting method cannot accurately distinguish between the two SSPs. In several cases it predicts combinations of log age 9.1 which is far from the correct value. The reason this wrong choice repeats several times for this age needs further investigation. For log age 6.9 the full spectrum fitting technique can correctly identify combinations with 50%, 60% and 70% contributions of this age, however for other contributions the results are not fully accurate. For log age 7.0 the two SSPs are correctly distinguished for combinations of 30%, 40% and 80%. For the other combinations wrong predictions are made for lower S/N. For log age 7.1 the predictions for the 80% are not accurate and for the other combinations wrong predictions occur for lower S/N. Finally, for log age 7.2 the full spectrum fitting can correctly predict the two SSPs for larger S/N.

5. Discussion and Future Work

In this work, we presented the preliminary results obtained from applying the full spectrum fitting technique to identify age-spreads when used with model spectral combinations for combination of S/N, cluster age and population mass fraction in the log age range (6.8 – 7.2). Although most SSP combinations were correctly distinguished, bad predictions specially at lower S/N were obtained. Even in cases where the correct two SSPs were identified, the percentage (f value) was not always accurately retrieved. We (Asa'd et al. in preparation) are currently performing a more accurate experiment to determine how reliable is the recovery of the input parameters. We are also expanding the study to cover more ages and use real stellar clusters that fall within those ages to analyze their spectral fits in light of the results obtained from resolved data.

Table 1: The results obtained with the combination of two SSP models.

S/N	SSP_1	SSP_2	f	S/N	SSP_1	SSP_2	f	S/N	SSP_1	SSP_2	f	S/N	SSP_1	SSP_2	f	S/N	SSP_1	SSP_2	f
10% of 6.8 with 90% of 6.9				10% of 6.9 with 90% of 7.0				10% of 7.0 with 90% of 7.1				10% of 7.1 with 90% of 7.2				10% of 7.2 with 90% of 7.3			
25	6.9	91	41%	25	6.8	7.0	15%	25	7.1	9.1	31%	25	7.1	7.2	3%	25	7.3	9.1	28%
50	6.9	91	53%	50	6.9	7.0	6%	50	7.0	7.1	9%	50	7.2	9.1	62%	50	7.0	7.3	1%
75	6.8	6.9	9%	75	6.9	7.0	15%	75	7.0	7.1	16%	75	7.1	7.2	7%	75	7.0	7.3	1%
100	6.9	6.9	0%	100	6.9	7.0	8%	100	7.0	7.1	20%	100	7.2	9.1	89%	100	7.2	7.3	10%
150	6.8	6.9	1%	150	6.9	7.0	11%	150	7.0	7.1	10%	150	7.1	7.2	17%	150	7.2	7.3	10%
200	6.9	6.9	0%	200	6.9	7.0	7%	200	7.0	7.1	10%	200	7.1	7.2	13%	200	7.2	7.3	12%
250	6.8	6.9	2%	250	6.9	7.0	8%	250	7.0	7.1	11%	250	7.1	7.2	10%	250	7.2	7.3	10%
20% of 6.8 with 80% of 6.9				20% of 6.9 with 80% of 7.0				20% of 7.0 with 80% of 7.1				20% of 7.1 with 80% of 7.2				20% of 7.2 with 80% of 7.3			
25	6.8	6.9	15%	25	6.9	7.0	20%	25	7.0	7.1	20%	25	7.1	9.1	18%	25	7.1	7.3	4%
50	9.1	6.9	60%	50	6.9	7.0	27%	50	6.9	7.1	2%	50	7.1	7.2	5%	50	7.2	7.3	28%
75	6.8	6.9	20%	75	6.9	7.0	16%	75	7.0	7.1	18%	75	7.1	7.2	25%	75	7.1	7.3	8%
100	6.9	6.9	0%	100	6.9	7.0	21%	100	7.0	7.1	21%	100	7.1	7.2	16%	100	7.2	7.3	14%
150	6.8	6.9	12%	150	6.9	7.0	14%	150	7.0	7.1	19%	150	7.1	7.2	23%	150	7.2	7.3	16%
200	9.1	6.9	43%	200	6.9	7.0	23%	200	7.0	7.1	23%	200	7.1	7.2	21%	200	7.2	7.3	19%
250	9.1	6.9	40%	250	6.9	7.0	19%	250	7.0	7.1	16%	250	7.1	7.2	27%	250	7.2	7.3	17%
30% of 6.8 with 70% of 6.9				30% of 6.9 with 70% of 7.0				30% of 7.0 with 70% of 7.1				30% of 7.1 with 70% of 7.2				30% of 7.2 with 70% of 7.3			
25	6.9	91	25%	25	6.9	7.1	49%	25	7.0	7.1	47%	25	7.1	7.2	19%	25	6.8	7.3	3%
50	6.9	91	38%	50	6.9	7.0	45%	50	7.0	7.1	36%	50	7.1	7.2	20%	50	7.0	7.3	4%
75	6.8	6.9	47%	75	6.9	7.2	33%	75	7.0	7.1	30%	75	7.1	7.2	46%	75	7.2	7.3	33%
100	6.8	6.9	30%	100	6.9	7.0	34%	100	7.0	7.1	27%	100	7.1	7.2	11%	100	7.2	7.3	27%
150	6.8	6.9	27%	150	6.9	7.0	30%	150	7.0	7.1	29%	150	7.1	7.2	31%	150	7.2	7.3	32%
200	6.8	6.9	16%	200	6.9	7.0	30%	200	7.0	7.1	26%	200	7.1	7.2	29%	200	7.2	7.3	26%
250	6.9	91	50%	250	6.9	7.0	29%	250	7.0	7.1	28%	250	7.1	7.2	34%	250	7.2	7.3	26%
40% of 6.8 with 60% of 6.9				40% of 6.9 with 60% of 7.0				40% of 7.0 with 60% of 7.1				40% of 7.1 with 60% of 7.2				40% of 7.2 with 60% of 7.3			
25	9.1	6.9	80%	25	6.9	7.1	60%	25	7.0	7.1	55%	25	7.1	9.1	26%	25	7.2	7.3	76%
50	6.9	91	29%	50	6.9	7.0	41%	50	7.0	7.1	32%	50	7.1	7.2	28%	50	7.2	7.3	49%
75	6.9	93	24%	75	6.9	7.0	39%	75	7.0	7.1	58%	75	7.1	7.2	27%	75	7.2	7.3	42%
100	6.8	6.9	22%	100	6.9	7.2	38%	100	7.0	7.1	40%	100	7.1	7.2	43%	100	7.2	7.3	46%
150	6.8	6.9	49%	150	6.9	7.0	38%	150	7.0	7.1	45%	150	7.1	7.2	55%	150	7.2	7.3	49%
200	6.8	6.9	44%	200	6.9	7.0	39%	200	7.0	7.1	39%	200	7.1	7.2	34%	200	7.2	7.3	37%
250	6.9	91	41%	250	6.9	7.0	40%	250	7.0	7.1	38%	250	7.1	7.2	46%	250	7.2	7.3	42%
50% of 6.8 with 50% of 6.9				50% of 6.9 with 50% of 7.0				50% of 7.0 with 50% of 7.1				50% of 7.1 with 50% of 7.2				50% of 7.2 with 50% of 7.3			
25	6.9	6.9	0%	25	6.9	7.0	62%	25	6.9	7.1	5%	25	7.1	7.3	70%	25	7.3	7.2	70%
50	6.8	6.9	18%	50	6.9	7.0	69%	50	6.8	7.1	9%	50	7.1	7.2	57%	50	7.2	7.3	41%
75	6.9	91	34%	75	6.9	7.0	53%	75	6.9	7.1	12%	75	7.1	7.3	80%	75	7.2	7.3	47%
100	6.8	6.9	33%	100	6.9	7.0	56%	100	7.0	7.1	48%	100	7.1	7.2	64%	100	7.2	7.3	46%
150	6.8	6.9	20%	150	6.9	7.0	57%	150	7.0	7.1	46%	150	7.1	7.2	41%	150	7.2	7.3	57%
200	6.8	6.9	32%	200	6.9	7.0	54%	200	7.0	7.1	52%	200	7.1	7.2	49%	200	7.2	7.3	57%
250	6.8	6.9	42%	250	6.9	7.0	52%	250	7.0	7.1	51%	250	7.1	7.2	60%	250	7.2	7.3	49%
60% of 6.8 with 40% of 6.9				60% of 6.9 with 40% of 7.0				60% of 7.0 with 40% of 7.1				60% of 7.1 with 40% of 7.2				60% of 7.2 with 40% of 7.3			
25	6.9	6.9	0%	25	6.9	7.0	62%	25	7.0	7.1	78%	25	7.1	9.1	15%	25	7.2	7.3	60%
50	6.8	6.9	51%	50	6.9	7.0	81%	50	6.8	7.1	9%	50	9.1	7.1	79%	50	7.2	7.3	59%
75	6.8	6.9	58%	75	6.9	7.0	62%	75	7.0	7.1	73%	75	7.2	7.1	40%	75	7.2	7.3	58%
100	6.8	6.9	55%	100	6.9	7.0	63%	100	7.0	7.1	65%	100	7.1	7.2	67%	100	7.2	7.3	48%
150	6.8	6.9	79%	150	6.9	7.0	58%	150	7.0	7.1	60%	150	7.1	7.2	50%	150	7.2	7.3	68%
200	6.8	6.9	52%	200	6.9	7.0	62%	200	7.0	7.1	56%	200	7.1	7.2	58%	200	7.2	7.3	65%
250	6.8	6.9	80%	250	6.9	7.0	61%	250	7.0	7.1	63%	250	7.1	7.2	66%	250	7.2	7.3	63%
70% of 6.8 with 30% of 6.9				70% of 6.9 with 30% of 7.0				70% of 7.0 with 30% of 7.1				70% of 7.1 with 30% of 7.2				70% of 7.2 with 30% of 7.3			
25	6.9	91	29%	25	6.9	7.0	69%	25	6.8	7	2%	25	7.1	9.1	44%	25	6.9	9.1	2%
50	6.8	6.9	20%	50	6.9	7.0	71%	50	6.9	7.2	14%	50	7.1	7.3	87%	50	7.2	7.3	77%
75	6.8	6.9	84%	75	6.9	7.0	74%	75	7.0	7.1	60%	75	7.1	7.2	68%	75	7.2	7.3	65%
100	6.8	6.9	42%	100	6.9	7.0	78%	100	7.0	7.1	75%	100	7.1	7.2	76%	100	7.2	7.3	84%
150	6.8	6.9	49%	150	6.9	7.0	71%	150	7.0	7.1	0.7	150	7.1	7.3	82%	150	7.2	7.3	74%
200	6.8	6.9	67%	200	6.9	7.0	69%	200	7.0	7.1	70%	200	7.1	7.2	69%	200	7.2	7.3	72%
250	6.8	6.9	81%	250	6.9	7.0	68%	250	7.0	7.1	72%	250	7.1	7.2	67%	250	7.2	7.3	71%
80% of 6.8 with 20% of 6.9				80% of 6.9 with 20% of 7.0				80% of 7.0 with 20% of 7.1				80% of 7.1 with 20% of 7.2				80% of 7.2 with 20% of 7.3			
25	6.9	6.9	0%	25	6.9	9.1	21%	25	7	9.1	23%	25	7.0	7.1	8%	25	7.2	7.3	84%
50	6.9	91	22%	50	6.9	7.0	80%	50	7	7.1	88%	50	7.1	9.1	40%	50	7.2	7.3	75%
75	6.8	75	87%	75	6.9	7.2	73%	75	7	7.1	78%	75	7.1	7.4	81%	75	7.2	7.3	72%
100	6.8	6.9	61%	100	6.9	7.0	81%	100	7	7.1	77%	100	7.1	9.1	41%	100	7.2	7.3	76%
150	6.8	6.9	50%	150	6.9	7.1	84%	150	7	7.4	79%	150	7.1	9.1	50%	150	7.2	7.3	82%
200	6.8	6.9	77%	200	6.9	7.0	81%	200	7	7.1	81%	200	7.1	9.1	63%	200	7.2	7.3	75%
250	6.8	6.9	83%	250	6.9	7.0	78%	250	7	7.1	77%	250	7.1	9	73%	250	7.2	7.3	79%
90% of 6.8 with 10% of 6.9				90% of 6.9 with 10% of 7.0				90% of 7.0 with 10% of 7.1				90% of 7.1 with 10% of 7.2				90% of 7.2 with 10% of 7.3			
25	6.8	6.9	73%	25	6.9	9.1	15%	25	6.8	7.1	19%	25	7.0	7.1	12%	25	7	9.3	3%
50	6.8	6.9	25%	50	6.9	6.9	0%	50	6.9	7.2	17%	50	7.0	7.1	4%	50	7.2	7.3	91%
75	6.8	6.9	46%	75	6.9	9.1	33%	75	7.0	7.1	76%	75	7.1	9.1	51%	75	7.2	7.4	84%
100	6.8	6.9	66%	100	6.9	7.0	93%	100	7.0	7.1	90%	100	7.1	7.2	83%	100	7.2	7.4	86%
150	6.8	6.9	88%	150	6.9	9.1	39%	150	7.0	7.1	89%	150	7.1	9.1	57%	150	7.2	7.3	88%
200	6.8	6.9	67%	200	6.9	9.1	42%	200	7.0	7.1	92%	200	7.0	7.1	1%	200	7.2	7.3	93%
250	6.8	6.9	79%	250	6.9	7.2	85%	250	7.0	7.1	89%	250	7.1	9.1	67%	250	7.2	7.3	88%

Acknowledgments:
We thank Sebastian Kamann for providing the code for producing random S/N for the theoretical data and Hicham El-Mir for updating the computational program used to perform the analysis of this work.

IOP Conf. Series: Journal of Physics: Conf. Series **1258** (2019) 012027 doi:10.1088/1742-6596/1258/1/012027

This research is supported by the EFRG-18-SET-CAS-74 grant P.I. Randa Asa'd at the American University of Sharjah.

References

Asa'd R. S., Hanson M. M., Ahumada A. V., 2013, PASP, 125, 1304
Cabrera-Ziri I., Bastian N., Davies B., Magris G., Bruzual G., Schweizer F., 2014, MNRAS, 441, 2754
Cabrera-Ziri I., et al., 2016, MNRAS, 457, 809
Chilingarian I. V., Asa'd R., 2018, ApJ, 858, 63
Choi J., Conroy C., Byler N., 2017, ApJ, 838, 159
Cid Fernandes R., Gonzalez Delgado R. M., 2010, MNRAS, 403, 780
Koleva M., Prugniel P., Ocvirk P., Le Borgne D., Soubiran C., 2008, MNRAS, 385, 1998
Kroupa P., 2001, MNRAS, 322, 231