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SURFACE-BRIGHTNESS FLUCTUATIONS IN STELLAR POPULATIONS

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RESUMEN

Se presenta una nueva calibración teórica de fluctuaciones de brillo de superficie (SBF) para poblaciones estelares de una sola edad y una sola metalicidad para filtros de bandas anchas del IR cercanos y del óptico, como también para filtros del HST WFPC2. El código estelar IAC se utiliza conjuntamente con dos bibliotecas de Padua y la de Teramo de evolución estelar. Se ha modelado un conjunto de poblaciones estelares de un solo estallido con un amplio rango de edades (3Gy - 15Gy) y de metalicidades (Z = 0.0001 - 0.03).

La presente calibración teórica de SBF del IR cercano representa poderosa herramienta para el estudio y la caracterización de poblaciones estelares no resueltas. Esto, junto con la alta resolución espacial, la magnitud límite y la calidad de la imagen de CIRCE@GTC la hace única para estudiar y caracterizar la edad y la metalicidad de poblaciones estelares de tipos tempranos no resueltas.

ABSTRACT

A new theoretical calibration of surface-brightness fluctuations (SBF) for single age, single metallicity stellar populations is presented for the optical and near-IR broad-band filters, as well as for the HST WFPC2 filters. The IAC-star code is used together with two Padua and the Teramo stellar evolution libraries. A set of single-burst stellar populations with a wide range of ages (3Gy-15Gy) and metallicities (Z=0.0001-0.03) have been computed.

The present theoretical calibration shows that the analysis of near-IR SBF provides a very powerful tool in the study and characterization of unresolved stellar populations. This, together with the high spatial resolution, limiting magnitude and image quality of CIRCE@GTC, makes this unique to study and characterize the age and metallicity of unresolved early type stellar populations.

Key Words: **GALAXIES: ELLIPTICAL AND LENTICULAR, CD — GALAXIES: FUNDAMENTAL PARAMETERS — GALAXIES: STELLAR CONTENT**

1. INTRODUCTION

The concept of surface-brightness fluctuations (SBF) was introduced by Tonry & Schneider (1988). They developed SBF for its use as an extragalactic distance indicator for early-type galaxies. The ratio of the second moment to the first moment of the stellar luminosity function of the galaxy is used as a standard candle:

$$\bar{L} \equiv \frac{\sum n_i L_i^2}{\sum n_i L_i} \tag{1}$$

where n_i is the number of stars of type i and luminosity L_i. The quantity $\bar{L}$ has units of luminosity. The absolute and apparent magnitudes of $\bar{L}$ are $\bar{M}$ and $\bar{m}$, respectively. As SBF are an intrinsic property of a stellar population, they can be used to study some characteristics of the stellar populations of a galaxy, such as age and metallicity as well.

Several attempts have been done to compute SBF magnitudes using population synthesis. Recently, the use of SBF in stellar population synthesis has received renewed interest with the works of Liu, Charlot, & Graham (2000, hereafter LCG00), Blakeslee, Vazdekis, & Ajhar (2001, hereafter BVA01) and Cantiello et al. (2003, hereafter C03). They presented SBF theoretical calibrations for unresolved stellar populations.

A comparison of the latest theoretical SBF calibrations reveals that LCG00, BVA01 and C03 results are not compatible. This highlights the need for a fully consistent SBF calibration.

2. STELLAR POPULATION SYNTHESIS

The IAC-Star code (Aparicio & Gallart 2004) presents a new algorithm for the computation of synthetic CMD. Although it is designed to generate synthetic CMDs, IAC-Star also provides integrated and SBF magnitudes and colors for the total synthetic stellar population.

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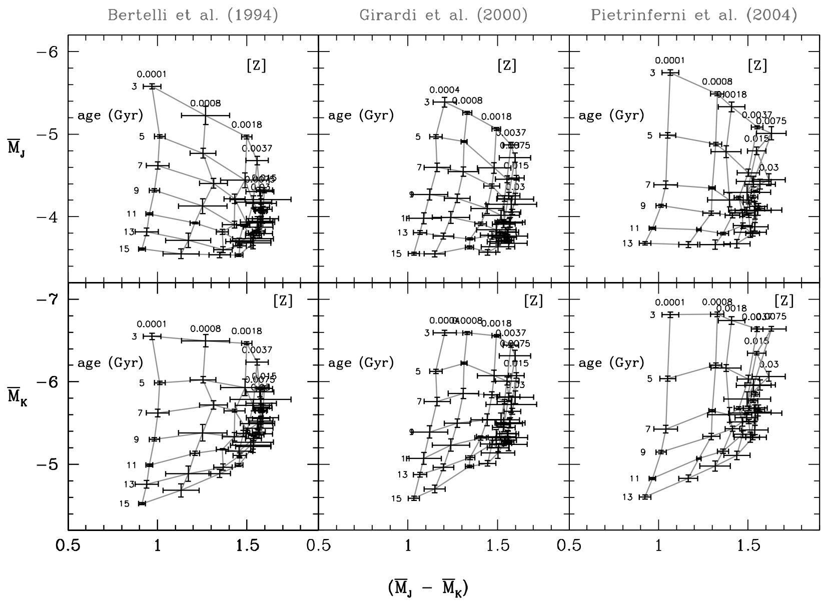

Fig. 1. FCMDs obtained using respectively the stellar evolution libraries by B94, G00 and P04. $\bar{M}_J$ and $\bar{M}_K$ have been chosen for this plot, as an example.

The idea behind this calibration is to develop a tool for unresolved stellar population research. This tool is being implemented through a number of calibration grids, or "Fluctuation Color-Magnitude Diagrams" (FCMD). These are diagrams of integrated colors and SBF magnitudes for a set of theoretical single-burst stellar populations (SSP). Each SSP is represented by a point in the diagram and the plot is completed by a grid of lines connecting same age and same metallicity SSP. Plotting real SBF results from observations onto them will provide estimations of age and metallicity for the observed stellar population.

In order to build the calibration grids, two Padua stellar evolution libraries, Bertelli et al. (1994, hereafter B94) and Girardi et al. (2000, hereafter G00), and the Teramo stellar evolutionlibrary by Pietrinferni et al. (2004, hereafter P04) are considered, together with the two bolometric correction libraries by Castelli & Kurucz (2003, for the optical and near-IR wavelengths) and Origlia & Leitherer (2000, for the HST WFPC2 filters).

3. RESULTS

An example of FCMD in the near-IR is shown in Figure 1. It shows the FCMD obtained using respectively the stellar evolution libraries by B94, G00 and P04.

Each SSP is the result of averaging five models with 10^7 stars each. It can be seen that the three stellar evolution libraries provide comparable results. It can also be seen that the age-metallicity degeneracy is broken for low metallicity (Z≤0.0018) stellar populations.

A detailed comparison with observational data is needed to ensure the reliability and/or the limits of each one of the theoretical calibrations. Here, the SBF theoretical calibrations are compared with observational data of galaxies and the so-called superclusters. Table 13 in Marín-Franch & Aparicio (2006) shows the considered sample of observed SBF magnitudes in galaxies, together with other galaxy properties.

On the other hand, it must be noted that the number of stars in a GC ($10^5 - 10^6$) is much lower than the number of stars in a galaxy. This translates in intrinsic uncertainties in SBF determinations due to statistical reasons. Stochastic effects in the brightest stars are not negligible in the SBF signal. The problem with the SBF determination in GC can be solved considering the co-adding of resolved GCs. González, Liu, & Bruzual (2004) and González-Lópezlira et al. (2005) presented the first attempt to empirically calibrate SBF in the near-IR. They used the co-adding of resolved globular clusters with similar age and metallicity, called "Superclusters", to compare empirical SBF with models. Here we consider their superclusters older than 3Gyr (table 15 in Marín-Franch & Aparicio 2006).

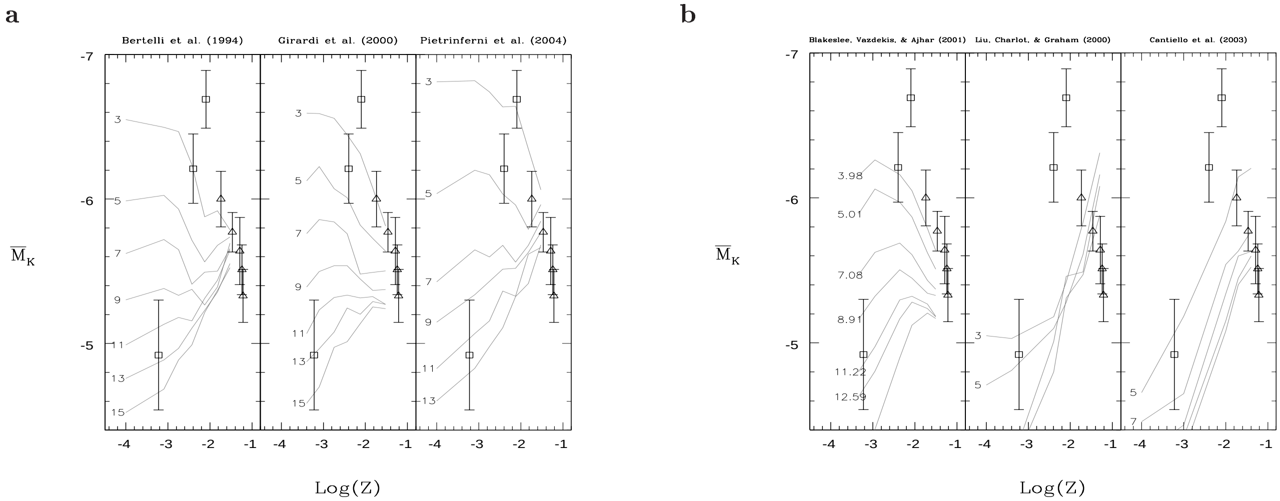

Fig. 2. Comparison of near-IR (K-band) observational SBF data with (a) our theoretical SBF calibrations, based on B94, G00 and P04, respectively, and (b) BVA01, LCG00 and C03 results. SBF theoretical results are plotted for different ages. Open squares represent the Superclusters and open triangles the galaxies.

Figure 2 shows the comparison of K-band SBF observational data with our theoretical SBF calibrations. SBF results, based on B94, G00 and P04, respectively, are plotted for different ages. Open squares represent the superclusters, and open triangles the galaxies. Comparing with galaxy data, the three sets of models reproduce fairly well the high metallicity SBF. If supercluster data is considered, the situation is different. Now P04 based models provide the best fit to data, offering an age estimation for the superclusters that fully agree with the age estimations shown in Table 15 in Marín-Franch & Aparicio (2006). This is a big argument favoring the P04 based models, since this is the only SBF calibration to date that properly reproduces near-IR supercluster data.

Figure 2 also shows a comparison of K-band SBF observational data with previous theoretical SBF calibrations. SBF results, based on BVA01, LCG00 and C03, respectively, are plotted for different ages. It can be seen here that LCG00 and C03 SBF calibrations fail to reproduce supercluster observations. Only BVA01 SBF calibration shows a similar trend as ours, but age determinations for the superclusters is less precise than those from P04 based models.

4. CONCLUSIONS

SBF analyses of unresolved stellar populations have been proved to be a very powerful technique to study and characterize the stellar content of early-type galaxies. Our model results show that SBF studies are particularly powerful for low metallicity stellar populations. In the low metallicity region, the age-metallicity degeneracy is broken, allowing an unambiguous characterization of the stellar population. To date, the theoretical SBF calibration showing best agreement with observational data is the Teramo (P04) based models, presented in this paper. Previous works fail for reproducing the low metallicity near-IR data.

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