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Investigating Resolved Stellar Populations with Surface Brightness Fluctuations

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Abstract. We present a new grid of SBF models in a wide range of age and metallicities. First optical SBF measurements for 11 star clusters in the Large Magellanic Cloud (LMC) are provided and successfully compared with theoretical predictions.

Key words. (galaxies:) Magellanic Clouds – galaxies: star clusters

1. Introduction

Surface Brightness Fluctuations (SBF) are recognized as an useful *distance indicator* of gas free galaxies beyond 100 Mpc with an accuracy of 5-10% (Tonry et al. 2001). In addition, being sensitive to the stellar populations mixture present in a galaxy (basically, age and metallicity) SBF amplitudes are expected to be an efficient *population tracer* (Worthey 1993) and *a diagnostic* tool for testing stellar evolution models (Raimondo et al. 2004). That is, SBF can probe the stellar content in galaxies without the need to resolve individual stars.

In this paper, we verify the capability of SBF as population tracer by applying the method to well-known stellar systems as the star clusters in the LMC, for which accurate photometry (thus, color-magnitude diagram, CMD) is available. This is a crucial step, before facing the problem of stellar populations in distant galaxies.

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2. The method

In star clusters, the stochastic fluctuations of the number of bright stars may affect SBF amplitudes as well as classical integrated magnitudes. The procedure we developed to compute SBF amplitudes fully accounts for these effects. It is based on Monte Carlo technique, and runs as follows: from each synthetic CMD we derive SBF by applying the definition of Tonry & Schneider (1988):

$$\overline{M}_X^{RS,j} = -2.5 \log \left[\frac{\sum_{i=1}^{N_{star}} f_i(X)^2}{\sum_{i=1}^{N_{star}} f_i(X)} \right] \qquad (1)$$

where j=1, N_{sim} is the number of independent simulations computed by assuming fixed age and chemical composition; $f_i(X)$ is the flux, in the generic filter X, of the i-th star in the j-th CMD. Then, the final SBF amplitudes are evaluated as the mean of the $\overline{M}_X^{RS,j}$ distribution over N_{sim}=5000 simulations, and the statistical uncertainty as the standard deviation (Resolved Systems).

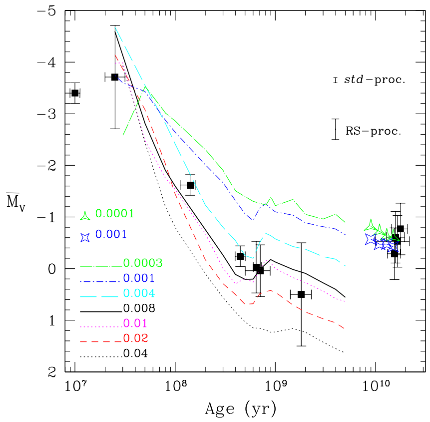

Fig. 1. SBF predictions are compared with HST-measurements (black squares) for a sample of LMC clusters.

For systems with a great number of stars (galaxies), to derive SBF we usually adopt the following procedure (Cantiello et al. 2005, 2003):

$$\overline{M}_X^{Std} = -2.5 \log \left[\frac{\langle (F_X - \langle F_X \rangle)^2 \rangle}{\langle F_X \rangle}\right] \qquad (2)$$

where F_X and $\langle F_X \rangle$ are, respectively, the integrated flux related to the j-th CMD, and the mean total flux averaged over N_{sim} CMDs.

By adopting both procedures, we calculate SBF for a grid of single-age single-metallicity models using the stellar population synthesis code developed by Brocato et al. (1999), Brocato et al. (2000), and Raimondo et al. (2005). We provide SBF predictions in the near-infrared and, for the first time, in the optical bandpasses for populations with ages ranging from 25 Myr to 15 Gyr, and metallicities from Z=0.0003 up to Z=0.04 (Raimondo et al. 2005; Cantiello et al. 2003). The two procedures provide very similar results when the number of stars included in each simulation is so large that all evolutionary phases up to the aymptotic giant branch are populated, while for under-sampled populations differences might be present.

3. Models vs. data

We measure V, I SBF for a sample of 11 star clusters of the LMC by using the single-stars photometry from high-resolution WFPC2/HST images (Raimondo et al. 2005; Brocato et al. 2003; Olsen et al. 1998). These are the first SBF measurements in the optical bands for LMC clusters. Clusters are selected with the aim of minimizing statistical effects (Sect.2). The observed $\overline{M}_V$ trend is well reproduced by models in the explored age range (few Myr up to several Gyr, Fig.1). SBF predictions are derived from Eq.2. The SBF measurements of clusters younger than 5 Gyr are well-fitted by models of metallicities Z=0.004-0.01, which are appropriate for young and intermediate LMC clusters. SBF measurements for very old clusters agree with 12–15 Gyr and lower metallicity models.

As expected, the agreement gets even better if we apply the RS-procedure (Eq. 1), especially for the faintest clusters in our sample (NGC 1868, NGC 2209, and *Hodge*14), for which statistical effects may be not negligible. In fact, the fainter is M_V^{tot} (small number of stars in the system), the larger is the *intrinsic* uncertainty, due to stochastic fluctuations. Note that, since statistical effects are mainly driven by fluctuations in the number of giant stars, for intermediate/old age populations we expect that they affect I-band and NIR bands SBF more than the V-band (Raimondo et al. 2005).

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