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UNCERTAINTIES IN THE GALAXY MASS AND AGE DETERMINATION FROM INVERSE POPULATION SYNTHESIS MODELS

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RESUMEN

Presentamos un análisis cuantitativo de la incertidumbre del valor recuperado de la masa y edad de galaxias a través del ajuste de modelos de síntesis de poblaciones estelares a espectros integrados de las mismas. Mostramos que el error en la determinación de estas cantidades depende de la fracción de estrellas más jóvenes que 10^8 años, pudiendo llegar hasta un factor de 2 la incertidumbre en la determinación de la masa y un factor de 2.6 en la edad. También mostramos que las soluciones obtenidas con métodos veloces de minimización de χ^2, son consistentes con las soluciones que se obtienen con métodos que exploran de forma exhaustiva el espacio de parámetros y que consumen gran cantidad de tiempo de cómputo.

ABSTRACT

We present a quantitative analysis of the uncertainties in the galaxy mass and age recovery via inverse population synthesis methods. We show that the error in the determination of these quantities depends on the fraction of stars younger than 10^8 yr and that it can be a factor of 2 in mass and 2.6 in age. We also find that the solutions obtained with fast methods of χ^2 minimization are consistent with more time consuming methods that exhaustively explore parameter space.

Key Words: galaxies: fundamental parameters — galaxies: stellar content

1. INTRODUCTION

The so called inverse population synthesis models have been proven to be a valuable tool to derive physical parameters from integrated spectra of galaxies. At the present there exists a handful of methods, some of them freely available (e.g. STARLIGHT Cid Fernandes et al. 2005, STECMAP Ocvirck et al. 2006), that are widely used to investigate the stellar mass build up in the universe. It is well known that the recovery of galaxy physical parameters is not free of uncertainties of several types. Discussions on this topic have been widely presented by authors of different methods, e.g., Heavens et al. (2000), Cid Fernandes et al. (2005), Tojeiro et al. (2009), Magris et al. (2009). It has also been discussed that the SED fitting, via χ^2 minimization, might not to be the best estimate of the expectation value of each parameter, and that via the best-fit model, we cannot guarantee the robustness of the solution (Acquaviva, Gawiser & Guaita 2011). We have developed a test to explore the accuracy to which the mass and age of the stellar content of galaxies are derived by using spectral fitting models.

2. MODEL

In order to exhaustively explore the space of parameters, we have implemented a very simple model based on Dinbas3D (Mateu 2009). Briefly, we compute a family of models $F_{\rm mod} = \sum_{i=0}^{3} a_i f_i(\lambda)$ with all the possible linear combinations of three simple stellar population sed's, $f_i(\lambda)$, from the library of Charlot & Bruzual (2007, personal communication) solar metallicity model, and a very fine mesh of a_i.

In parallel, we generate a library of 'mock galaxy' spectra with a subset of the star formation rate histories suggested by Kauffmann et al. (2003). To mimic observational conditions, we add to the galaxy flux a random Gaussian noise with the same wavelength dependence as the spectra in the SDSS, and with a nominal S/N ratio in the r band equal to 20. We compare the spectrum of each mock galaxy, $F_{\rm mock}(\lambda)$, with the spectrum of every model k in the library, $F_{{\rm mod},k}(\lambda)$, and compute the corresponding goodness-of-fit of that model: $\chi^2_k = \sum_l ((F_{{\rm mod},k}(\lambda_l) - F_{\rm mock}(\lambda_l))^2/\sigma_l^2$, where σ_l is the uncertainty (noise) in $F_{\rm mock}(\lambda_l)$. We choose the best estimate of each parameter to be the mean of the probability density function built by weighting the value of that parameter for the k^{th} model by the

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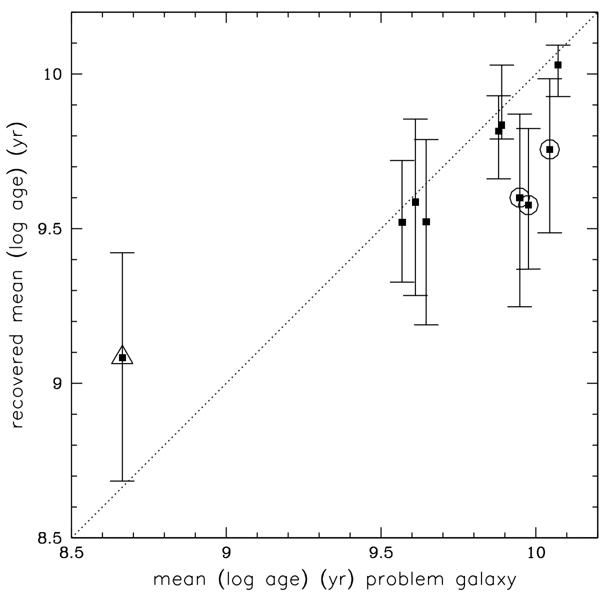

Fig. 1. Best estimate of age, compared to the true value. The error bars indicate the 16−84 percentile range in the recovered distribution of this parameter.

function $\exp|1 - \chi^2|$, and the associated confidence interval to be the 16−84 percentile range.

3. RESULTS

In Figure 1 we compare our best estimate of age to the true value for the 10 mock galaxies in our sample, and in Figure 2 we show the fractional difference between our best estimate of mass and the true value as a function of mean age. We can see that the mass and the mean age are, in general, well recovered parameters. However, some galaxies show an uncertainty as large as a factor of 2 in the age, and of 2.6 in mass (points marked as circles and triangle in Figures 1 and 2). These galaxies have an important fraction of young stars in their stellar population. The galaxy marked with a triangle has been actively forming stars since its birth, with a mean stellar age of 4.6×10^8 yr, additionaly, it experienced a massive burst of star formation that duplicated its mass, 10^8 yr ago. On the other hand, circled points represent galaxies with a dominant population of old stars, that underwent an intense burst of 10% of the total galaxy mass in the last 10^8 yr, or a less massive, 1% of the galaxy mass, but more recent burst, 2×10^7 yr ago. In any case, the burst doesn't significantly change the mean age of the galaxy but leaves a mark in the spectral energy distribution.

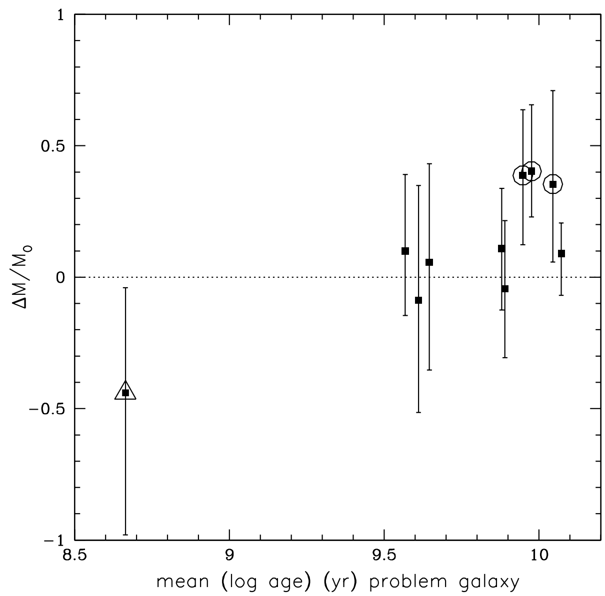

Fig. 2. Relative mass difference between our best estimate and the true value, $(M_{\rm recovered} - M_{\rm true})/M_{\rm true}$, as function of true age. The error bars correspond to the 16−84 percentile range in the recovered distribution of this difference.

4. CONCLUSIONS

We conclude that from inverse population synthesis models, the mass and mean galaxy age can be estimated with a 10−15% accuracy for the quiescently star forming galaxies. For galaxies with a present day active star formation rate, or that underwent a recent burst, the uncertainty can become as large as a factor of 2 in age and a factor of 2.6 in mass.

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