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RECOVERING FOSSIL RECORDS FROM GALAXY SPECTRA USING A 2D DYNAMICAL BASE

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RESUMEN

El estudio de poblaciones estelares ha ganado mayor importancia en los últimos años gracias a la disponibilidad de espectros de la alta calidad de un número considerable de galaxias (por ejemplo el Sloan Digital Sky Survey - SDSS). Extraer la mayor cantidad de información de estos espectros ha sido el objetivo de numerosas investigaciones. En general, estos métodos se basan en el principio de que el espectro de una galaxia se puede representar como una combinación lineal de los espectros de las poblaciones estelares que la componen, cada una con su edad y composición química correspondiente. Sin embargo, las componentes de esta combinación lineal, es decir, los espectros de las poblaciones estelares simples representadas como vectores en un espacio N-dimensional (elementos de la base), son casi paralelos a pesar de ser linear independiente y esto, combinado con las incertidumbres de los espectros observados, causa que diferentes historias de la formación estelar reproduzcan el mismo espectro observado. La cantidad de información que puede ser extraída esencialmente dependerá de la razón señal ruido y del intervalo de longitud de onda del espectro observado. Hasta este momento los algoritmos para recuperar la historia de la formación estelar de espectros observados utilizan una base estática con un número de elementos entre 8 y 125. Al aumentar el número de elementos de la base mejora ciertamente el ajuste del espectro observado, pero también aumenta la degeneración de la solución significativamente, haciendo muy difícil la interpretación de los resultados. En este trabajo desarrollamos un nuevo algoritmo con una base dinámica (no estática) de solamente 2 elementos que se utiliza para recuperar los coeficientes de la combinación lineal y la edad de los vectores base. Hicimos algunas simulaciones diseñadas para probar el algoritmo con las que obtuvimos ajustes de excelente calidad, con resultados fáciles de interpretar e incertidumbres muy bien definidas.

ABSTRACT

The study of stellar populations has gained importance in the last years thanks to the availability of high quality spectra of a considerable number of galaxies (for example the Sloan Digital Sky Survey - SDSS). Extracting the greater amount of information from these spectra has been the objective of many investigations. In general, these methods are based on the principle that the spectrum of a galaxy can be represented as a linear combination of the spectra of the populations that compose it, each one with its corresponding age and chemical composition. Nevertheless, the components of this linear combination, that is the spectra of the stellar population represented as a vector in a N-dimensional space (elements of the basis), are almost parallel in spite of being linearly independent and this, combined with the uncertainties of the observed spectra causes that different star formation histories reproduce the same observed spectrum. The amount of information that can be extracted will essentially depend on the signal to noise ratio and wavelength interval of the observed spectrum. Until now the algorithms to recover the star formation history from observed spectra use a static basis with a number of elements between 8 and 125. When increasing the number of basis elements it certainly improves the fitting of the observed spectrum but also it increases the degeneration of the solution significantly, making very difficult the interpretation of the results. In this work we developed a new algorithm with a dynamical (not static) basis of only 2 elements which is used to recover both the coefficients of the linear combination and the age of the basis vectors. We made some simulations designed to test the algorithm obtaining excellent, high quality fittings with easy to interpret results and very well defined uncertainties.

Key Words: galaxies: evolution

1. INTRODUCTION

The problem of extracting the maximum information from galaxy spectra using Stellar Population Synthesis has been solved by many authors (Cid Fer-

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nandes et al. 2005; Mateus et al. 2006; Heavens et al. 2000; Mateu et al. 2001) each using different approach but always using a fixed set of Simple Stellar Population spectra. In this work we establish that the problem should be solved by using a simple to complex scheme, the complexity of the model would depend on the amount of information contained in the data. The simplest model for an arbitrary stellar population is a linear combination of Simple Stellar Population (SSP) components assuming constant metalicity. Nevertheless, observational uncertainties and limited wavelength range results in that different linear combination of SSP provide an accurate fit of the observed spectrum, that means one problem with different solutions. For many galaxies, such as old ellipticals, a single SSP model is enough to obtain a perfect fit. In this work, we show that for any composed stellar population, with the SDSS (York et al. 2000) spectral range and quality, two components are enough to extract maximum information. For better quality and wider spectral range we probably would need to increase the number of component.

2. THE METHOD

From Stellar Population Synthesis model BC2003 (Bruzual & Charlot 2003) we obtain an array of 221 Simple Stellar Population spectra with ages from 0 to 20 Gyrs and a fixed metallicity. We want to represent an arbitrary observed spectrum as a linear combination of two SSP model spectra, so we need to minimize:

$$\chi^2(t_1,t_2) = \sum_{i=1}^{M} \frac{\left(f_o(\lambda_i) - a_1 f(\lambda_i,t_1) - a_2 f(\lambda_i,t_2)\right)^2}{\sigma_i^2}\,, \tag{1}$$

where a_1 and a_2 are the mass formed in each burst of age t_1 and t_2 respectively and to calculate them we need to solve the following linear system:

$$a_1 \sum \frac{f(\lambda_i,t_1)^2}{\sigma_i^2} + a_2 \sum \frac{f(\lambda_i,t_1) f(\lambda_i,t_2)}{\sigma_i^2} = \sum \frac{f_o(\lambda_i) f(\lambda_i,t_1)}{\sigma_i^2}\,,$$

$$a_1 \sum \frac{f(\lambda_i,t_1) f(\lambda_i,t_2)}{\sigma_i^2} + a_2 \sum \frac{f(\lambda_i,t_2)^2}{\sigma_i^2} = \sum \frac{f_o(\lambda_i) f(\lambda_i,t_2)}{\sigma_i^2}\,.$$

Constrainig the solution to be non-negative, once obtained the values of the formed mass a_1 and a_2 we are able to find t_1 and t_2 that minimizes the surface (equation 1). We run the program with different metallicity models and take the lowest value of χ^2, this means that we are assuming a constant metallicity in the evolution of galaxies, which is compatible with a fast enrichment law at formation age.

In order to test the method we carried out a set of simulations for more than 1000 test galaxy spectra, in the spectral range of the SDSS, generated using different combinations of continuos and discrete Star Formation Histories (SFHs), metallicity, and signal to noise ratio. We used a continuous exponentialy decreasing SFH combined with random instant bursts. In all cases, the fitting using DINBAS2D was perfect, which reflects degeneration in the SFHs recovered.

We applied DINBAS2D to a sample of 22290 SDSS galaxy spectra with redshift between 0.10 y 0.12. We correct for velocity dispersion and assume constant metallicity. Three metallicities were considered: 0.4 $Z_\odot$, $Z_\odot$ and 2.5 $Z_\odot$. We obtain an age-mass relation for this sample, and we found a power law age-mass relation in which older galaxies are more massive than younger.

3. CONCLUSION

We obtain an excellent fitting of any composed stellar population spectrum using a 2 component dynamical basis. We also applied the method to an observed sample, recovering the star formation history and metallicity.

In spite of the fact that we cannot avoid degeneration, with this method we can extract maximum information from galaxy spectra using the simplest model. When increasing the amount of information available (e.g., more realistic models or better quality spectra), it is straightforward to add more components to our SSP basis in order to recover with more detail the SFH.

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