RevMexAA (Serie de Conferencias), **37**, 147–149 (2009)

AGE-METALLICITY DEGENERACY AT MID-UV WAVELENGTHS

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RESUMEN

La degeneración edad-metalicidad, que afecta las propiedades de los espectros ópticos de poblaciones estelares, también está presente en el intervalo ultravioleta. En este trabajo presentamos los resultados para dos objetos: el Sol (que se supone ser representativo de una estrella de *turnoff* de una población estelar) y M 32. Desde un punto de vista teórico, hemos explorado las propiedades de la degeneración edad-metalicidad a través de 17 índices definidos entre 2100 y 3100 Å: nuestros resultados preliminares muestran un valor del parámetro de sensibilidad a la metalicidad de 1.7±1.2, que es compatible con el valor de 3/2 obtenido por Worthey en el intervalo del visible.

ABSTRACT

The so-called age-metallicity degeneracy, which affects the optical spectral properties of stellar populations, is also present at mid-ultraviolet wavelengths. We give here the results for two reference objects: the Sun (assumed as representative of the turnoff star of a single stellar population) and M 32. Within a theoretical framework, we have explored the properties of the age-metallicity degeneracy by means of 17 spectroscopic indices from 2100 to 3100 Å: our preliminary results show a metallicity sensitivity parameter value of 1.7±1.2, which is compatible with the Worthey's value of 3/2 in the optical interval.

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

1. INTRODUCTION

The effects of age and metal content conspire to produce similar integrated spectral energy distributions (SED) from different stellar aggregates which are dominated by a single population: a young metal rich system resembles an older metal poor one. A quantitative study, in the optical regime, of this age-metallicity degeneracy (AMD) has been carried out by Worthey (1994) by means of broad band colors and spectroscopic indices from evolutionary single stellar population (SSP) models. He found that a change of a factor 3 in age produces the same variation in colors and indices than a change of a factor of 2 in metallicity (Z). More recently, Dorman et al. (2003) found that the AMD is significantly reduced when mid-ultraviolet (mid-UV) broad band colors are added to optical ones, but not eliminated. A similar conclusion is reached by Kaviraj et al. (2007), which used the two ultraviolet *Galaxy Evolution Explorer* passbands along with the Johnson photometry.

The improvement of telescopes and instrumentation now allows to have good quality spectroscopic observations of high-redshift red galaxies ($z > 1$), at a (rest frame) spectral resolution of FWHM<10 Å (e.g., Dunlop et al. 1996; Cimatti et al. 2002; Abraham et al. 2004; Vanzella et al. 2008). Breaking the AMD is therefore important to unambigously determine the main parameters of these objects, which can provide stringent constraints on the galaxy formation epoch and early evolution. We have implemented the high-resolution synthetic stellar library UVBLUE (Rodriguez-Merino et al. 2005) in the Buzzoni's code (Buzzoni 1989) to produce 2 Å FWHM integrated spectral energy distributions (SED) of SSP models. They span an age interval from 2 to 15 Gyr at six different metallicities [Z=0.0001, 0.001, 0.01, 0.017 (solar), 0.03, and 0.1]. In this work, we use models which assume a Salpeter Initial Mass Function (s=2.35) and a red morphology of the horizontal branch. We focus our attention on the analysis of the mid-UV regime, between 2000 and 3200 Å. This wavelength interval is suitable to investigate the integrated emission of evolved galaxies at $1 < z < 2$ (the "redshift desert"), as it is observed from ground-based 8–10 m class optical telescopes.

2. AGE AND METALLICITY DETERMINATION

The age and the metallicity of the population which dominates the mid-UV emission of a stellar system can be provided by identifying the best match, between the observed spectrum and a grid of SSP SEDs, which minimizes the reduced chi-square

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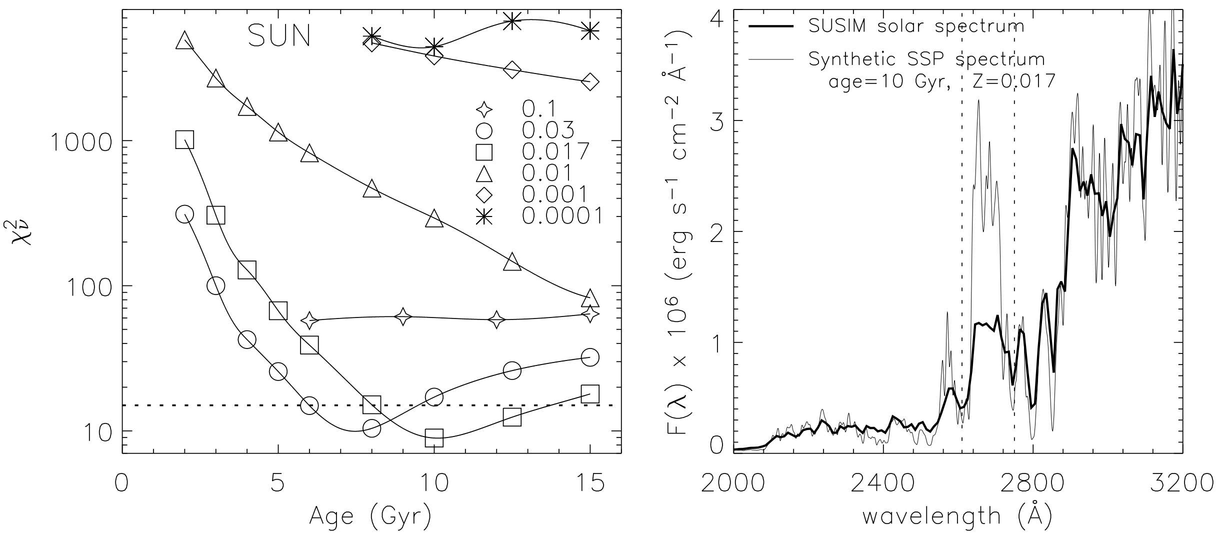

Fig. 1. *Left panel*: The distribution of the χ^2_ν vs. age at different metallicities (symbols code the metallicity as indicated in the panel). Note that the y-axis is logarithmic. *Right panel*: The observed solar spectrum (thick line) is shown, along with the theoretical integrated spectrum of the SSP model which provided the minimum χ^2_ν: age=10 Gyr, Z=0.017.

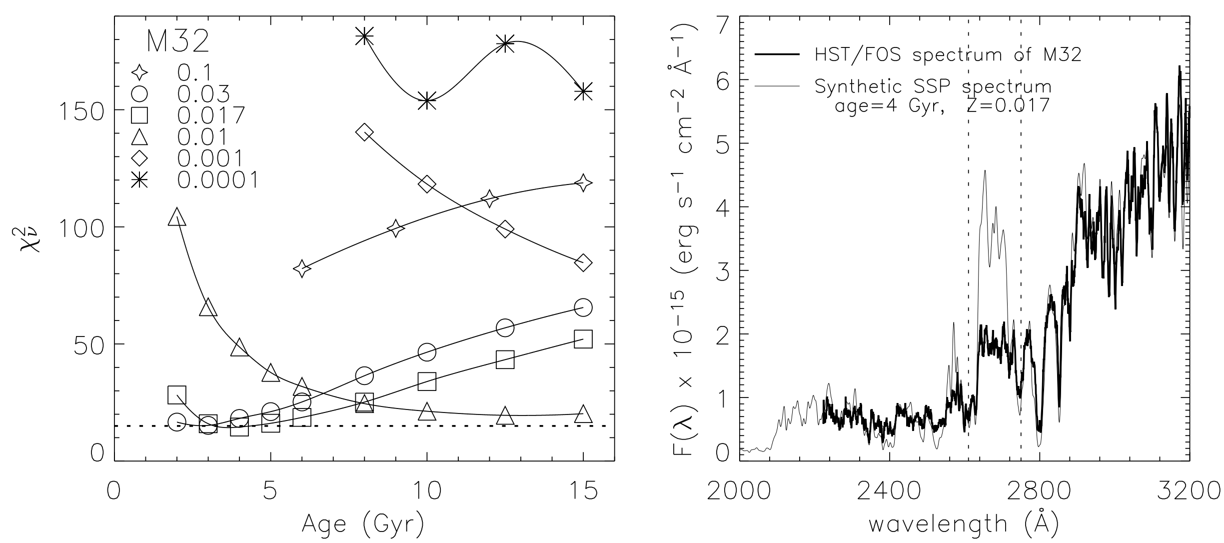

Fig. 2. Same as Figure 1, but for M32. In this case, a linear y-axis is adopted in the left panel and the SSP model shown in the right panel has an age of 4 Gyr and solar metallicity.

χ^2_ν. We present here the results from two objects: the Sun and the nearby dwarf elliptical M 32.

The Sun. If we assume that the mid-UV emission of a SSP is dominated by turn-off stars, the spectrum of a single star could quite suitably represent the whole population. In this case, the best fit should provide an age which corresponds to the life time that the star has spent on the main sequence. We perform the test using the mid-UV solar spectrum extracted from the UARS/SUSIM archive[3]), averaging 769 observations from September 1991 to February 1993. We can suppose, for a population that would have at the turn-off a star of the same spectral type as the present Sun, an age of approximately 10.5 Gyr (e.g., Jorgensen 1991). The spectrum and the results of the fitting procedure are shown in Figure 1; we note that, even if the best fit is found on

[3]`http://daac.gsfc.nasa.gov/data/dataset/UARS/SUSIM`.

TABLE 1

INDEX SENSITIVITY FOR A ZERO POINT MODEL OF 12 GYR AND SOLAR METALLICITY

Index	S	Index	S
Fe II 2332	0.64	2600-3000	3.00
Fe II 2402	0.87	2609/2660	2.69
BL 2538	2.07	2828/2921	1.03
Fe II 2609	3.30	S2850	4.85
BL 2720	1.03	S2850 L	2.38
BL 2740	2.00	2110/2570	1.39
Mg II 2800	0.04		
Mg I 2852	0.91		
Fe I 3000	0.98		
BL 3096	0.96		
Mg Wide	1.20		

the solar metallicity curve and provides an age of 10.1 Gyr, a second fit with similar quality is found for Z=0.03 at about 7.5 Gyr.

M 32. The spectrum, shown in Figure 2, of the central part of the nearby dwarf elliptical galaxy M 32 was observed with the Faint Object Spectrograph onboard the Hubble Space Telescope[4]. We obtain a "best" fiducial age for the stellar population of the central region of M 32 of 3.6 Gyr, at solar metallicity, which is in agreement with the age of 3–4 Gyr at solar (or slightly super solar) metallicity, which several authors assigned to M 32 (see, e.g, Worthey 1994; Schiavon et al. 2004). However, similar minimum chi-square values are also found at Z=0.01 and 0.03. The results from this two examples clearly indicate that the AMD is also present when the mid-UV interval alone is considered.

3. AGE AND METALLICITY SENSITIVITY OF MID-UV INDICES.

We have explored the properties of a set of 17 mid-UV spectroscopic indices of our set of SSPs, in order to quantify their sensitivity to age and metallicity. The definition of all indices is given in Chavez et al. (2007). They are mainly gathered from the work of Fanelli et al. (1992) and measure the strength of relevant spectral absorption features or the slope of the SEDs (a sort of very narrow band color).

We computed the same quantity defined by Worthey (1994) to measure the Z sensitivity, with respect to age, of each spectroscopic index I:

$$S = [\Delta I/(\Delta Z/Z)]/[\Delta I/(\Delta \mathrm{age}/\mathrm{age})]\,,$$

which means that the variation of the each index around a zero point model is divided by the corresponding relative difference in age and metallicity, taking into account the nearest points. The highest the value, the greater the sensitivity to Z.

In Table 1 we report the results for the same zero point (12 Gyr, solar metallicity) used by Worthey (1994). The mean value is $<S>=1.7\pm1.2$, which is compatible with the 3/2 value obtained by Worthey in the optical interval. We can note, however, that the dispersion is quite high and that, on average, the slope indices are more sensitive to metallicity than the line indices.

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[4]programme 1D=6636; PI: M. Gregg.