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NEW ROUTES IN THE ANALYSIS OF COMPOSITE STELLAR POPULATIONS

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RESUME. Nous présentons une nouvelle méthode d'analyse de populations stellaires composites. Cette méthode prend en compte les fortes variations de composition chimique des générations successives d'étoiles au cours de l'évolution d'une galaxie, jusqu'à des valeurs $[Z/Z_\odot] \sim 0.6$. Elle permet ainsi de reproduire le spectre observé dans les régions centrales des galaxies elliptiques massives et, par extension, elle permet d'étudier les populations stellaires dans des galaxies d'amas à grand redshift. Ce dernier point est illustré dans le cas de l'amas Abell 370 à z = 0.374 et il nous amène à conclure que, du point de vue de leur population stellaire et de leur contenu en éléments lourds, les galaxies cD de cet amas résultent de la fusion de galaxies très semblables aux galaxies elliptiques massives observées aujourd'hui.

ABSTRACT. We describe a new method for synthesizing composite stellar populations. This method takes into account the large metallicity changes occuring along the galaxy evolution, which, near the center can increase up to $[Z/Z_\odot] \sim 0.6$. Therefore, this method allows to reproduce the spectrum observed in the central regions of massive elliptical galaxies. It can be used to interpret stellar populations in galaxy clusters at large redshifts. We illustrate this possibility through the case of Abell 370 at z = 0.374 and we find that both their stellar population and their content in heavy elements indicate that cD galaxies result from the merging of galaxies quite similar to present-day massive elliptical ones.

Key words: GALAXIES-STELLAR CONTENT

I. INTRODUCTION

In this communication, we shall briefly review the main steps of a new method for population synthesis, which we have developed recently (Bica, 1988). Our original aim was to synthesize composite stellar populations in the central region of galaxies : firstly from a sample of nearby objects (Shapley-Ames Catalogue with $V_R \leq 6000$ km s^{-1}) and ultimately from distant clusters of galaxies. In galaxy clusters at large redshifts, only the bright massive objects can be accessed in terms of a spectrum with appropriate signal to noise ratio for population analysis. It was then imperative to get first an excellent fit to the observed spectrum from nearby, present-day massive galaxy nuclei. From our 164 nearby galaxy sample, we find that around 30% are massive elliptical or spiral galaxies : their spectrum exhibits huge metallic absorption features which cannot be reproduced with stellar libraries being at most of a solar metallicity. This originally led Spinrad and Taylor (1971) to introduce the so-called super metal rich stars in early population synthesis. But then, continuity problems in populating the H-R diagram become crucial. We have undertaken a different approach to avoid this problem and to fully consider metallicity effects in population synthesis.

THE STAR CLUSTER METHOD

In this method, we propose to represent a composite spectrum using *exclusively a library of* *ar cluster integrated spectra, parametrized through their age and metallicity* Therefore, we have ›llected at the European Southern Observatory, a data base of 63 star clusters which is thoroughly ›scribed in Bica and Alloin (1986a, 1987a), and of 164 galaxy nuclei (Bica and Alloin, 1987b) We ›ose a spectral resolution of about 12Å, so as to match the velocity dispersion observed in massive ılaxy nuclei.

A step forward, with respect to previous population synthesis has been to introduce in the ar cluster base, clusters towards the Galactic bulge, such as NGC 6528 and 6553 which are clearly the ost metal-rich clusters observed so far in our Galaxy. They may have a metal content $[Z/Z_{\odot}]$ as large ; 0.1.

A second original point has been to select around 40 windows accross the spectral range '00Å to $1\mu_m$, isolating prominent absorption features and continuum points, and to *analyze their* *›haviour as a function of age and metallicity*. The star cluster sample spans ages from 2 x 10^6 yr to 6 x 10^{10} yr and metallicities from -2 to 0.1 in $[Z/Z_{\odot}]$ logarithmic notation. From the behaviour over e {-2, 0.1} metallicity interval, at every age, we have obtained a straightforward extrapolation at $:/Z_{\odot}] \sim 0.6$ for each window. This procedure allowed us to build a grid of the star cluster spectral operties over the ranges {-2, 0.6} in $[Z/Z_{\odot}]$ and {2 x 10^6, 1.6 x 10^{10} yr} in age (Bica and Alloin, ›86b ; 1987a) from which we have extracted a set of 35 components - the grid star clusters - to be ›ssibly used in the population synthesis.

We have selected also, among the 40 windows, those which provide better constraints on the nthesis : i.e. features primarily depending on one of our parameters (age or metallicity) and as dependent as possible one from other. The latter condition is better fulfilled if the windows are stributed accross a broad wavelength range.

The synthesis is performed so as to reproduce, through a combination of N grid star usters, $N \leq 35$, the equivalent widths measured for the selected windows in the composite spectrum to › matched. This is an inverse problem which deserves some discussion regarding the uniqueness of the ıcountered solution. Indeed, the galaxy equivalent widths are affected by measurement errors and the ›lected windows are not fully independent one from the other. To proceed with the synthesis, we have ed two different procedures :

) direct combinations (Bica, 1988) for which we have restricted the exploration within the parameter ›ace (age, metallicity) to that of chemical evolutionary paths, i.e., a monotonic increase of the etallicity as the age of the component decreases. Several paths were tested, the maximum

TABLE 1. Percentage contribution at λ = 5870Å, from each component in the synthesis. a) the case of massive elliptical galaxies, b) the case of a dwarf elliptical galaxy with a recent burst of star formation.

a.

RHII	E7	5E7	E8	5E8	E9	5E9	>E10	AGE $[Z/Z_{\odot}]$
					3	8	66	+0.6
							9	+0.3
							5	0.0
							3	-0.5
							3	-1.0
							2	-1.5
							1	-2.0

b.

RHII	E7	5E7	E8	5E8	E9	5E9	>E10	AGE $[Z/Z_{\odot}]$
								+0.6
								+0.3
								0.0
2	7	6	5	56	2	1	11	-0.5
							6	-1.0
							3	-1.5
							1	-2.0

metal–enrichment being varied. In this case, an estimate of the uniqueness of the solution can be derived as the number ratio of satisfactory solutions ($|W_{synth.} - W_{obs.}|$ < measurement error) to that of tested solutions.

(ii) a multiminimization algorithm was later used, allowing the full exploration of the parameter space in a fast and efficient way (Schmidt et al., 1989), while a statistical treatment led to the adopted solution. An extended discussion of the uniqueness problem is provided in Bica et al. (1990).

III. ILLUSTRATION OF THE METHOD

The method is illustrated through the case of massive elliptical galaxies (Bica, 1988). The synthesis results are given as the percentage flux contribution from each grid component, at 5870Å (Table 1a). The old metal–rich component is found to be dominant in this case. The "visual" representation of the solution, in terms of a synthetic spectrum to be compared to the observed one, cannot be performed in this case, as the spectrum of a star cluster at large $[Z/Z_\odot] \sim 0.6$ is not available (only the extrapolated grid cluster properties have been used in the calculation). On the contrary, we can predict how it should look, by subtracting from the observed galaxy spectrum the contributions from all the other synthesis components for which a star cluster spectrum is directly available in our cluster base (Fig. 1). The synthesis for a dwarf elliptical galaxy having suffered a recent burst of star formation is also presented (Table 1b and Fig. 2).

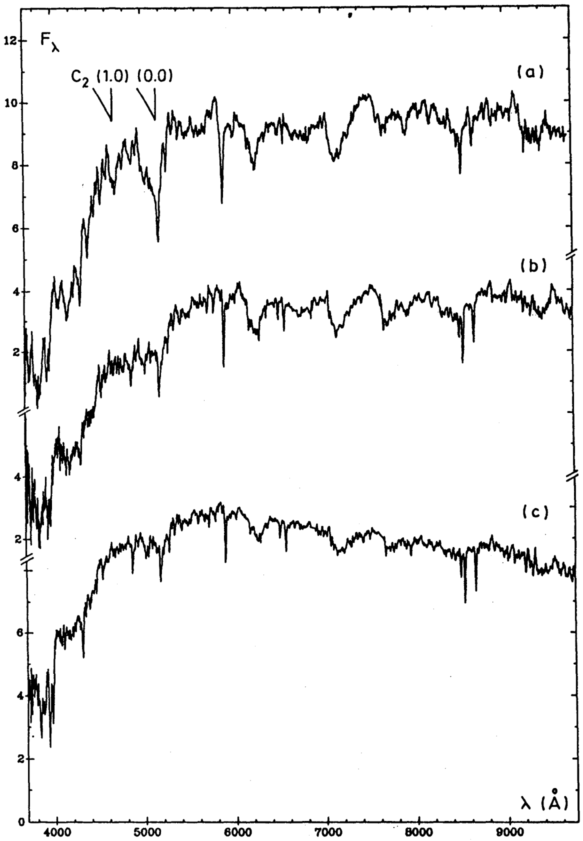

Fig.1 : Predicted spectrum for a globular cluster at $[Z/Z_\odot]$ = 0.6 (a). Observed spectra for globular clusters at $[Z/Z_\odot]$ = 0.1 and −0.4, respectively (b) and (c).

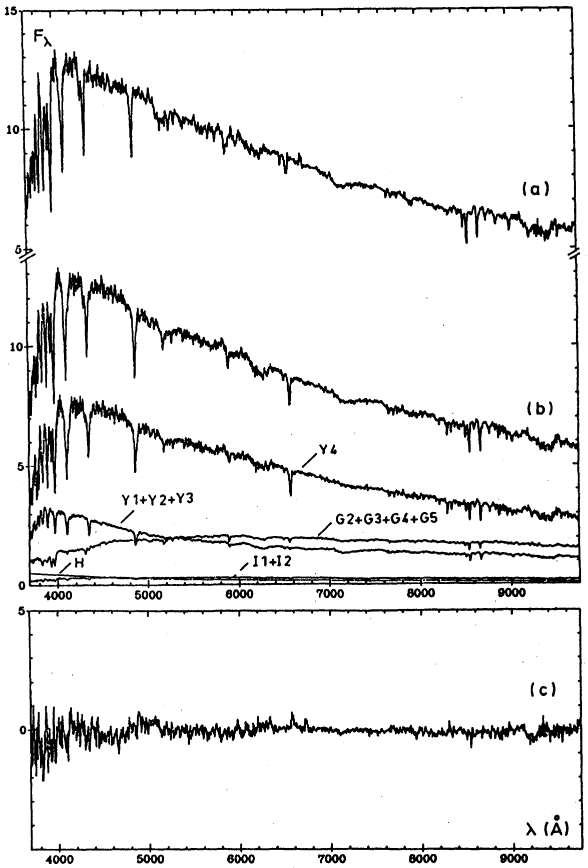

Fig.2 : Visualization of the synthesis result for a dwarf elliptical galaxy having suffered a recent burst of star formation. The observed spectrum (a), the synthetic spectrum (b), components entering the synthesis (G 2,3,4,5 are old components at $[Z/Z_\odot]$ from −0.4 to −2.0 ; I1,2 are intermediate age components and Y1,2,3,4, H are young components). The difference between (a) and (b) is given below, in part (c).

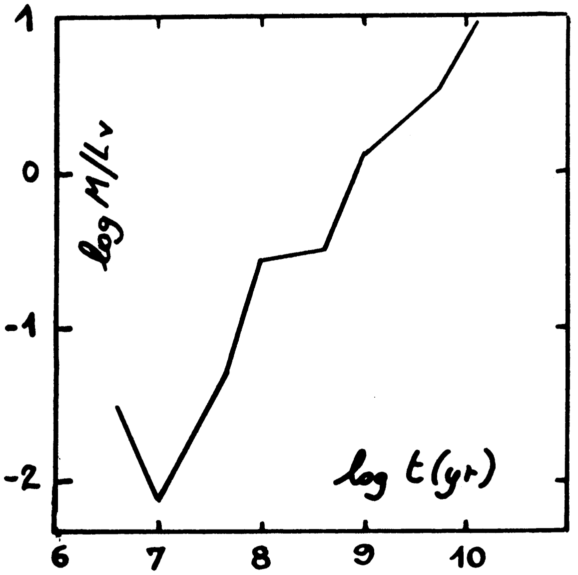

Fig.3 : Evolution of the mass to luminosity ratio for a single generation model (star cluster).

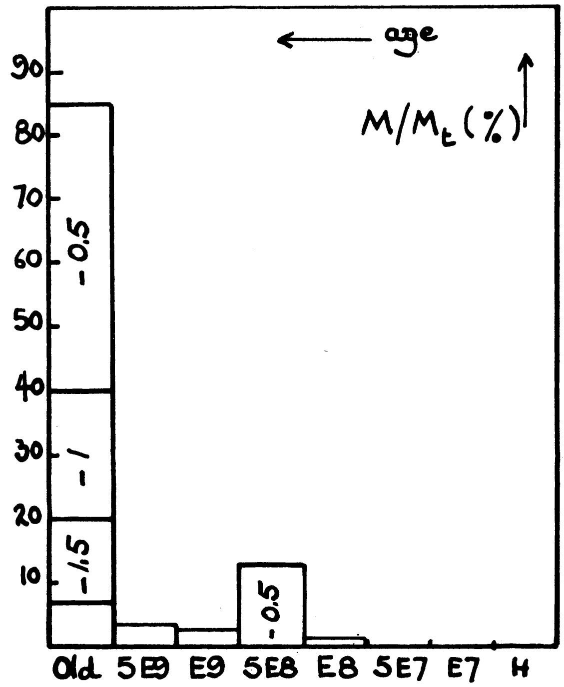

Fig.4 : Mass fraction (M/M_{total} x 100) involved in each component of the synthesis for the case presented in Fig.2 of a dwarf elliptical galaxy with a star formation burst. The metallicity values is displayed in the corresponding box.

Finally, we wish to present some population analysis we have performed on red galaxies in distant galaxy cluster Abell 370 at a redshift z = 0.374 (Jablonka et al., 1990). In this galaxy cluster, have identified three different groups of red galaxies on the basis of their photometric colours and ninosity. For all three groups, we find that the light is dominated by old metal-rich components : no smological effects show up yet at z = 0.374. The population synthesis results for the three groups differ the maximum value of the achieved metal enrichment $[Z/Z_{\odot}]_{max}$. If we plot these values on the ninosity - metallicity relationship we have obtained from our Shapley-Ames galaxy sample (Fig. 5), two ts can be noticed :

comparing groups R_3 in Abell 370 to the present-day giant elliptical galaxies at $M_B \sim -22$, we find that does not show as large a metal content. This reflects a dilution effect , as in R_3 the region we look at a few 10 kpc size around the galaxy centre, owing to Abell 370 distance, much larger than the mean pc region in present-day massive elliptical galaxies. The dilution effect lowers the metallicity by 0.3 in (.

even if one takes into account this metallicity dilution effect, groups R_2 and R_1 show far too low a tal content if they were to follow the luminosity - metallicity relationship. It implies that extremely ninous objects were not born with that large a mass, and that such very luminous galaxies have been med through merging processes between massive galaxies which had already achieved the bulk of ir star formation.

A population synthesis aims at reproducing the *light* (spectrum in that case) from the mposite population. We would like to know as well the mass contribution corresponding to each mponent, in order to recover the star formation history in the object. This further step requires the owledge of the M/L evolution of a star cluster. We have derived it using the evolutionary synthesis code Yoshii and Arimoto (1987) and the curve is shown in Fig. 3 (Bica et al., 1988). We provide in Fig. 4 the r formation history corresponding to the case of the dwarf elliptical galaxy with a recent burst of star mation shown in Fig. 2.

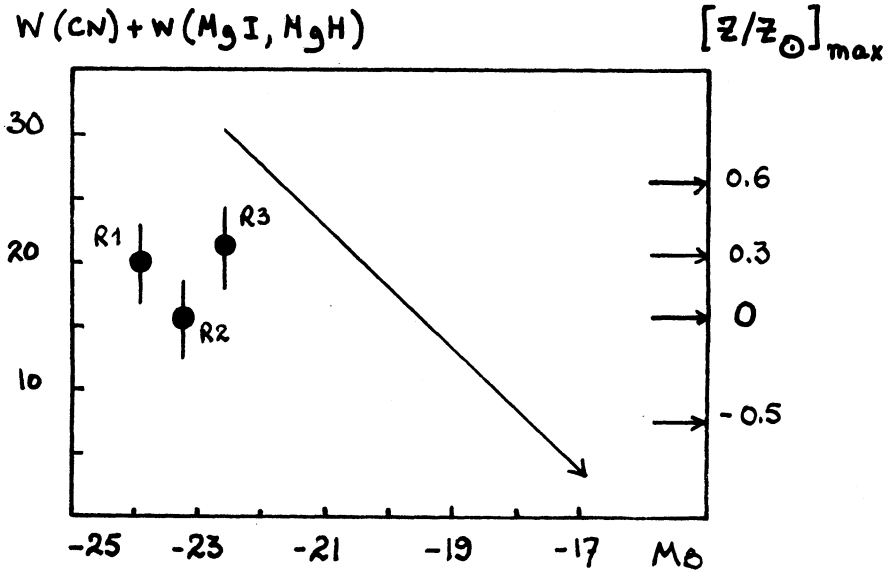

Fig.5 : Results of the population synthesis for the three groups of red galaxies in Abell 370, compared to the luminosity - metallicity relationship previously derived in the case of present-day galaxy nuclei.

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