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METALLICITY GRADIENT AND THE HYBRID FORMATION SCENARIO FOR EARLY-TYPE GALAXIES

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RESUMEN

Presentamos gradientes radiales del índice de Lick Mg_2 para 40 galaxias tempranas. En gráficas de $\triangle Mg_2$ vs. indicadores de masa, tales como $\log \sigma$, el borde inferior de la distribución de puntos puede estar poblada por galaxias formadas predominantemente por colapso monolítico. Las galaxias que muestran gradientes más planos a mayor masa pueden representar objetos que han sufrido importantes episodios de fusión. Por tanto, nuestros resultados apoyan un escenario de formación híbrida. Para eliminar posibles efectos de edad, calculamos los gradientes de metalicidad ($\triangle[Z/H]$) usando los índices Mg_2 y $H\beta$ para un modelo de población estelar de $[\alpha/Fe] = 0.3$. Las conclusiones permanecen igual.

ABSTRACT

We present radial gradients of the Lick index Mg_2 for 40 early-type galaxies. In plots of $\triangle Mg_2$ versus mass indicators, such as $\log \sigma$, the lower boundary of the points distribution may be populated by galaxies which predominantly formed by monolithic collapse. Galaxies showing flatter gradients at higher masses could represent objects which suffered important merging episodes. Thus, our results support a hybrid formation scenario. To remove possible age effects, we computed metallicity gradients ($\triangle[Z/H]$) using Mg_2 and $H\beta$ indices for an $[\alpha/Fe] = 0.3$ single stellar population model. The conclusions remain the same.

Key Words: **GALAXIES: ABUNDANCES — GALAXIES: ELLIPTICAL AND LENTICULAR**

1. INTRODUCTION

Two distinct galaxy formation scenarios have been proposed to explain the build-up of elliptical galaxies: Monolithic Dissipative Collapse (MDC) and Hierarchical Clustering (HC). In the MDC model a galaxy forms rapidly from a primordial cloud. An important prediction of this scenario is that early-type galaxies should present a metallicity gradient (MG) and that this MG should correlate with the object mass. In the HC scenario a galaxy is formed by coalescence of smaller objects. No MG is expected, since the successive mergers along the history of a galaxy are expected to remove this feature. Results of numerical simulations (Kobayashi 2004) show that, even in a HC scenario, both mechanisms are necessary to explain the observed behavior of MG. Ogando et al. (2005) determined Mg_2 radial gradients ($\triangle Mg_2$) for a sample of early-type galaxies and their major conclusion points to the necessity of a hybrid scenario to explain the observations. Here we repeat the analysis including MG for 10 more objects.

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2. SAMPLE AND OBSERVATIONS

Galaxies were selected from the ENEAR survey (da Costa et al. 2000), which contains a database of photometric (Alonso et al. 2003) and spectroscopic (Wegner et al. 2003) parameters for a sample of early-type galaxies, which are representative of the nearby Universe. The spectroscopic data were obtained with the 1.52 m telescope at ESO. The 1-D extractions were made as follows: the central aperture has 3 pixels (≃2.5"). Successive lateral apertures are set in such a way that their central pixels are the outermost pixels of the previous apertures, keeping the same size. This process continues while a $S/N \geq 20$ is obtained for the spectra. Conversion to Lick system was made by: degrading spectral resolution and corrections for offsets and velocity dispersions. A linear fit weighted by the indices' errors was used to measure its variation as a function of $\log(r/r_e^*)$, where r_e^* is r_e corrected for the galaxy ellipticity ($r_e^* = r_e(1-\epsilon)^{-1/2}$). For the analysis in the next section, we also included the data obtained by Carollo, Danziger & Buson (1993); Carollo & Danziger (1994a,b). The set of galaxies in the present analysis has similar σ distribution to that of ENEAR to a 97% of confidence level given by the Kolmogorov-Smirnov test.

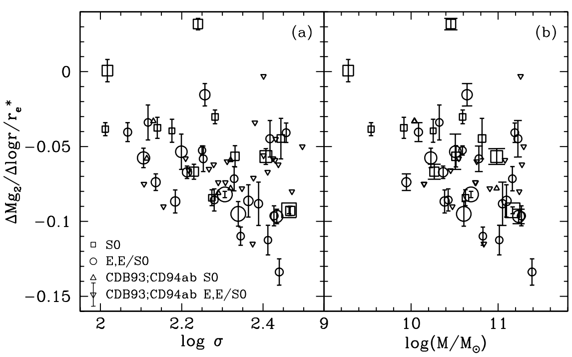

Fig. 1. Radial Mg_2 gradients vs. central velocity dispersion σ (panel a) and versus $Mass$ (panel b). We include the data by Carollo, Danziger & Buson (1993); Carollo & Danziger (1994a,b). Their Es and $E/S0$s are indicated by "∇", the $S0$s by "$\triangle$". The size of the symbol is proportional to the fraction of r_e in which we measured the $\triangle Mg_2$ (the bigger ones means $r/r_e \approx 1$).

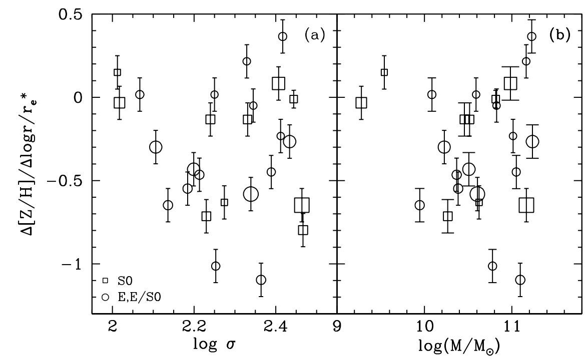

Fig. 2. Radial $\triangle[Z/H]$ as a function of galaxy central velocity dispersion σ (panel a) and $Mass$ (panel b). The number of points is smaller in this plot because some line indices measurements of Mg_2 and $H\beta$ used to determine $[Z/H]$ fall outside the grid of single stellar population models by Thomas, Maraston, & Bender (2003).

3. RESULTS AND DISCUSSION

To test one of the predictions of MDC model, the dependence of MG with galaxy mass we assume that Mg_2 line index predominantly reflects the metallicity. In Fig.1 (panel a) we plot $\triangle Mg_2/\triangle \log\ r/r_e^*$ versus log σ. This plot reveals that at least part of the galaxies located at the lower boundaries of the point distribution show an Mg_2 gradient which increases with σ presenting an $MG-\sigma$ relation similar to that in the simulations of Kobayashi (2004), indicating the dominance of monolithic collapse. The galaxies which occupy the locus of low MGs, according to the same simulations coincide with products of mergers.

In Fig.1 (panel b) we plot the $\triangle Mg_2$ vs. log $Mass$ ($Mass \propto r_e\sigma^2$), where r_e is the effective radius. This plot is very similar to that of panel (a) and reinforces the hypothesis of existence of objects reflecting the dominance of collapse or merger in the process of galaxy formation.

To remove possible age effects, we estimate [Z/H] gradients using Mg_2 and $H\beta$ indices and single stellar population models of Thomas, Maraston, & Bender (2003) for [α/Fe]=+0.3. [Z/H] are estimated for $r_e/8$ and $r_e/2$ from the Mg_2 and $H\beta$ values interpolated in the linear index vs. $\log r/r_e$ relations. In Fig.2 we display the $\triangle[Z/H]/\triangle \log\ r/r_e^*$ versus σ (panel a) and $\triangle[Z/H]/\triangle \log\ r/r_e^*$ versus $Mass$ (panel b) for 25 galaxies. The overall distribution of the data points is very similar to that in Fig.1.

These results give observational support to the hybrid scenario and show that we can interpret galaxy formation not as an exclusive dominance of either MDC or HC scenarios. Each galaxy has its particular formation history depending on the merger events of its building blocks, their nature (predominantly gas or stars) and their efficiency to collapse. The location of a galaxy in a $MG-\sigma$ diagram may be a useful tool to infer the relative importance of mergers or collapse to its formation.

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