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H II GALAXIES AT $z = 0.1$–0.7: PROGENITORS OF TODAY'S SPHEROIDALS?

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RESUMEN

Hemos analizado las propiedades globales de una muestra de galaxias compactas con $z = 0.1$–0.7. Estas galaxias se caracterizan por ser intrínsicamente muy luminosas, tener colores muy azules, tamaños pequeños, líneas de emisión intensas y dispersión de velocidades bajas. Todo esto indica que son, en realidad, galaxias H II. Proponemos que estas galaxias H II lejanas pueden ser los progenitores de las actuales galaxias esferoidales.

ABSTRACT

We study the global properties of a sample of faint blue compact galaxies at $z = 0.1$–0.7. Their very blue colors, small sizes, high luminosities, strong emission lines, and low velocity widths, all suggest that these objects are most likely low-mass, extreme star-forming H II galaxies. We argue that these distant H II galaxies may be the progenitors of today's spheroidal galaxies, such as NGC 205.

Key words: **GALAXIES: COMPACT — H II REGIONS — STARS: FORMATION**

1. INTRODUCTION

The nature of the numerous faint blue galaxies observed in deep sky images is one of the major unsolved questions of modern cosmology (see review by Koo 1994, and references therein). The high surface density and weak clustering of these galaxies argue against their being either the progenitors or the merging components of present-day bright galaxies (Lilly, Cowie, & Gardner 1991; Efstathiou et al. 1991). Various theoretical scenarios have instead suggested that the faint blue galaxies are low-mass stellar systems experiencing their initial starburst at redshifts $z \leq 1$, some of which turn into the present population of spheroidal galaxies, such as NGC 205 (Babul & Ferguson 1996). A new approach to investigate the nature of these faint galaxies is to compare their global properties (i.e., sizes, surface brightnesses, luminosities, internal velocities and abundances) to those of the local population. This paper summarizes the results of such a study based on *HST* and Keck observations of a subset of faint blue galaxies characterized by being very compact and having narrow emission lines (Koo et al. 1994; Koo et al. 1995; Guzmán et al. 1996).

2. THE NATURE OF THE FAINT COMPACT BLUE GALAXIES

Our galaxies were selected from a sample of compact narrow emission line galaxies (CNELGs) at $z \sim 0.1$–0.7 with $B \sim 20$–23 and B-$V \sim 0.4$ (Koo & Kron 1988). These objects have luminosities around L^* and emission-line ratios characteristic of H II galaxies (see Figure 1). *HST* measurements of half-light radii (Re) reveal that, despite their high luminosities, CNELGs have typical sizes of only ~ 2 kpc (Koo et al. 1994), i.e., they are dwarf stellar systems similar to the most compact H II galaxies. Emission-line velocity widths (σ) were measured using HIRES at Keck and range from ~ 30 to 80 km s^{-1}. Most of the CNELGs in our sample follow remarkably well the correlations between σ and Hβ luminosity or B-band absolute magnitude found for local H II galaxies (see Figure 2). We conclude that the local counterparts of our CNELGs are not blue compact dwarfs, clumpy irregulars, or starburst nuclei, but are instead low-mass, extreme star-forming systems like H II galaxies (Koo et al. 1995; Guzmán et al. 1996).

3. PROGENITORS OF TODAY'S SPHEROIDAL GALAXIES?

CNELGs are so blue and have such strong emission lines that they are most likely to be near the peak of their luminosity after a major burst of star formation. Unless reignited by new star formation, they should fade within a few Gyrs. The issue of fading and transformation of one galaxy class to another is quite complex.

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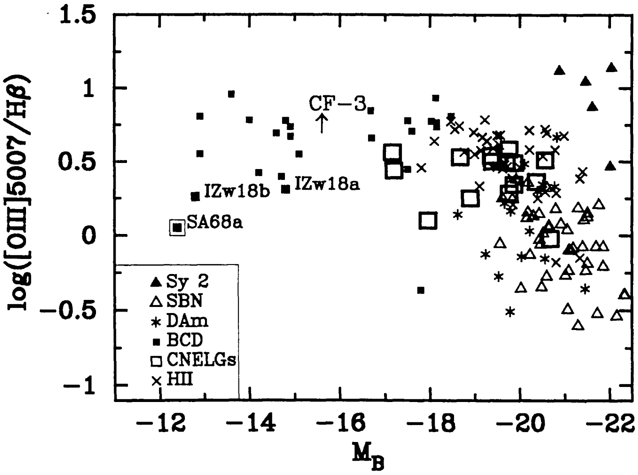

Fig. 1. Line ratio vs. luminosity diagram for various nearby emission line galaxies (Gallego 1995) and CNELGs (open squares). CNELGs tend to occupy the same locus than H II galaxies in this diagram. Particularly interesting is the object SA68a, whose position in this diagram suggests it may have lower metallicity than IZw18, the lowest metallicity object known.

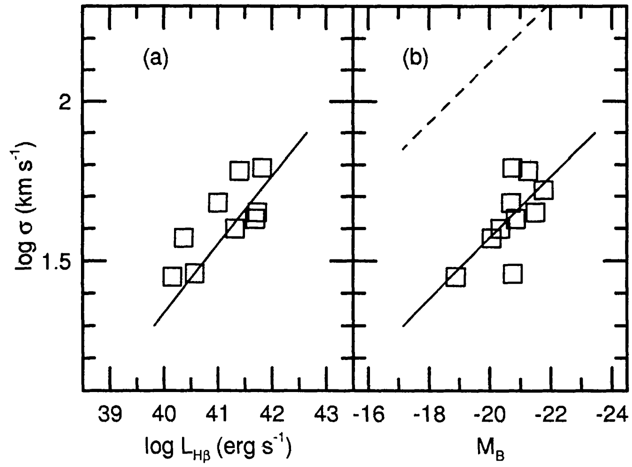

Fig. 2*(a)* Hβ luminosity vs. velocity width σ. The solid line shows the average relation derived for H II galaxies by Melnick, Terlevich, & Moles (1988). *(b)* Rest-frame B absolute magnitude M_B vs. σ. The solid line shows the average relation derived for H II galaxies (Telles & Terlevich 1993) superposed on our data points. The dashed line shows the approximate position of nearby elliptical and spiral galaxies.

Perhaps one of the most useful tools we have to study how distant young galaxies relate to nearby evolved stellar systems is the $Re - \sigma$ diagram, since both Re and σ do not depend strongly on the fading of the stellar population. In Figure 3*a* we show this diagram for our CNELGs as well as for a representative sample of various types of nearby galaxies. Although there are several physical processes that may modify Re and σ during galaxy evolution (e.g., dissipation, mergers, tidal stripping or galactic winds), we find no evidence against the idea that CNELGs are related, both structurally and kinematically, to the nearby population of low-mass spheroidal and irregular galaxies (Guzmán et al. 1996). The evolution of CNELGs into one galaxy class or another may depend critically on their ability to retain part of their interstellar medium in the likely event of starburst-driven galactic winds. The extremely low mass-to-light ratios of our CNELGs (i.e., $M/L \sim 0.1$ solar) suggest that the kinetic energy supplied by the current starburst is likely to be large enough, compared to their binding energy, to blow out most of the gas, thus preventing future star formation. Without additional star formation, Koo et al. (1995) have shown that CNELGs will fade enough to match the low luminosities and surface brightnesses of spheroidal galaxies (Figure 3*b*). There are also other arguments in favour of this evolutionary scenario. In particular, there is no evidence for a CNELG-phase, i.e., a dominant early burst, in the star formation history of nearby irregulars (Skillman & Bender 1995). The nearly constant star formation rate of Irr galaxies poses a serious challenge to the idea that CNELGs may be their progenitors. In contrast, all well observed spheroidals appear to have experienced a dominant burst of star formation typically a few Gyrs ago (Skillman & Bender 1995). If we could trace back in time the star formation history of spheroidal galaxies, what would these dominant bursts look like? The answer is simple: they would have luminosities, surface brightnesses, colors and redshifts virtually identical to those actually observed in our CNELGs. We thus conclude that a class of faint, blue compact galaxies at intermediate redshifts has been identified as being among the progenitors of today's spheroidal galaxies.

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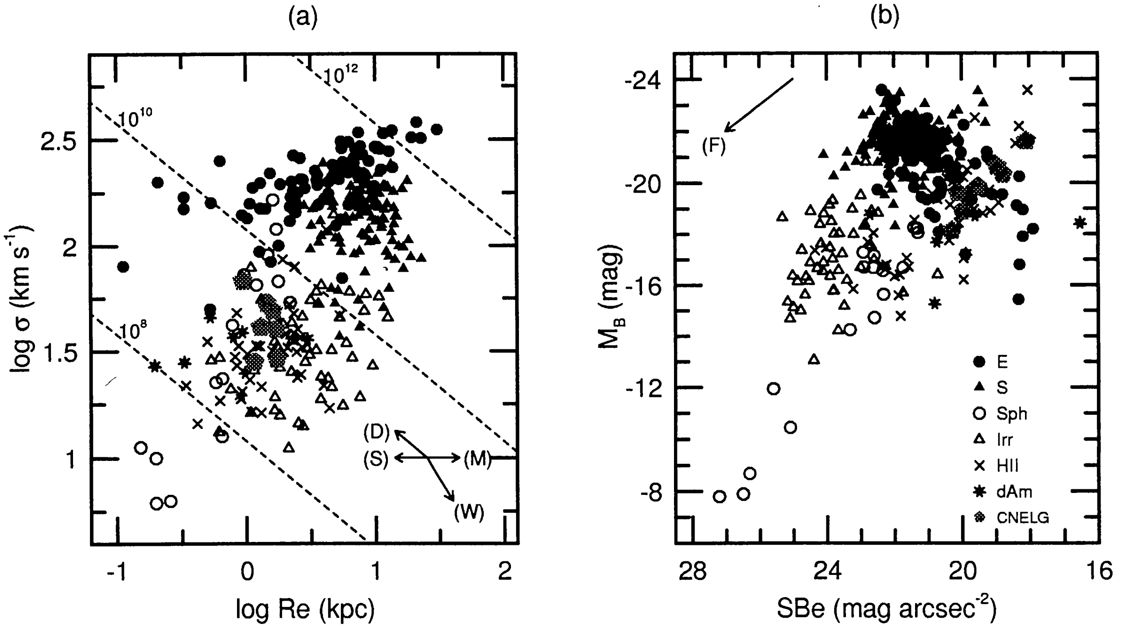

Fig. 3*(a)* The half-light radius (*Re*) vs. velocity width (σ) for for our CNELG sample (open pentagons) as well as for a representative sample of various types of nearby galaxies. The vectors represent the direction in which *Re* and σ change due to different physical processes: (D) Dissipation; (M) Mergers; (S) Tidal Stripping; (W) Galactic winds. The dashed lines correspond to constant-mass lines of 10^8, 10^{10} and 10^{12} $M_\odot$, respectively. Their position in this diagram confirms that CNELGs are indeed low-mass, dwarf galaxies ($M \sim 10^9$ $M_\odot$) related both, structurally and kinematically, to nearby spheroidals and irregular galaxies. *(b)* The rest-frame B absolute magnitude (M_B) vs. the average rest-frame blue surface brightness within the half-light radius (SBe) for the same galaxy sample. The vector (F) represents the effect of the fading of the stellar population after the starburst. Without additional star formation, evolutionary stellar population models predict that CNELGs will fade $\sim$ 5–6 mag to match the low luminosities and surface brightnesses typical of nearby spheroidals.

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