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THE EXTREME PROPERTIES OF THE "GREEN PEA" GALAXIES. NEW HINTS FROM GTC OBSERVATIONS

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RESUMEN

Presentamos resultados recientes de un estudio espectrofotométrico de galaxias "Green Pea" (GP), basado en observaciones de OSIRIS-GTC. Las GPs son galaxias compactas con líneas de emisión intensas con desplazamiento al rojo $z \sim 0.15 - 0.35$, que muestran un ritmo de formación estelar por unidad de masa alto y baja metalicidad. Mostraremos cómo las observaciones con OSIRIS-GTC nos permiten: (a) derivar propiedades físicas y abundancias químicas del gas ionizado con gran precisión y, (b) imponer nuevas restricciones a la historia de formación estelar de las GPs, combinándolas con modelos evolutivos y de síntesis de poblaciones estelares. Los resultados proporcionan nuevas pistas sobre la naturaleza y estado evolutivo de las GPs y resaltan su importancia como laboratorios para el estudio de la evolución de galaxias en épocas cósmicas tardías.

ABSTRACT

We review recent findings of a detailed spectrophotometric study based on OSIRIS-GTC observations of "Green Pea" (GP) galaxies. These compact, emission-line galaxies at redshift $z \sim 0.15 - 0.35$ are metal-poor, low-mass objects with high star formation rates. We show how high quality GTC data allow us to: (a) derive physical properties and chemical abundances of the ionized gas with high accuracy and, (b) to place constraints on the star formation history using the combined approach of evolutionary and population spectral synthesis models. These results provide additional clues on the nature and evolutionary state of the GPs and highlight their importance as laboratories for studying galaxy evolution at late cosmic epochs.

Key Words: galaxies: abundances — galaxies: dwarf — galaxies: evolution — galaxies: starburst

1. INTRODUCTION

The "Green Pea" (GP) galaxies are a large and homogeneous sample of emission-line galaxies at redshift $z \sim 0.15-0.35$, characterized by their unusually strong nebular emission and very compact appearance by Cardamone et al. (2009). This and subsequent studies (Amorín et al. 2010; Izotov et al. 2011) based on SDSS data showed that GPs are rare, low-mass ($M_\star \lesssim 10^{10}\ M_\odot$) galaxies rapidly forming stars (SFR $\sim 3-60\ M_\odot\ \mathrm{yr}^{-1}$) in a compact ($r_{50} \sim 1$ kpc) and low-metallicity ($Z \sim 1/5\ Z_\odot$) environment.

The GPs are identifiable with the high-luminosity end of nearby Blue Compact Dwarf (BCD) galaxies, probably passing through a short and extreme phase in their evolution. In order to elaborate a coherent evolutionary picture for GPs, several key issues still need detailed investigation. Some examples are their star formation history (SFH), which is still not well-constrained, and their photometric structure.

Recently, a detailed study for three GPs has been presented by Amorín et al. (2012). This work is based on deep, intermediate-resolution OSIRIS spectrocopy at the 10.4 m GTC and deep HST archival images. Our results have shed new insights on the SFH, photometric structure and chemical enrichment of GPs. Here, we review our main findings and remark the importance of high-quality data, like those provided by GTC, to go one step further in the understanding of the nature of the GPs.

2. CHEMICAL ABUNDANCES

The high signal-to-noise (S/N) OSIRIS spectra have allowed to derive chemical abundances and physical properties of the ionized gas with high precision, and to confirm some trends found in previous studies (Amorín et al. 2010; Izotov et al. 2011). Electron densities and temperatures were calculated and used to derive ionic and total abundances of several species (He, O, N, Ne, Ar, S, and Fe). While for most of them values are similar to those typically found in nearby BCDs, the three GPs show remarkably higher N/O ratios compared with most galaxies of similar metallicity (Figure 1). An apparent N overabundance was already suggested by Amorín et al.

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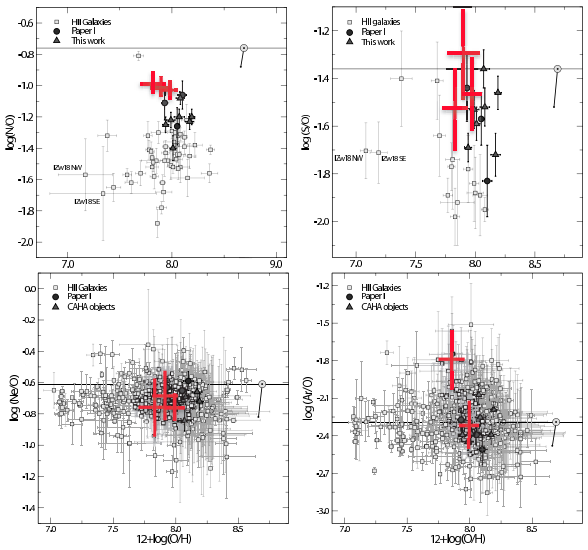

Fig. 1. Abundance ratios vs. metallicity for the three observed GPs and samples of BCD/HII galaxies from Hägele et al. (2008).

(2010) by comparing the position of GPs and thousands of SDSS galaxies in the N/O-O/H diagram.

Our deep OSIRIS spectra has allowed the detection of clear signatures of Wolf-Rayet (WR) stars in the three GPs. Their presence has strong impact to age-date the starburst, and also allows to explore, at some length, the effects of the WR strong stellar winds in the chemical abundances of GPs. Although some *localized* N overabundance cannot be ruled-out, comparison with the predictions of models used in similar studies (see Pérez-Montero et al. 2011) suggests that the pollution induced by the observed number of WRs is not enough to explain such a high *global* N/O ratio.

3. STAR FORMATION HISTORIES

In order to shed new light on the SFH of GPs, we carried out a pilot study of the three objects using two different approaches: (a) a population synthesis code in conjunction with both the new generation of single stellar population (SSP) library POPSTAR (Mollá et al. 2009), which includes nebular emission, and (b) an evolutionary synthesis code that self-consistently accounts for Balmer emission line equivalent widths for simplified SFH comprising an old and a young stellar population.

The central outcome from (a) and (b) is in qualitatively agreement. The derived SFHs of these objects show large discontinuities between a few 10^8 yr and several Gyr, strongly suggesting a SFH dominated by starbursts (Figure 2). These GPs currently

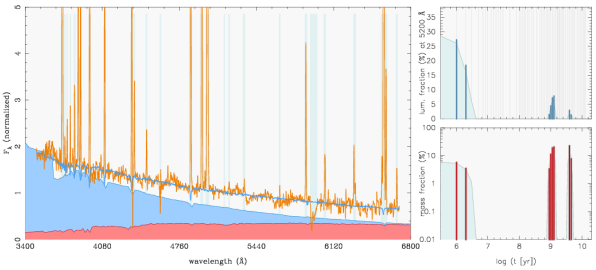

Fig. 2. Best-fitting SED based on population synthesis models overimposed on the rest-frame spectrum of a GP. The red and blue components represent the old and young stellar populations.

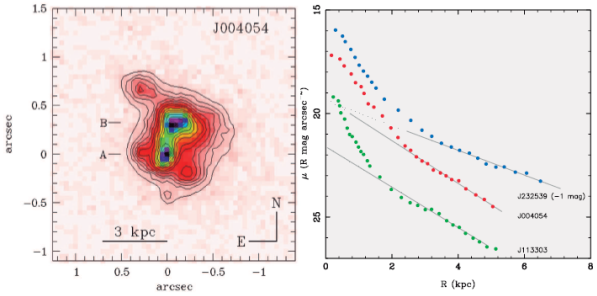

Fig. 3. HST F606W image with contours of the GP J004054 (left). Best-fit exponential models overimposed on the surface brightness profiles –derived from deep HST F606W images– of the three observed GPs.

undergo a major starburst producing ∼4%–20% of their stellar mass. However, as models imply, the 3 GPs are old galaxies having had formed most of their stellar mass several Gyr ago. The above results are strongly supported by the presence of both very young stars (WRs) and old stars, the latter verified spectroscopically by the detection of MgI 5167,5173 in absorption for one GP. Additionally, surface photometry based on HST data, indicates that the 3 GPs posses an exponential low-surface brightness envelope (Figure 3) that is structurally compatible to the evolved hosts of BCDs (e.g. Amorín et al. 2009). This suggests that GPs may represent major episodes in the assembly history of local BCDs.

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