Studying the star formation history of the dwarf galaxy *CGCG014-074*

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Abstract

Early-type dwarf galaxies (dE, dS0) are the most common galaxy type in nearby galaxy clusters and groups. According to the hierarchical theory of formation and evolution of the large-scale structures in the Universe, dwarf galaxies would be the building blocks of those bright galaxies we observe today. In particular, the formation scenarios for dE and dS0 focus mainly on the transformation of late-type to early-type galaxies through different processes (e.g., interactions, mergers), including environmental effects in high-density environments (e.g., ram-pressure stripping, harassment, suffocation). However, **it is not yet clear whether these processes would be relevant in low-density environments** such as poor groups and the field. In this sense, analyzing the morphology of dwarf galaxies turns out to be one of the fundamental elements to understand their underlying dynamics as well as their assembly histories. In this work, **we present a preliminary photometric and spectroscopic study** of the dS0 galaxy `CGCG014-074` that forms a small group with `NGC 4546`, an S0 galaxy located in a low-density environment. The analysis presented here is part of a larger study carried out by the SEECC research group and shows the first results obtained from the dS0 galaxy.

Photometric Analysis

Photometric data were obtained with the *GMOS* instrument of the *Gemini South* telescope, under excellent seeing conditions (0.55−0.68 arcsec; program `GS-2014A-Q-30`), using 4×100 sec. exposures in the g',r',i' filters and 4×290 sec. in the z' filter. Some data of `CGCG014-074` and `NGC 4546` are shown in the following table:

Property	CGCG014-074	NGC 4546	unit
α	12:35:50.95	12:35:29.5	h:m:s (J2000)
δ	−03:45:58.5	−03:47:35.5	d:m:s (J2000)
Type	dS0 edge-on	SB0$^-$(s)	–
V_T^0	–	10.57±0.01	mag
$R_{\rm eff}$	–	22.23	arcsec
$V_{\rm hel}$	998±54	1057±5	km/s

Table 1: Properties of CGCG014-074 and NGC 4546 obtained from the literature. Distance modulus adopted for the group: $(m-M)_0 = 30.73 \pm 0.14$ (14.0 ± 0.9 Mpc; Tully et al. 2013). The associated spatial scale is 1 arcsec = 67 pc. The $V_{\rm hel}$ values of CGCG014-074 and NGC 4546 were obtained from Colless et al. 2003 and Cappellari et al. 2011, respectively.

We study the light distribution of the dwarf using the `Ellipse` task of the `IRAF` software, obtaining the variation of the isophotal parameters (ellipticity (ϵ), position angle (PA) and Fourier coefficient B_4) as a function of the equivalent radius ($r_{\rm eq} = a\sqrt{1-\epsilon}$). Figure 1 shows only the case for the filter g' (the rest of the filters present similar results). The ϵ and PA (measured from north to east) **change dramatically in the central region** ($r_{\rm eq}$ <0.05 arcmin; 0.2 kpc). Furthermore, both parameters show a significant variation in $r_{\rm eq} < 1$ arcmin (< 4 kpc), with ϵ decreasing from 0.6 to 0.3 and PA varying ∼13°. In the case of the Fourier coefficient B_4, it indicates a change from discy isophotes (B_4 >0) to boxy isophotes (B_4 <0) from $r_{\rm eq} \sim 0.4$ arcmin (∼1.6 kpc). On the other hand, the surface brightness profile (Figure 2) shows that **the light distribution of the galaxy seems to be composed of more than one component**. Therefore, we fit different parametric functions (Gaussian profile for the centre and two Sérsic profiles for the outermost components) to the 1D surface brightness profile in filter g' as shown in Figure 2.

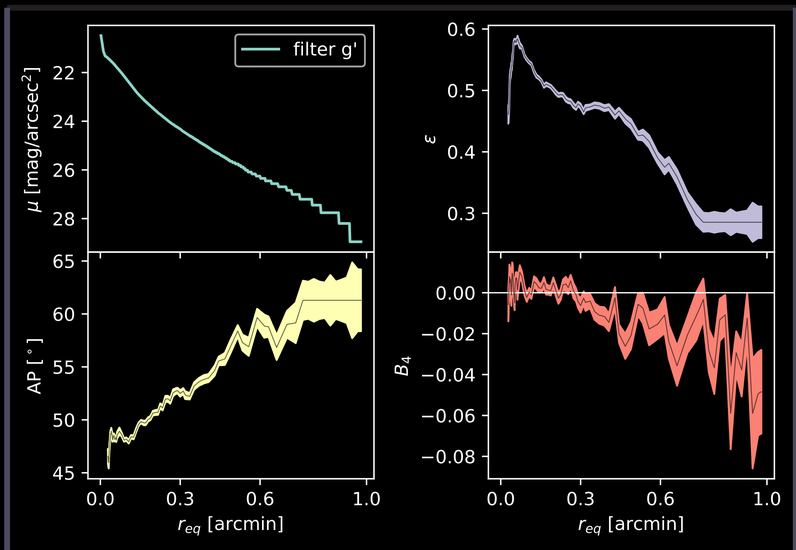

Figure 1: `Ellipse` parameters for filter g'.

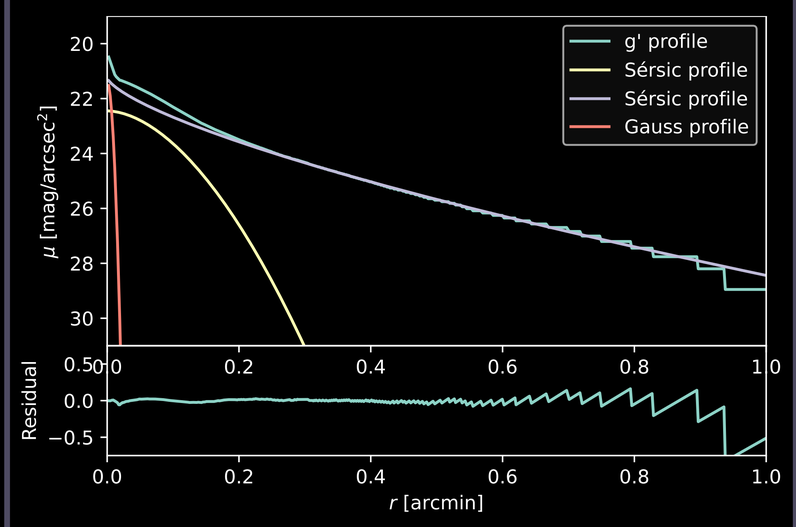

Figure 2: Surface brightness profile in g' filter, together with the fitted subcomponents and the residual of the model.

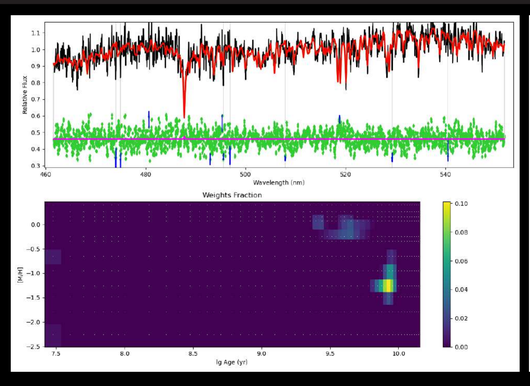

Figure 4: Spectral fit and mass-weighted stellar populations of the nucleus (region 1)

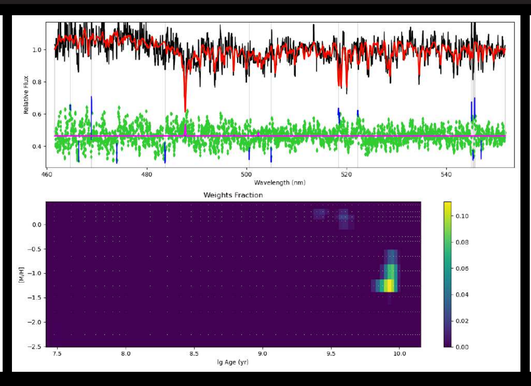

Figure 5: Spectral fit and mass-weighted stellar populations of region 2 (located 10 arcsec from the centre)

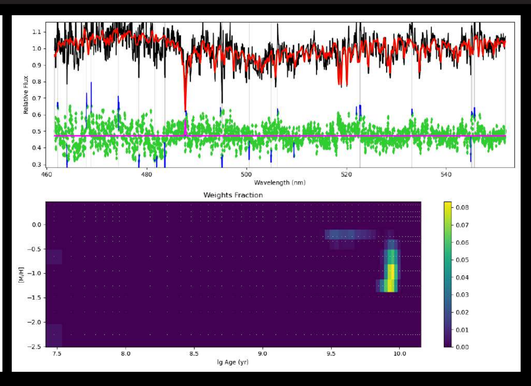

Figure 6: Spectral fit and mass-weighted stellar populations of region 3 (located 10 arcsec from the centre)

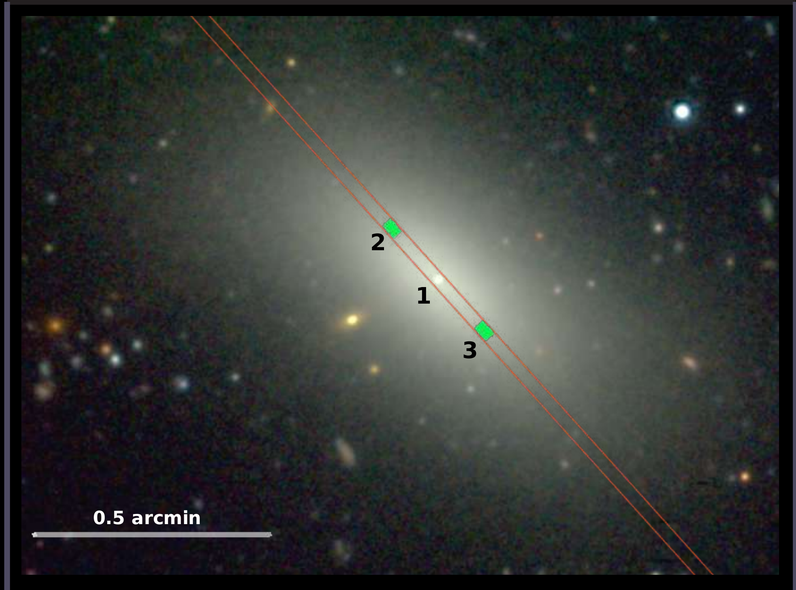

Figure 3: Position of the long-slit and regions from which the analyzed spectra were extracted.

Spectroscopic Analysis

We use the *GMOS* instrument in long-slit mode to obtain information on `CGCG014-074` along its semi-major axis (PA = 48°). The dataset is made up of 9 exposures of 1540 sec. obtained with the B1200 grating, a 2×2 binning and slit width of 1 arcsec. This instrumental setup provides a spectral resolution of ∼1.9 Å. Three spectra were extracted along the slit (regions 1, 2 and 3 in Figure 3) with S/N>8 per pixel.

We determined the radial velocity, velocity dispersion, and stellar population parameters by the *full spectral fitting technique* using the `pPXF` code (Cappellari 2017) together with the stellar population synthesis models `MILES` (BaseFe models, $-2.27 <$ [Z/H] $< +0.4$ dex, $1.0 <$ ages < 14.0 Gyr). Figures 4, 5 and 6 show the best fit obtained and the mass-weighted stellar populations for the three regions considered. The radial velocity values for regions 1, 2 and 3 were **1002, 986 and 1016 km/s**, respectively, **clearly indicating signs of rotation in `CGCG014-074`**. In the case of the velocity dispersion obtained for each region, the estimated values were similar ∼15 km/s. The analysis of the stellar populations shows the clear **presence of a population with an age ∼8.5 Gyr and metallicity [Z/H] = −1.0 dex**, and **the contribution of a less significant mass-weighted population of younger age** (∼4 Gyr) **and higher metallicity** ([Z/H] = −0.2 dex).

Results

Photometric and spectroscopic analysis of `CGCG014-074` indicates that it is a nucleated dS0 galaxy (dS0,N).

From the photometric analysis, significant variations of PA and ellipticity ($\Delta PA = 13°$ and $\Delta\epsilon = 0.3$) were obtained within $0.05 < r_{eq} < 0.7$ arcmin ($0.2 < r_{eq} < 2.8$ kpc), indicating that **the light of the dwarf begins to orient itself towards the dominant galaxy of the group (NGC 4546) as its radius increases**. Also, in the same radial interval, we observe the **change from discy to boxy isophotes** at $r_{eq} \sim 0.4$ arcmin (∼ 1.6 kpc). The presence of boxy isophotes is generally associated with possible interaction and/or fusion events (Kormendy and Bender 1996).

On the other hand, the spectroscopic analysis in three different regions reveals **signs of rotation in `CGCG014-074`**, while the study of its stellar populations indicates the **presence of at least two populations different in age** (∼8.5 and ∼4 Gyr) and metallicity ([Z/H] = −1.0 and [Z/H] = −0.2 dex).

These features shown by `CGCG014-074` would suggest a **possible interaction with probably its companion `NGC 4546` in the recent past**. However, there is also the possibility that the current appearance and properties of `CGCG014-074` are the product of a remnant of two merged disk galaxies, where the initial gas was driven inward forming the inner disk, while the stars at large radii experienced a dissipationless merger event giving rise to boxy isophotes.

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