Early-type dwarf galaxies in low-density environments: the case of CGCG014-074

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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 photometric 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 shows the first results obtained on the dS0 galaxy, using deep Gemini-GMOS images in the filters $g'r'i'z'$, we characterize the photometric properties of the dwarf galaxy by determining its isophotal parameters, surface brightness profiles, colour gradients, and different structural components. This initial analysis allows us to inquire about its evolutionary past, giving us an idea if its current morphology could be due to internal galaxy properties and/or environmental mechanisms (nature or nurture).

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CGCG014-074: photometric data

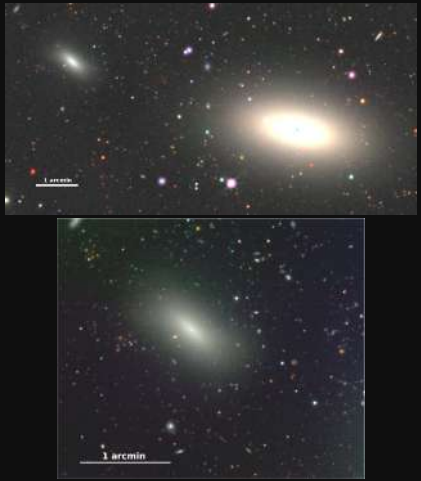


Figure 1: *Top*: DSS image of the lenticular galaxy NGC 4546 and its dwarf companion CGCG014-074. *Bottom*: GMOS image of the dS0 galaxy CGCG014-074.

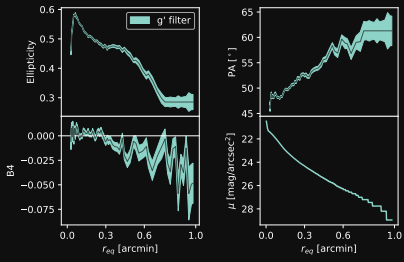
The photometric study is based on deep images taken with the *GMOS* camera of the *Gemini-South* telescope. The images were taken under excellent seeing conditions (0.55 − 0.68 arcsec), as part of Gemini programme ***GS-2014A-Q-30***, using 4×100 sec exposures in the g',r',i' filters and 4×290 sec exposures in the z' filter.

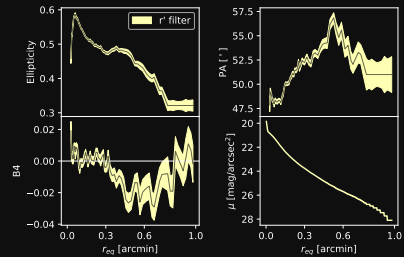
The field shows our object of study, the dS0 edge-on galaxy CGCG014-074, and its dominant companion the lenticular galaxy NGC 4546. Both galaxies, located at a projected distance of ∼5.5 arcmin (∼22 kpc) from each other, reside in a low-density environment ($log\ (\rho) = -1.14$ Mpc^{-3}) and have similar radial velocities: CGCG014-074: $V_{hel} = 998 \pm 54$ km/s (Colless et al., 2003) & NGC 4546: $V_{hel} = 1057 \pm 5$ km/s (Cappellari et al., 2011).

Property	CGCG014-074	NGC 4546	units
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_{eff}	–	22.23	arcsec
V_{hel}	998±54	1057±5	km/s

Table 1: Properties of CGCG014-074 and its companion 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.

CGCG014-074: ellipse model

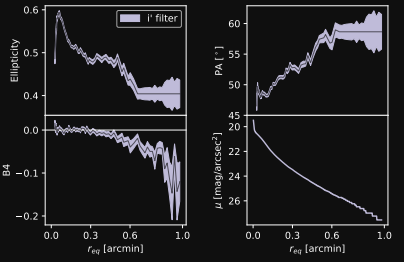




To study the light distribution of CGCG014-074 we use the IRAF software.

Running the Ellipse task we have obtained the variation of the isophotal parameters (ellipticity, position angle (PA), and the Fourier coefficient B_4) and the surface brightness profiles as a function of the equivalent radius ($r_{eq} = a\sqrt{1-\epsilon}$) as shown in figures 2a and 3a.

The ellipticity and PA (measured from north to east) change drastically in the central region ($r_{eq} < 0.05$ arcmin; 0.2 kpc), and a significant variation of the ellipticity is observed dropping from 0.6 to 0.3 within $r_{eq} < 1$ arcmin (< 4 kpc). This variation can also be seen in the PA changing $\sim$13° within the mentioned radius. In addition, the Fourier coefficient B_4 changes from discy ($B_4 > 0$) to boxy ($B_4 < 0$) isophotes starting at $r_{eq} \sim 0.4$ arcmin ($\sim$1.6 kpc).



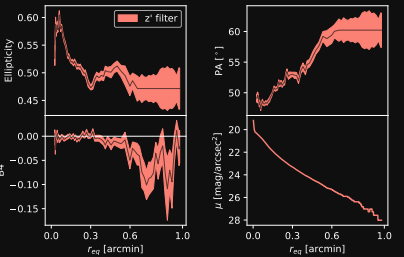
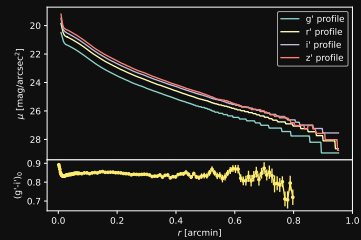


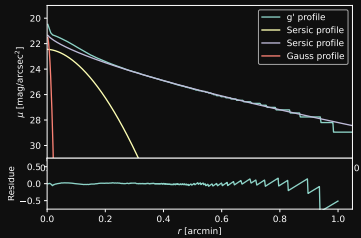
Figure 2a: Ellipse parameters

Figure 3a: Ellipse parameters

CGCG014-074: profile fitting



(4a) *Top*: Surface brightness profiles in the different filters. *Bottom*: Colour profile $(g' - i')_0$.



(4b) Surface brightness profile in g' filter and the residual between the data and the fitted model. The red, yellow and purple lines show the different fitted subcomponents.

From the surface brightness profiles obtained in each filter (figure 4a upper panel) we calculate the colour profile $(g' - i')_0$. As can be seen in the figure (bottom panel), the profile has a mean colour $(g' - i')_0 \sim 0.85$ mag within $r_{eq} < 0.65$ arcmin (2.6 kpc),while the inner region $r_{eq} < 0.05$ has a redder colour of $(g' - i')_0 \sim 0.9$ mag.

The surface brightness profiles clearly show that the light distribution is not a simple one-component curve.
Fitting different parametric functions to the 1D surface brightness profile in the g' filter: one Gaussian and two Sérsic functions, we get the parameters and the fit shown in the table 2 and top figure 4b.

Filter	Model	$\mu_{0/\mathrm{eff}}$ (mag arcsec^{-2})	R_{eff} (arcsec/kpc)	n	σ (arcsec/kpc)
g'	Gaussian	21.4	—	—	0.29/0.02
	Sérsic	23.3	5.0/0.33	0.55	—
	Sérsic	23.9	15.1/1.01	1.42	—

Table 2: Parameters obtained for each fitted function. The different columns indicate the used filter, fitted models, surface brightness for Gaussian and Sérsic functions, effective radius (R_{eff}) for the Sérsic functions, Sérsic index, and the σ ($\equiv$ FWHM=0.68 arcsec = 0.04 kpc) value obtained, respectively.

From the fits obtained on the surface brightness profiles, we integrate them to calculate the apparent magnitude (and absolute) in the four filters. The values obtained are:

$$m_g = 15.08 \quad m_r = 14.50 \quad m_i = 14.22 \quad m_z = 14.06$$
$$(M_g = -15.65 \quad M_r = -16.23 \quad M_i = -16.51 \quad M_z = -16.67)$$

Summary and Future Work

We present the preliminary photometric analysis of *CGCG014-074*. Through IRAF, we obtained the variation of the isophotal parameters as a function of the equivalent radius, as well as the surface brightness profiles in the different filters. The shape of the latter shows that a single component to describe them is not enough. Hence, to model the 1D profile of the g' filter we considered: a Gaussian for the innermost component (FWHM=0.68 arcsec $=$ 0.04 kpc); a Sérsic function with parameters $n = 0.55$ and $R_{eff} = 5$ arcsec (0.33 kpc), for the second most internal component; and another Sérsic for the outermost component of the dwarf galaxy with $n = 1.42$ and $R_{eff} = 15.1$ arcsec (1.01 kpc), which adequately reproduces the profile in the filter g' .

CGCG014-074 seems to be a nucleated dS0 galaxy (dS0,N) due to the well-defined, reddened inner component.

On the other hand, the isophotal parameters of ellipticity and PA show a significant variation ($\Delta\epsilon = 0.3$ and $\Delta PA = 13°$) between $0.05 < r_{eq} < 0.7$ arcmin ($0.2 < r_{eq} < 2.8$ kpc). This variation can be observed during Ellipse fitting with the isophotes orienting towards the direction of NGC 4546. In this same sense, within the aforementioned radius, the Fourier coefficient B4 changes from discy to boxy isophotes in approx $r_{eq} \sim 0.4$ arcmin (~ 1.6 kpc).

These features displayed by CGCG014-074 would hint at a possible interaction with probably its companion NGC 4546 in the recent past. However, like the case of the dwarf galaxy LEDA 074886 (Graham et al., 2012), it cannot be ruled out that CGCG014-074 could be a remnant of two merged disk galaxies, where the initial gas was driven inwards forming the inner disk, while stars towards larger galactocentric radii experienced a dissipationless merger event giving rise to boxy isophotes.

For this reason, the next step in our study is to analyze long-slit GMOS spectroscopic data of dS0 to investigate its stellar populations and kinematics, and thus give us a more concrete idea about its history.

References:

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