Revisiting the low-luminosity galaxy population of the NGC 5846 group with SDSS

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ABSTRACT

Context. Low-luminosity galaxies are known to outnumber the bright galaxy population in poor groups and clusters of galaxies. Yet, the investigation of low-luminosity galaxy populations outside the Local Group remains rare and the dependence on different group environments is still poorly understood. Previous investigations revealed photometric scaling relations for early-type dwarfs and a strong dependence of morphology with environment.

Aims. The present study aims to analyse the photometric and spectroscopic properties of the low-luminosity galaxy population in the nearby, well-evolved and early-type dominated NGC 5846 group of galaxies. It is the third most massive aggregate of early-type galaxies after the Virgo and Fornax clusters in the local universe. Photometric scaling relations and the distribution of morphological types as well as the characteristics of emission-line galaxies are investigated.

Methods. Spectroscopically selected low-luminosity group members from the Sloan Digital Sky Survey with \( cz < 3000 \text{ km s}^{-1} \) within a radius of \( 2' = 0.91 \text{ Mpc} \) around NGC 5846 are analysed. Surface brightness profiles of early-type galaxies are fit by a Sérsic model \( \propto r^{1/n} \). Star formation rates, oxygen abundances and emission characteristics are determined for emission-line galaxies.

Results. Seven new group members showing no entry in previous catalogues are identified in the outer (>80 arcmin) parts of the system. Several photometric scaling relations for dEs as well as the morphology-density relation for dwarf galaxies are reproduced. Moreover, the correlation between host and satellite morphologies in poor groups of galaxies is confirmed. Nucleated dwarfs are found to be located in the vicinity to the brightest ellipticals in the group. Only two faint galaxies show fine structure. Emission-line dwarfs show no interaction induced activity.

Key words. galaxies: clusters: individual: NGC 5846 Group – galaxies: dwarf – galaxies: photometry – methods: data analysis

1. Introduction

Redshift surveys have shown that most galaxies in the nearby universe are located in poor groups (Tully & Fisher 1988). These aggregates are not only made up of the ordinary bright Hubble types but consist also of a low-luminosity dwarf galaxy population outnumbering their brighter counterparts by far. Previous observations studying the distribution and morphological properties of such low-luminosity galaxy populations have mainly focused on large-scale structures, e.g. the Virgo and Fornax clusters (Sandage & Binggeli 1984, Ferguson 1989) representative of high-density environments. Complementary, poor groups serve as ideal laboratory to study the environmental dependence of low-luminosity galaxy populations in a low-density environment with galaxy interactions, mergers, and the coalescence of individual galaxies as the driving physical processes. However, detailed photometry and spectroscopy of low-luminosity galaxies is challenging. Indeed, only the Local Group and a few other nearby galaxy aggregates have been investigated in detail to analyse the connection between low-luminosity galaxies to their environment (Karachentsev et al. 2002, Côté et al. 1997, Jerjen et al. 2000, Grützbauch et al. 2009). Because ΛCDM cosmology suggests a hierarchical growth of galaxies in the course of mergers, it is obvious to classify poor groups based on their optical morphologies (Zabludoff 1999). Spiral dominated aggregates represent un-evolved systems in this scenario while aggregates with tidal signatures and the formation of tidal dwarf galaxies mark an intermediate stage (Temporin et al. 2003). Groups dominated by early-type morphologies are in an advanced phase of coalescence. Dynamically, these well-evolved aggregates are more likely to show virialised systems compared to groups with a higher spiral fraction. Moreover, the dwarf-to-giant ratio (DGR) is expected to increase with time as bright, massive galaxies are more affected by mergers than their faint counterparts (Zabludoff & Mulchaey 1998). The number of faint galaxies in groups and clusters is puzzling, however. ΛCDM cosmology suggests more dwarfs than observed, an issue widely referred to as the missing satellite problem (Klypin et al. 1999).

This paper focuses on the low-luminosity galaxy population of the X-ray bright galaxy group around the giant elliptical NGC 5846 in the Local Supercluster. The group was first catalogued in de Vaucouleurs (1978). Since then, the system has appeared in many similar catalogues (Geller & Huchra 1983, Garcia 1993). Zabludoff & Mulchaey (1998) identified 13 dwarfs in the central region of the system. Mahdavi et al. (2005), hereafter [MTT05] state 251 ± 10 group members including 83 spectroscopically confirmed ones. Carrasco et al. (2006) have discovered 16 additional low surface brightness dwarfs. The NGC 5846 group of galaxies is located at a distance of 26.1 Mpc in the Virgo III Cloud of galaxies, a major component of the Local Supercluster (Tully 1982). Being an elongated structure ranging from the Virgo cluster out of the Supergalactic Plane, this cloud contains about 40 luminous galaxies with the NGC 5846 system as the biggest aggregate in the region. The
NGC 5846 group is the most massive of only three dense groups (NGC 4274, NGC 5846 and M96) in the Local Supercluster that are dominated by elliptical and lenticular galaxies, being the third most massive aggregate of early-type galaxies (after the Virgo and Fornax clusters) in the local universe. Moreover, with an average galaxy density of $p = 0.78 \pm 0.08$ Mpc$^{-3}$ compared to $p = 0.49 \pm 0.06$ Mpc$^{-3}$ for the Local Group and $p \sim 5$ Mpc$^{-3}$ for the central regions of the Virgo cluster, the NGC 5846 system presents also one of the densest galaxy environments found for poor groups. The group is dominated by early-type galaxies with a massive central elliptical surrounded by a symmetric X-ray halo. The large early-type fraction, the prevalence of dwarf galaxies together with the strong and extended diffuse X-ray emission marks the NGC 5846 group as an evolved system. The group is composed of two smaller aggregates around the two galaxies together with the strong and extended diffuse halo. The large early-type fraction, the prevalence of dwarf galaxies, and the strong and extended diffuse X-ray emission marks the NGC 5846 group as an evolved system.

The best-fit model is stored as the model magnitude. $M_B = -16$, UGC 9751 and UGC 9760 are listed as bright members due to their classification as Scd and Sd in NED.

Corrected FITS frames (bias subtracted, flat-fielded and cleaned of bright stars) have been extracted from the SDSS for these 55 dwarfs in the $g'$, $r'$ and $i'$ band. SDSS model magnitudes have been adopted from the database for each individual galaxy and transformed to the Johnson-Morgan-Cousins $B$ band via transformation equations from Smith et al. (2002). Absolute magnitudes were derived assuming an average extinction value of $A_B = 0.22$ from Schlegel et al. (1998) for the whole galaxy population. An isophote analysis was carried out for the $g'$-band example using the ellipse task within the IRAF stsdas package to fit ellipses to the galaxy images and measure the deviations from purely elliptical isophote shapes. A detailed description of the procedure is given by Jedrzejewski (1987). The analysis resulted in surface brightness profiles and the harmonic content of the isophotes. A Sérsic (1968) law

$$
\mu(r) = \mu_e + 1.086 \cdot b_n \cdot \left( (r/r_e)^{1/n} - 1 \right) $$

with an effective radius $r_e$, an effective surface brightness $\mu_e$ and a shape parameter $n$ as free parameters was fit to each object. The quantity $b_n$ is a function of $n$ and chosen so that half the galaxy luminosity is located within the effective radius. The fitting was carried out using a Levenberg-Marquardt algorithm until a minimum in $\chi^2$ was achieved, yielding the parameters $n$, $r_e$, and $\mu_e$ with the corresponding uncertainties. The innermost parts of the surface brightness profiles ($\leq 1.4$ arcsec) have not been taken into account for the fitting procedure due to seeing. Central surface brightnesses $\mu_0$, have been derived from the fit. The results of the isophote analysis are presented in Table 2, Sérsic models have been subtracted from the original images yielding residual frames which are investigated for photometric substructures. In addition to the photometric data, wavelength and flux calibrated spectra (sky subtracted and corrected for telluric absorption) have been examined for all sample galaxies. The spectra cover a wavelength range of $\lambda L_{3800}$ to $9200 \AA$ and have been checked for spectral lines in both emission and absorption. Identified spectral lines were fit by Gaussians yielding central wavelengths and full widths at half maximum (FWHM). The derived central wavelengths were subsequently used to verify SDSS redshifts.

### 2. Sample Selection and Data Analysis

In order to extend the existing sample of low-luminosity galaxies in the NGC 5846 system, we have queried the SDSS for all galaxies with $cz < 3000$ km s$^{-1}$ within a radius of $2'$, similar to the second turnaround radius $r_{2i} = 1.85'$. Galaxies beyond these limits are very likely to be characterised as field or background objects. The query resulted in a total sample of 74 galaxies: 19 bright objects and 55 dwarfs (see Table 1 and Figure 1) with seven objects found in the outer parts ($\geq 1.33'$) of the system that show no entry in previous catalogues. Though being slightly fainter than $M_B = -16$, UGC 9751 and UGC 9760 are listed as bright members due to their classification as Scd and Sd in NED.

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### 3. The Low-Luminosity Galaxy Population

Table 1 lists the NGC 5846 galaxy group sample as studied in this work. Morphological types for dwarfs have been classified through visual inspection of SDSS images and spectra. Objects with a smooth light distribution and exponential profiles were classified as dEs. The $g'$ ellipticity was determined from the isophote analysis. Dwarfs showing a blue patchy appearance and emission lines were classified as dIrrs. Morphological types for bright galaxies have been taken from NED. Dwarfs are identified with increasing projected radial distance from NGC 5846.
files or their compactness. 35 dwarfs (~63%) have been identified as dEs according to their optical appearance and red colours \((B-V)_0 \approx 0.85\). 18 objects (~32%) are dwarf irregulars showing a patchy, blue optical appearance with emission lines indicating ongoing star formation. Three galaxies (~1%) reveal photometric fine structure and are in the transition to bright galaxies. 11 dwarfs (~31% of the dEs) are found to be nucleated on basis of the analysis of the surface brightness profiles.

Our list of nucleated dwarfs is nearly identical to the list obtained by [MTT05] with exception of only three objects classified differently. Taking the Schechter luminosity function derived by [MTT05], we conclude that with an absolute magnitude of \(M_B = -13.32\) for our faintest object, the sample of our work comprises at most 34% of the total number of galaxies expected in the system down to a limiting magnitude of \(M_B = -10\). Our sample yields a dwarf-to-giant-ratio (DGR) of \(\sim 3\) as lower limit. Following the photometric dwarf classification of [MTT05], this value could rise to \(\sim 12\), confirming that the NGC 5846 group is indeed one of the richest groups in the Local Supercluster.

The projected spatial distribution of all investigated galaxies is illustrated in Figure 1. The distribution indicates two substructures of the system around the two brightest ellipticals NGC 5846 and NGC 5813. A third, however much smaller subgroup can be found around UGC 9760, which in contrast to the NGC 5846 and NGC 5813 aggregates shows no noteworthy X-ray counterpart. We present on Figure 2 a colour-magnitude diagram for the studied group galaxy population. The diagram indicates the prevalence of an early-type dwarf morphology and the continuation of a red sequence similar to that found in galaxy clusters [Gladders et al. 1998] into the dwarf regime. Figure 3 shows the \(n - M_B\) relation consisting of our dE sample as well as the bright galaxies classified as ellipticals in NED. Sérsic shape parameters of the low-luminosity galaxy population show a mean value of \(n = 1.19\) with a scatter of \(\sigma_n = 0.23\) representing nearly exponential surface brightness profiles as expected for dwarf ellipticals. Three dwarfs (N5846_10, N5846_15, N5846_43) show comparatively large error bars of the shape parameter due to their faintness or contamination of the surface brightness profile by a central nucleus. Our data confirm the trend of more luminous galaxies showing greater shape parameters, thus a steeper surface brightness profile than the less luminous objects. Interestingly there are no objects with intermediate Sérsic parameters between \(2 < n < 3\).
NGC 5813 shows a comparatively high shape parameter around $n \sim 8$.

3.1. Scaling relations

When addressing the question of the influence of the environment on the evolution of galaxies, scaling relations of the photometric properties of early-type galaxies are a useful tool. However, the environment does not seem to affect all early-type systems alike. The fundamental plane of bright ellipticals is found as much independent of environment as possible, while dwarf ellipticals show a stronger variation (Nieto et al. 1990; Peterson & Caldwell 1993). Elliptical galaxies and bulges are known to show a tight correlation in the $\mu - M_B$ plane with higher surface brightnesses indicating smaller total luminosities (Kormendy 1977). Dwarf galaxies exhibit an opposite trend, being a distinct class of objects with possibly different formation and evolution histories. Binggeli & Jerjen (1998), hereafter [BJ98] have investigated the $\mu - B$ plane for Virgo cluster early-type dwarfs and confirm this trend. Figure 4(a) shows the $\mu_{0\mathrm{ff}} - M_B$ plane for our dEs and the relationship taken from the [BJ98](dash-dotted line) sample of Virgo dwarf ellipticals (assuming a Virgo distance of 16.5 Mpc corresponding to a distance modulus of $\sim 31.09$). Remaining relations 4(b)-(f) focus on $M_B$, $\log n$, $\mu_{0\mathrm{ff}}$, $\log r_0$ and ellipticity $\epsilon$. Sérsic shape parameters used here should not be mixed up with those of [BJ98]: $n = 1/n_{\text{BESS}}$. The parameter $r_0$ is the scale radius of the Sérsic model: $I(r) = I_0 \exp[-(r/r_0)^{1/n}]$. Table 2 presents the corresponding values of the isophote analysis. Objects with larger errors than the data itself are not listed.

Our data in the $\mu_{0\mathrm{ff}} - M_B$ plane are in agreement with the work of [BJ98]. One object falling outside the $2\sigma$ limit is N5846_01 with a comparatively too high surface brightness with respect to its luminosity (see section 3.2). In the log $n - M_B$ plane, our data show a larger scatter $\sigma_{\log n} = 0.19$. Compared to the dwarf sample of the Virgo cluster, our dwarfs match the Virgo dwarf relation, however. Our sample also confirms the trend between shape parameter $n$ and scale radius $r_0$ with smaller objects exhibiting higher shape parameters. Again N5846_01 is the only object in our sample to fall off the trend. The scale radius $r_0$ shows also a strong correlation with the central surface brightness as seen in the $\mu_{0\mathrm{ff}} - \log r_0$ plane. The NGC 5846 dwarfs match with the relation obtained for the Virgo dwarfs with a lower scatter in magnitude ($\sigma = 0.83\text{mag arcsec}^{-2}$) than [BJ98] who derive a value of $\sigma = 1.25\text{mag arcsec}^{-2}$. Similarly to [BJ98] we also derived the best fitting linear combination between shape parameter $n$, central surface brightness $\mu_0$ and absolute $B$ band magnitude with a scatter of $\sigma = 0.59\text{mag}$. Finally, we also checked for a correlation between shape parameter $n$ and ellipticity. There is a slight trend of flattened objects showing shallower surface brightness profiles.

The structural properties of early-type systems can furthermore be investigated in the Hamabe & Kormendy (1987) relation, a photometric projection of the fundamental plane of galaxies relating the logarithm of effective radii and effective surface brightnesses linearly (Ziegler et al. 1999; di Serego Alighieri et al. 2005). This relation divides early-type systems in regular and bright classes separated at the effective radius of $r_e \approx 3 \text{kpc}$ (Capaccioli et al. 1992). In hierarchical evolution scenarios, regular galaxies are thought to be the progenitors of bright ones evolving through successive mergers along the Hamabe-Kormendy relation (Cappellato et al. 1995). However, recent numerical simulations of Efstathiou et al. (2004) suggest that low mass systems like dwarf galaxies can only follow this scenario with a large amount of dissipation involved. Figure 5 shows the Hamabe-Kormendy relation for the faint galaxy population of our work. Open squares are dwarfs from X-ray dim and X-ray bright groups studied by Khosroshahi et al. (2004). All faint galaxies of our sample represent regular systems and show properties similar to the dwarfs from Khosroshahi et al. (2004) suggesting no strong difference of the structural properties of the early-type dwarfs from the NGC 5846 group compared to other group environments. Again, N5846_01 is the only dwarf clearly separated from the main cloud of dEs.

3.2. Comments on individual objects

Most of the investigated dwarfs do not show any photometric or spectroscopic peculiarities. A few galaxies in the sample are worth a closer look, however. Figure 6 presents all objects which evidently exhibit fine structure in their optical appearance with $r'$ band images and residual frames shown for each galaxy. These objects lie furthermore in the transition to bright galaxies due to their relatively large angular diameter.

N5846_01 is the closest dwarf elliptical to NGC 5846 with a much higher central surface brightness than the rest of our dwarfs. It is furthermore the most reddish galaxy from our low-luminosity galaxy sample. With an average effective radius of only $r_e \sim 200 \text{pc}$ in all studied passbands, this object is also the most compact of our sample. Due to the visual appearance and the close proximity to NGC 5846, (MTT05) suggested that N5846_01 has very likely been affected by tidal stripping and can therefore rather be classified as ultra compact dwarf. This idea is also supported by the fact that the nearby object NGC 5846A shows a similar morphological appearance. In fact, NGC 5846A is one of the extremely rare "compact ellipticals" like M32, the prototypical object of this class. Thus, NGC5846_01 fits per-
Fig. 4. Photometric scaling relations of the low-luminosity galaxy population in the NGC 5846 group. (a)-(d): dash-dotted lines are the relations of the Virgo cluster early-type dwarfs from [BJ98] assuming a distance to the Virgo cluster of 16.5 Mpc. The scatter of our data with respect to the [BJ98] relations is given in the lower left corner of each panel. $1\sigma$ deviations are indicated as dashed lines. (a): $\mu_0 - M_B$ plane. N5846_01, classified as ultra-compact dwarf by [MTT05] is located outside $2\sigma$. (e): best-fitting linear combination of shape parameter $n$ and central surface brightness $\mu_0$ with respect to absolute magnitude $M_B$. N5846_01 was excluded from the fit and is not shown in the diagram. The dotted line indicates identity. (f): Sérsic shape parameter versus ellipticity. Objects with high ellipticity tend to have shallower surface brightness profiles. The dotted line indicates an exponential profile.
fectly into the picture that the structural differences of compact ellipticals and ordinary dEs result from the fact that the com-

Many of the compact galaxies have a mass of $M_{25} \sim 7 \text{kpc}$ which locates the galaxy in the transition between bright and dwarf galaxies. The spectrum of NG5846.07 reveals strong He emission together with the weaker H$_\alpha$, [NII] and [SII] features indicating ongoing star formation. Two spiral arms are identified in the optical image which could also be interpreted as signatures of ongoing interaction with the nearby irregular dwarf NG5846.08, only 21kpc away.

NG5846.41/42 are two large HII regions of the irregular dwarf KKR15 (Huchtmeyer et al. 2000; Karachentseva et al. 1999) classified as individual galaxies in SDSS. The host galaxy shows an extremely blue colour, the majority of light contained in the two HII regions with the brighter one, NG5846.41, being the bluest object of our sample. Due to the high concentration of light, NG5846.41/42 are present by far the highest S/N ratio of all spectra in our sample. Besides the usual H$_\alpha$, H$_\beta$, [OIII], [NII] and [SII] features both spectra also show the weaker Balmer lines H$_\gamma$, H$_\delta$, H$_\epsilon$ along with the more uncommon HeI $\lambda$5875.6, [Ne III] $\lambda$3867.8 and ArII $\lambda$7135.8 transitions. Of all emission-line galaxies in our sample, NG5846.41/42 show the lowest oxygen abundance with an average value of $12+\log(O/H)=7.68$ (see section 3.3).

NG5846.54 and NG5846.55 were both classified as S0 galaxies in the [M96] sample and are the only objects of our work that show photometric substructures. With a projected linear extent of $D_{25} \sim 4$ and 7 kpc these objects can, similarly to NG5846.07, be placed in the transition to dwarf galaxies. The surface brightness profile of NG5846.55 exhibits a rather flat gradient up to 1 arcsec, wherefrom the light distribution falls much steeper, indicating a possible bar feature (Gadotti et al. 2007). Spectroscopically, both galaxies show ongoing star formation.

### 3.3. Spatial distribution of morphological types

We have studied the morphology distribution for the low-luminosity galaxy population in the NGC 5846 system for both the early- and late-type populations. Figure 7 illustrates the clustering for both the dE and dIrr samples with the projected number density shown separately for each morphological type. The diagram displays the same field of view as presented in Figure 1. Density contours have been created using a grid with a spatial resolution of 0.5° × 0.5°. The segregation between early- and
late-type low-luminosity galaxies in the NGC 5846 system is evident: dwarf ellipticals are found predominantly in the vicinity of bright galaxies while irregulars are clearly detached from this distribution and diffusely arranged in the outer regions of the group. Morphology shows also a strong correlation with the projected number density. Early-type dwarps populate the high-density regions around NGC 5846 and NGC 5813, while irregulars show comparatively low agglomeration. Moreover, the satellite morphologies resemble the morphology of their elliptical hosts (NGC 5846 and NGC 5813). Similar results have been found by Weinmann et al. (2006) who, on the basis of a large sample of SDSS groups, inferred that the satellite morphologies in groups correlate strongly with the morphology of the central host galaxy. Regarding the radial morphology distributions, Figure 7 indicates that the projected number density of the early-type population shows a much higher radial gradient than the irregular subsample, merely presenting any radial variation. In addition to the optical picture, the diffuse X-ray component correlates also with the early-type dwarf distribution (see MTT05), indicating the dark matter potentials of the group. We have also checked the distribution of nucleated dwarps within the NGC 5846 system shown in Figure 8. With the exceptions of two objects, all nucleated dwarps are in the vicinity (~260kpc) of NGC 5846 and NGC 5813. Research on the distribution of nucleated dwarps in the Virgo cluster has also shown that nuclei are predominantly found in the central regions and not in the outskirts (Binggeli & Cameron 1999), Oh & Lin 2000) argued that this could be explained assuming nuclei to be the result of orbital decay of globular clusters. Through a series of numerical simulations they showed that for dwarf galaxies exposed to little external tidal perturbation dynamical friction can lead to significant orbital decays of globular clusters and the formation of compact nuclei within a Hubble-time. Thus, a larger fraction of nucleated dwarps is expected in the centres of galaxy clusters where the extragalactic tidal perturbation tends to preserve the integrity of dwarf galaxies unlike in the outskirts where this perturbation tends to be disruptive.

### 3.4. Emission-line dwarfs

Line fluxes from H$\alpha$, H$\beta$, [N $\alpha$] $\lambda\lambda6548.1, 6583.4$ Å, [O $\text{III}$] $\lambda\lambda4959.9, 5006.8$ Å, and [S $\text{II}$] $\lambda\lambda6717.0, 6731.3$ Å features together with star formation rates and oxygen abundances have been measured for dwarps showing emission lines in their spectra. The data are presented in Table 3. Star formation rates (SFRs) were derived via H$\alpha$ fluxes using the Kennicutt (1998) relation: SFR($M_\odot$ year$^{-1}$) = 7.9 $\cdot$ 10$^{-42}$ L(H$\alpha$) ergs s$^{-1}$). H$\alpha$ extinction was taken into account using an average extinction value of 1.10 mag for H$\alpha$. Extinction and reddening effects together with specific absorption components underlying H$\alpha$ and H$\beta$ can considerably affect line flux measurements. A correction was applied to the

| galaxy | H$\beta$ | [O $\text{III}$] $\lambda\lambda4959.9, 5006.8$ Å | [O $\text{III}$] $\lambda\lambda6548.1, 6583.4$ Å | [N $\text{II}$] $\lambda\lambda6548.1, 6583.4$ Å | H$\alpha$ | [N $\text{II}$] $\lambda\lambda6548.1, 6583.4$ Å | [S $\text{II}$] $\lambda\lambda6717.0, 6731.3$ Å | SFR | 12 + log(O/H) |
|--------|--------|---------------------------------|---------------------------------|---------------------------------|--------|---------------------------------|---------------------------------|--------|----------------|
| N5846a | 548.1  | 45.8                            | 128.4                           | 14.0                            | 922.0  | 51.7                            | 47.7                            | 0.0084(3) | 8.2(1)         |
| N5846b | 619.6  | -                               | 4.2                             | 62.5                            | 1765.9 | 173.7                           | 107.2                           | 81.3            | 0.0114(4) | 8.4(1) |
| N5846c | 79.0   | -                               | 18.9                            | 3.1                             | 225.1  | 8.5                             | 21.4                            | 16.5            | -             | 8.1(1) |
| N5846d | 300.1  | 93.9                            | 270.4                           | 7.9                             | 855.4  | 16.6                            | 47.6                            | 26.7            | 0.0055(3) | 7.8(2) |
| N5846e | 409.9  | 71.9                            | 212.0                           | 10.1                            | 1168.3 | 47.8                            | 89.3                            | 64.0            | 0.0075(4) | 8.1(2) |
| N5846f | 149.7  | -                               | 39.9                            | 17.5                            | 487.5  | 42.4                            | 51.4                            | 37.5            | -             | 8.4(1) |
| N5846g | 30.7   | -                               | 7.7                             | -                               | 51.0   | 7.2                             | 12.5                            | 8.0             | -             | 8.5(1) |
| N5846h | 46.7   | -                               | -                               | -                               | -      | -                               | -                               | -               | -             | 8.6(1) |
| N5846i | 29.7   | -                               | -                               | -                               | -      | -                               | -                               | -               | -             | 8.6(1) |
| N5846j | 298.8  | 15.6                            | 50.1                            | 21.2                            | 851.5  | 67.1                            | 64.5                            | 52.6            | 0.0055(3) | 8.3(1) |
| N5846k | 103.8  | 12.1                            | 40.8                            | 8.6                             | 298.8  | 20.5                            | 16.2                            | 14.4            | -             | 8.3(1) |
| N5846l | 34.0   | -                               | 10.4                            | -                               | 96.8   | 9.3                             | 19.2                            | 12.7            | -             | 8.4(1) |
| N5846m | 428    | -                               | -                               | -                               | -      | -                               | -                               | -               | -             | 8.4(1) |
| N5846n | 2576.2 | 1222.0                          | 3664.0                          | 20.6                            | 7342.2 | 68.1                            | 182.0                           | 127.8           | 0.0473(9) | 7.6(2) |
| N5846o | 914.9  | 475.5                           | 1385.0                          | 10.9                            | 2607.5 | 31.4                            | 76.4                            | 48.9            | 0.0168(5) | 7.7(2) |
| N5846p | 233.7  | 15.3                            | 43.8                            | 16.6                            | 637.6  | 51.7                            | 53.9                            | 43.1            | 0.0041(3) | 8.3(1) |
| N5846q | 28.9   | -                               | 8.7                             | -                               | 82.3   | 2.4                             | 5.3                             | 7.7             | -             | 8.0(1) |
| N5846r | 32.2   | -                               | -                               | -                               | -      | -                               | -                               | -               | -             | 8.3(1) |
| N5846s | 38.8   | -                               | -                               | -                               | -      | -                               | -                               | -               | -             | 8.3(1) |
| N5846t | 38.8   | -                               | -                               | -                               | -      | -                               | -                               | -               | -             | 8.3(1) |

Table 3. Spectral properties of emission-line dwarfs. Fluxes present the integrals of the fitted Gaussians and are given in units of 10$^{-17}$ ergs s$^{-1}$ cm$^{-2}$. H$\alpha$ and H$\beta$ fluxes have been corrected for extinction. Numbers in parentheses indicate errors of the last significant digit.
Fig. 6. Modeling of faint galaxies with significant fine structure. Figures show SDSS $r'$ band images (upper panel) and residual images (lower panel) of N5846_07, N5846_54 and N5846_55. Since no Sérsic model was obtained for N5846_07, gaussian smoothing was applied to the galaxy.

emission-line galaxies by taking $H\alpha$ extinction into account and assuming a Balmer decrement of $H\alpha/H\beta = 2.85$ for HII region-like galaxies (Veilleux & Osterbrock 1987) to consider $H\beta$ extinction too.

Figure 9 distinguishes HII region-like galaxies from AGNs such as Seyferts or LINERS, according to the diagnosis proposed by Veilleux & Osterbrock (1987). All emission-line galaxies can be explained by photoionization. Only few bright galaxies have SDSS spectra. Furthermore their $H\beta$ flux is strongly contaminated by the old stellar population, which makes a proper measurement of the line ratio problematic. In addition, the [OIII] feature at $\lambda 5007\AA$ is not seen in most of the investigated bright galaxies. However, just from the measurements of the [NII]$\lambda 6583/H\alpha$ and [SII]($\lambda 6716 + \lambda 6731$)/$H\alpha$ ratios, all these objects can be classified as HII region-like objects. There is no evident correlation between star formation activity and location of emission-line dwarfs within the group. Lequeux et al. (1979) suggested that the oxygen abundances correlate with total galaxy mass for irregular galaxies with more massive galaxies exhibiting higher metal content. Since the galaxy mass is a poorly known parameter, the metallicity-luminosity relation instead of the mass-metallicity relation is usually considered. Figure 10 shows the oxygen abundance of emission-line dwarfs measured via the $N_2$ method versus absolute blue magnitude. Most of our dwarfs lie above the metallicity-luminosity relation from Richer & McCall (1995). Only the two HII regions N5846_41/42 of KKR15 (Huchtmeier et al. 2000) (see Section 3.2) and N5846_12 fall below this sequence. The error bars reflect merely the uncertainty of the $N_2$ flux ratio and the error of the linear least squares fit of Denicolò et al. (2002).

4. Discussion and Conclusions

We have undertaken an analysis of the photometric and spectroscopic properties of the low-luminosity galaxy population of the NGC 5846 group of galaxies located in the Virgo III Cloud of galaxies in the Local Supercluster. The group is of particular interest since it is the most massive of only three dense groups (NGC 4274, NGC 5846 and M96) in the Local Supercluster that are dominated by elliptical and lenticular galaxies, being the third most massive aggregate of early-type galaxies (after the Virgo and Fornax clusters) in the local universe. Of the 19 bright galaxies in our sample, E and S0 galaxies amount to ~58%. Seven new group members in the outer regions (>80 arcmin) of the group have been identified via SDSS and NED redshifts complementing existing member catalogues.

The dwarf-to-giant-ratio (DGR) of the NGC 5846 system is large: our sample of spectroscopically determined group members yields a DGR of ~3. Taking into account the photometric classification of group members down to $M_R = -10$ by [MTT05] this value could rise up to ~12. Ferguson & Sandage (1991) have shown that the DGR increases with the richness of a group and constitute an early-type-dwarf-to-giant-ratio (EDGR), ($dE+dE,N+dS0$ over $E+S0$) of 5.77 for the Virgo cluster and 3.83 for the Fornax cluster down to $M_B = -13.5$. For the Coma cluster Secker & Harris (1996) state an EDGR of 5.80 ± 1.33 down to $M_B = -13.5$. Our data yield an EDGR of 2.69 for the NGC 5846 system down to our faintest dwarf ($M_B = -13.32$). This value shows that the NGC 5846 system has less early-type dwarfs per giant early-type galaxy compared to clusters but still a much larger EDGR than other groups (Leo: 1.48, Dorado: 1.44, NGC 1400: 2.08; all down to $M_B = -13.5$, see Ferguson & Sandage (1991)), indicating that NGC 5846 is indeed one of the more massive aggregates in the Local...
A colour-magnitude diagram of the investigated group members reveals a red sequence displaying the well-known trend of early-type galaxies exhibiting redder colours (higher metallicities) for higher luminosities (Caldwell 1983). In contrast, irregular dwarfs do not form a sequence but show a large spread in colours. There is no evident segregation between bright galaxies and dwarfs.

Photometric scaling relations have been studied for early-type dwarfs and compared with the relations derived by [BJ98] for Virgo cluster dwarf ellipticals. If bright ellipticals and early-type dwarfs share a similar evolution, a continuous sequence in scaling relations with respect to the galaxy luminosity would be expected. It is known that in the surface-brightness-luminosity ($\mu - M$) plane (Kormendy 1977), early-type dwarfs and bright ellipticals follow different trends, marking dwarf galaxies a distinct class of objects that have undergone a different evolutionary path compared to ordinary ellipticals. Our data match the trends from Virgo cluster dEs suggesting a similar evolutionary path compared to ordinary ellipticals. Our data also show that early-type dwarfs with high ellipticity tend to have shallower surface brightness profiles. We also checked the location of the NGC 5846 low-luminosity galaxy population in the $\mu_e - \log(r_e)$ plane with respect to the Hamabe-Kormendy relation, a photometric projection of the fundamental plane of galaxies relating the logarithm of effective radii and effective surface brightnesses linearly. The NGC 5846 dwarfs represent regular galaxies in the classification of Capaccioli et al. (1992), indicating that these systems are the building blocks of more massive galaxies, in agreement with $\Lambda$CDM cosmology. Moreover, the dwarfs are comparable with dwarfs from X-ray dim and X-ray bright groups studied by Khosroshahi et al. (2004).

Scaling relations for dwarf ellipticals are not the only way to enlighten their origin and evolution. Morphological segregation within clusters and groups also gives the opportunity to test the formation and environmental dependence of the faint galaxy population. The well-known morphology-density relation (Dressler 1980) is not only restricted to the normal Hubble types but is also found to apply to dwarf galaxies (Binggeli et al. 1987). This relation has been investigated in detail in our immediate vicinity, the Local Group (Grebel 1999). We confirm this morphology-density relation for dwarf galaxies in the NGC 5846 system. While early-type dwarfs are concentrated around the two massive ellipticals NGC 5846 and NGC 5813, objects of irregular type are more randomly distributed and found predominantly in the outer regions. This morphological segregation could be explained by gas stripping due to the infall of the dwarfs in the group centre. This scenario was also investigated by Weinmann et al. (2006) and Park et al. (2008), who inferred that satellite morphologies in groups tend to be similar to those of hosts. With the comparatively high density of the NGC 5846 system and the hot and dense halo gas present around NGC 5846 and NGC 5813, the dependence of the satellite morphology on host morphology can be interpreted by the hydrodynamic and radiative interaction of the hot X-ray

Fig. 9. Classification of emission-line galaxies in the NGC 5846 group according to Veilleux & Osterbrock (1987). The line separates HII region-like galaxies from AGNs. All measured objects show flux ratios explained by simple photoionization.

Supercluster.

A colour-magnitude diagram of the investigated group members reveals a red sequence displaying the well-known trend of early-type galaxies exhibiting redder colours (higher metallicities) for higher luminosities (Caldwell 1983). In contrast, irregular dwarfs do not form a sequence but show a large spread in colours. There is no evident segregation between bright galaxies and dwarfs.
gas of the two host galaxies with their surrounding satellites. We have also checked the distribution of nucleated dwarfs in the NGC 5846 system with respect to non-nucleated ones. Interestingly, nearly all dwarfs that show a nucleus superimposed on the underlying smooth surface brightness profile are found in the vicinity of NGC 5846 and NGC 5813 within a radius of ∼260kpc. This is in agreement with the work of Binggeli & Cameron (1991) on the Virgo cluster, who show that dwarfs located near the centre of the cluster are mostly nucleated while those in the outskirts are non-nucleated. Assuming the formation of the nuclei due to the orbital decay of globular clusters, Oh & Lin (2003) argued that this could be explained by extragalactic tidal perturbation which tends to preserve the integrity of dwarf galaxies at cluster centres but tends to disrupt dwarf galaxies in their outskirts.

Only two objects of the low-luminosity galaxy population show photometric fine structure. These galaxies exhibit ongoing star formation and diameters in the transition to bright galaxies. This lack of photometric peculiarities in the low-luminosity galaxy population emphasises the fact that the NGC 5846 system is an old, well-evolved aggregate where no recent interactions between individual members have occurred. Emission characteristics and star formation rates of the irregular dwarfs show typical values for low-luminosity galaxies, additionally supporting the idea of a system without recent activity enhancing star formation. Oxygen abundances have been derived indirectly via the \(N_2\) method as proposed by Deniclo et al. (2002). Our abundances show a large scatter (\(\sigma = 0.36\) dex) with respect to the metallicity-luminosity relation of Richer & McCall (1995) due to the intrinsic scatter in the \(N_2\) method itself. Nevertheless, all objects outside 1σ deviations lie above the metallicity-luminosity relation, indicating a comparatively high oxygen abundance for irregular
dwarfs in the NGC 5846 group.

The study of the low-luminosity galaxy population of the NGC 5846 group has revealed that the dwarf galaxies in this massive group match the trends observed for dwarf galaxies in other aggregates indicating a similar formation and evolution scenario. The spatial distribution of morphological types suggests that the structural properties of dwarf galaxies are clearly dependent on the location within the group. The structural properties of the dwarfs confirm the evolved state of the system. The group remains special due to the dominating early-type morphology, the strong X-ray emission and the large dwarf-to-giant-ratio compared to other groups.

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| galaxy      | [MTT05] | $\alpha_{2000}^d$ | $\delta_{2000}^d$ | $d$ [arcmin] | $cz$ [km s$^{-1}$] | $v^b$ | $r^b - r^{1b}$ | $M_{B}$ | type  |
|-------------|---------|-----------------|-----------------|--------------|---------------------|------|----------------|-------|-------|
| NGC 5806    | 037     | 15 00 00.39     | 01 53 28.7      | 98.7         | 1350±30            | 11.41| 0.46           | -19.03| SAB(s)b |
| NGC 5846    | 042     | 15 00 16.58     | 02 18 02.6      | 102.1        | 1830±30            | 14.19| 0.36           | -16.55| S0     |
| NGC 5811    | 046     | 15 00 27.40     | 01 37 24.1      | 90.5         | 1529±15            | 13.83| 0.31           | -17.30| SB(s)m  |
| NGC 5846    | 048     | 15 00 33.03     | 02 13 49.2      | 96.6         | 1260±30            | 16.03| 0.27           | -14.83| dE,N   |
| NGC 5846    | 055     | 15 00 52.59     | 01 24 17.7      | 85.0         | 1890±60            | 15.35| 0.35           | -15.37| dE5,N   |
| NGC 5846    | 058     | 15 00 59.36     | 01 52 36.2      | 84.1         | 2190±90            | 17.56| 0.28           | -13.32| dE,N   |
| NGC 5846    | 059     | 15 00 59.36     | 01 38 57.1      | 82.5         | 2430±60            | 16.80| 0.41           | -13.84| dE1    |
| NGC 5846    | 060     | 15 01 00.86     | 01 00 49.8      | 89.5         | 1740±30            | 17.48| -0.10          | -14.15| dIrR   |
| NGC 5854    | 061     | 15 01 03.11     | 00 42 27.4      | 97.7         | 1770±60            | 14.69| 0.32           | -16.20| S0/a   |
| NGC 5846    | 063     | 15 01 06.96     | 02 05 25.2      | 85.7         | 1950±60            | 17.11| 0.24           | -13.74| dE     |
| NGC 5813    | 064     | 15 01 11.23     | 02 42 07.1      | 79.7         | 1973±60            | 10.75| 0.46           | -19.63| E1-2   |
| NGC 5846    | 068     | 15 01 15.33     | 01 29 53.5      | 78.8         | 2220±90            | 16.57| 0.27           | -14.62| dIrR   |
| NGC 5846    | 069     | 15 01 15.89     | 01 46 24.5      | 79.0         | 1500±60            | 16.73| 0.27           | -14.24| dE5,N   |
| NGC 5846    | 073     | 15 01 38.38     | 01 43 19.8      | 73.1         | 2280±60            | 16.47| 0.40           | -14.22| dE2,N   |
| NGC 5846    | 075     | 15 01 38.61     | 01 52 12.6      | 74.4         | 2160±30            | 16.42| 0.27           | -14.62| dIrR   |
| NGC 5846    | 083     | 15 02 03.50     | 01 50 28.6      | 67.9         | 1241±06            | 13.62| 0.24           | -17.55| SB(rs)d |
| NGC 5846    | 088     | 15 02 28.13     | 01 21 51.1      | 62.0         | 1470±90            | 17.11| 0.25           | -13.95| dE     |
| NGC 5846    | 090     | 15 02 33.02     | 01 56 08.2      | 62.3         | 1650±60            | 17.07| 0.24           | -13.93| dE     |
| NGC 5846    | 091     | 15 02 36.03     | 02 01 39.5      | 63.6         | 1980±60            | 16.87| 0.33           | -13.99| dE5,N   |
| NGC 5846    | 113     | 15 03 44.28     | 02 33 08.1      | 70.2         | 1770±60            | 16.21| 0.29           | -14.65| dE1    |
| NGC 5846    | 114     | 15 03 49.93     | 00 58 31.7      | 54.9         | 2010±90            | 15.88| 0.07           | -15.65| dIrR   |
| NGC 5846    | 115     | 15 03 50.31     | 01 07 36.5      | 49.0         | 1590±30            | 14.85| 0.39           | -15.79| dE3    |
| NGC 5846    | 115     | 15 03 50.31     | 01 07 36.5      | 49.0         | 1590±30            | 14.85| 0.39           | -15.79| dE3    |
| NGC 5846    | 115     | 15 03 50.31     | 01 07 36.5      | 49.0         | 1590±30            | 14.85| 0.39           | -15.79| dE3    |

Table 1. Galaxies within 2' around NGC 5846 as studied in this work.
Table 1. continued.

| galaxy   | [MTT05] | $\alpha_{2000}$ | $\delta_{2000}$ | $d$ [arcmin] | $cz$ [km s$^{-1}$] | r' - i' | $r^{gb}$ | $M_B$ | type       |
|----------|---------|-----------------|-----------------|--------------|------------------|--------|--------|------|------------|
| N5846.23 | 287     | 15 09 07.86     | 00 43 29.5      | 66.1         | 1680±30          | 0.24   | -14.43 |      | dIrr       |
| N5846.24 | 290     | 15 09 14.97     | 01 55 17.1      | 45.5         | 1740±30          | 0.31   | -15.44 |      | dE4       |
| NGC 5864 | 299     | 15 09 33.56     | 03 03 09.9      | 98.3         | 1800±30          | 0.40   | -19.21 |      | SB(s)sp   |
| NGC 5869 | -       | 15 09 49.41     | 00 28 12.2      | 84.5         | 1934±15          | 0.39   | -19.01 |      | S0        |
| UGC 9746 | 305     | 15 10 16.54     | 01 56 03.3      | 60.1         | 1830±60          | 0.33   | -17.24 |      | Sbc       |
| UGC 9751 | 311     | 15 10 58.44     | 01 26 15.9      | 68.0         | 1574±15          | 0.26   | -15.80 |      | Scd       |
| N5846.34 | 313     | 15 11 01.33     | 01 40 50.1      | 68.2         | 1710±30          | 0.32   | -14.81 |      | dE2       |
| N5846.36 | 317     | 15 11 21.63     | 01 36 37.6      | 73.1         | 1950±90          | 0.21   | -14.70 |      | dE        |
| UGC 9760 | 321     | 15 12 02.18     | 01 41 51.3      | 83.4         | 2024±03          | 0.38   | -16.15 |      | Sd        |
| N5846.46 | 323     | 15 12 08.15     | 01 35 08.6      | 84.7         | 2010±60          | 0.28   | -15.25 |      | dE1       |
| N5846.52 | -       | 15 12 24.05     | 02 04 48.2      | 93.1         | 1740±30          | 0.32   | -15.17 |      | dE3,N     |
| N5846.56 | -       | 15 12 31.74     | 00 48 45.3      | 102.3        | 1830±60          | 0.32   | -15.82 |      | dlrr      |
| N5846.51 | -       | 15 12 41.39     | 01 37 23.7      | 93.0         | 1920±60          | 0.28   | -14.80 |      | dE4       |

$^a$ galaxy identification from Mahdavi et al. (2005)
$^b$ coordinates and magnitudes taken from SDSS DR4
$^c$ projected radial distance to NGC 5846
$^d$ N5846.41/42 are two HII regions classified as individual galaxies in SDSS (see section 3.2)