An $\text{H}\alpha$ survey of cluster galaxies V: cluster – field comparison for early-type galaxies

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ABSTRACT

We have extended our $\text{H}\alpha$ objective prism survey of 8 low-redshift clusters (viz. Abell 262, 347, 400, 426, 569, 779, 1367 and 1656) to include a complete sample of early-type galaxies within 1.5 Abell radii of the cluster centres. Of the 379 galaxies surveyed, 3% of E, E–S0 galaxies, 6% of S0s and 9% of S0/a galaxies were detected in emission. From a comparison of cluster and supercluster field galaxies, we conclude that the frequency of emission-line galaxies (ELGs; $W_\lambda \geq 20\text{Å}$) is similar for field and cluster early-type galaxies. A similar result has previously been obtained for galaxies of types Sa and later. Together, these results confirm the inference of Biviano et al. that the relative frequency of ELGs in clusters and the field can be entirely accounted for by the different mix of morphological types between the differing environments, and that, for galaxies of a given morphological type, the fraction of ELGs is independent of environment. Detected emission is classified as ‘compact’ or ‘diffuse’, identified as circumnuclear starburst or AGN emission and disk emission respectively. By comparing spectroscopic data for cluster early-type ELGs with data for field galaxies from the Palomar Spectroscopic Survey of nearby galactic nuclei, we demonstrate there is modest evidence for an enhancement of compact HII emission relative to AGN emission in the early-type cluster ELGs as compared to the field. For the cluster early-type galaxies, compact HII emission correlates strongly with a disturbed morphology. This suggests that, as for later type cluster galaxies, this enhanced compact HII emission can readily be explained as an enhancement of circumnuclear starburst emission due to gravitational tidal interactions, most likely caused by sub-cluster merging and other on-going processes of cluster virialisation.

Key words: surveys – galaxies: clusters:general – galaxies: elliptical and lenticular,cD – galaxies: evolution – galaxies: interactions – galaxies: starburst

1 INTRODUCTION

Clusters of galaxies are sites of strong morphological evolution of disk galaxies. While the fraction of ellipticals in clusters remains relatively unchanged with redshift, the fraction of spirals is 2–3 times larger in intermediate redshift clusters as compared to the present, with a corresponding decrease in the S0 population (Dressler 1980; Dressler et al. 1997). This dramatic change in the disk galaxy population since $z \sim 0.5$ suggests that processes associated with cluster virialisation cause the transformation of spirals to S0s.

Although a variety of mechanisms have been proposed to explain the morphological change of cluster disk galaxies, there is growing evidence to suggest that gravitational tidal effects are the predominant mechanism for these transformations. Intermediate redshift clusters have an unexpectedly high proportion of galaxies with unusual morphology, suggestive of merging and tidally interacting systems (e.g. Lavery & Henry 1988; Thompson 1988; Lavery, Pierce & McClure 1992; Dressler et al. 1994; Couch, Ellis & Sharples 1994; Oemler, Dressler & Butcher 1997). Furthermore, the dynamically interacting galaxies seem to be responsible for most of the galaxies that show spectroscopic signs of starbursts (Oemler et al. 1997), as may be expected from the consequences of tidal interactions (e.g. Barton et al. 2000). These tidal effects and gravitational interactions are able to transform spirals to S0s by gas stripping (e.g. Valluri & Jog 1991); by the loss of angular momentum of the disk gas, igniting a powerful central starburst which can assist in the formation of a bulge (e.g. Hernquist & Mihos 1995; Barnes & Hernquist 1996); by tidal heating of the disk stabilising it against gravitational instability and suppressing subsequent star formation (e.g. Gnedin 2003b); by truncation of the halo, halting any further infall of cold gas (e.g. Merritt
The correlation of star formation rate and local projected density which holds for galaxies up to several virial radii from the centres of clusters (e.g. Kodama et al. 2001, 2003; Lewis et al. 2002; Gomez et al. 2003) suggests that pre-processing due to tidal forces in galaxy groups is a significant means to change galaxy morphology (e.g. Zabludoff & Mulchaey 1998). However, recent numerical simulations demonstrate that the tidal forces associated with on-going cluster formation and sub-cluster merging also play a major role in the morphological transformation of cluster disk galaxies (e.g. Bekki 1999; Gnedin 1999, 2003a, 2003b).

Changes in cluster disk galaxy morphology were dramatic in the past. However it is important to consider whether such changes are continuing in clusters at the present epoch. If morphological transformations of cluster disk galaxies are occurring at the present, albeit on a reduced scale, the processes involved may be studied in much greater detail than is easily possible at higher redshifts. In fact, there is growing evidence that activity similar to that seen in distant clusters is still on-going at the present epoch. In previous work (Moss & Whittle 1993; Moss, Whittle & Pesce 1998; Moss & Whittle 2000), we have shown that the residual spiral population of low-redshift clusters shares characteristics of the more abundant spiral population in higher redshift clusters. There is an enhancement of circumnuclear starburst emission in cluster spirals as compared to their counterparts in the field. Moreover, a high proportion of the spirals in low-redshift clusters (e.g. ~ 40% in Coma) have a distorted morphology, strongly correlated with circumnuclear starburst emission, typical of tidally disturbed systems. Similarly Caldwell & Rose (1997) in a study of 5 nearby clusters, conclude that 15% of early-type galaxies show signs of on-going or recent star formation, characteristic of starburst or post-starburst galaxies, and that the frequency of such galaxies is enhanced as compared to the field. Further evidence that tides and interactions are not solely responsible for galaxies of types Sa and later for the remaining clusters (cf. Caldwell et al. 1993; Caldwell & Rose 1997), and we are able to provide an unbiased comparison of emission for early-type galaxies from the Hα survey data have already been published for Abell 1367 (cf. Moss, Whittle & Pesce 1998) In section 2 we list the early-type galaxies surveyed, and present ELG identifications for the remaining 7 clusters. A comparison of emission in field and cluster early-type galaxies is made in section 3. In section 4 we investigate possible enhancement of starburst emission in cluster early-type galaxies. Conclusions are given in section 5.

2 OBJECTIVE PRISM SURVEY OF EARLY-TYPE CLUSTER GALAXIES

2.1 Survey sample

An objective prism survey for combined Hα + [NII] emission from cluster galaxies in 8 low-redshift clusters (viz. Abell 262, 264, 400, 426, 569, 779, 1367 and 1656) has been undertaken using the 61/94-cm Burrell Schmidt telescope on Kitt Peak. The survey technique and methods, and the plate material used have been described in detail in previous papers (Moss et al. 1988; Moss & Whittle 1993; Moss et al. 1995; Moss & Whittle 2000, Papers I–IV respectively). For convenience, a brief summary of these details is given here. For each field, two plates were taken using hypersensitised II-IaF emulsion, with an emulsion/filter combination giving a ~ 350Å bandpass centred on 6655Å with a peak sensitivity of ~ 6717Å. All plates were taken in conditions of good seeing and good transparency, and a Hα detection was accepted only if the galaxy was independently detected on both plates. Previous work has shown that the approximate detection limit of Hα + [NII] emission is an equivalent width, $W_\alpha \simeq 20\AA$.

The initial survey list comprised all 727 CGCG galaxies within a radial distance from the cluster centre, $r \leq 1.5r_A$, where $r_A$ is the Abell radius (Abell 1958). In addition, 79 CGCG galaxies (all in Abell 1367, except one in Abell 400) which lie in the region, $1.5r_A < r \leq 2.6r_A$, were included in the survey. Adopted values of the Abell radius for each cluster, and plate boundaries of the survey plate material are given in Papers III and IV. Of the 806 CGCG galaxies in the initial list, 37 are double systems. The components of these were surveyed separately, giving a total of 843 galaxies.

Galaxy types according to the revised de Vaucouleurs system (de Vaucouleurs 1959, 1974) were obtained for all galaxies in the initial survey list. Types were either taken from the UGC (Nilson 1973) or determined by inspection from a variety of Schmidt plate material. Details of the type classification procedure are given in Papers III and IV. Types for galaxies in Abell 1367 are given in Paper III, and for galaxies of types Sa and later for the remaining clusters in Paper IV.

Papers III and IV list types and Hα + [NII] emission detection for 460 galaxies, which are mainly of types Sa and later. The present paper completes the survey by listing...
types and $\text{H}\alpha + [\text{NII}]$ emission detection for the remaining 383 galaxies of the survey, which are predominantly of types S0/a and earlier.

Combining the data from this paper with those for Papers III and IV, there is a total of 95 galaxies omitted from the survey due to plate defects (68), or a velocity $\geq 12000$ km s$^{-1}$ (27). Thus the final total of surveyed galaxies is 748.

### 2.2 Emission detection

In Table 1 we give galaxy types for the remaining 383 galaxies of the initial survey list, together with the heliocentric velocity taken from the NASA Extragalactic Database (NED). With the exception of 8 galaxies in Abell 262 typed as spirals and one galaxy in Abell 347 typed as ‘peculiar’, accidentally overlooked in previous work, the remaining 374 galaxies are all of types S0/a and earlier, or are untyped (type class ‘...’).

Of the galaxies listed in Table 1, 30 could not be surveyed due to plate defects (these galaxies are listed in the Notes to the Table), or due to a velocity $\geq 12000$ km s$^{-1}$, since in the latter case any H$\alpha$ emission is redshifted beyond the sensitivity limit of the plate. Thus there is a total of 353 surveyed galaxies.

Of these 353 predominantly early-type galaxies, 28 galaxies were detected in emission. The emission-line galaxies (ELGs) are listed in Table 2. For galaxies in Table 2 which are untyped (type class ‘...’), we list additional type information from NED, where available. The visual classification of the detected emission according to visibility (S – strong; MS – medium-strong; M – medium; MW – medium-weak; and W – weak) and concentration (VC – very concentrated; C – concentrated; N – normal; D – diffuse; and VD – very diffuse) is given according to the scheme used in previous work (cf. Papers I–IV). Similarly, for the subsequent analysis, we choose binary ranks for the H$\alpha$ appearance, yielding two parameters: compact emission (concentration classes VC, C or N); and diffuse emission (concentration classes D or VD).

Notes on individual objects are appended to the Table.

In Table 3 we summarise emission detection frequency with morphological type. In order to approximate a volume-limited sample (cluster galaxies and galaxies proximate to the cluster in the supercluster field), we restricted the sample to galaxies with velocities within 3$\sigma$ of the cluster mean. For each morphological type class, the Table lists the total sample number ($n_t$), the numbers of detected galaxies with compact and diffuse emission ($n_{c,e}$ and $n_{e,d}$ respectively), and the overall percentage of galaxies detected in emission ($p_e$). Corresponding values are also given when NED types, where available, have been included for galaxies with undetermined types ($n'_t$, $n'_{e,c}$, $n'_{e,d}$, $n'_e$).

Similar results have been given and discussed previously (cf. Paper IV). The present work provides a greatly increased sample for early-type galaxies (S0/a and earlier) and confirms, as expected, a much lower detection frequency for early-type galaxies as compared to spirals and later types. Moreover the detected emission for early-type galaxies is seen to be predominantly compact emission. The likely origin for this emission is discussed in section 4 below.

### 3 EMISSION IN CLUSTER AND FIELD GALAXIES

The earliest studies which compared the frequency of emission between field and cluster galaxies were in agreement in finding, for a given galaxy morphological type, a lower frequency of ELGs in clusters (e.g. Osterbrock 1960, Gisler 1978, Dressler et al. 1985, Hill & Oegerle 1993). However Biviano et al. (1997) identified a hitherto unsuspected systematic effect which causes an overestimate in the fraction of ELGs at fainter magnitudes, due to the bias that operates against the successful determination of redshifts for faint galaxies without emission lines. When field galaxies are on average fainter than the cluster galaxy sample and redshift data are incomplete, this systematic effect works to overestimate the frequency of emission in field as compared to cluster galaxies.

Based on the ESO Nearby Abell Cluster Survey spectral data (5634 galaxies in the directions of 107 cluster candidates), Biviano et al. concluded that the observed difference in frequency of ELGs between field and cluster galaxies could be entirely accounted for by the variation in this frequency with galaxy morphological type, and the differing morphological mix between field and cluster galaxies. By inference, there is expected to be no difference in the ELG frequency for galaxies of a given morphological type between cluster and field environments, in disagreement with all earlier studies.

For the present prism survey, field and cluster galaxies have been surveyed in an identical manner to the same magnitude limit. Redshift data are available for most ($\sim 96\%$) of the galaxy sample, and field and cluster samples have both been limited to galaxies with velocities within 3$\sigma$ of the cluster mean. Field galaxies thus comprise an approximately volume-limited sample, and both field and cluster galaxies are expected to have similar distributions in both apparent and absolute magnitude. Accordingly, we expect comparative frequencies of cluster and field ELGs determined from this survey to be free of the bias identified by Biviano et al. as well as systematic effects due to any dependence of the H$\alpha$ emission on absolute magnitude.

Using data from the prism survey, we have previously shown that for galaxies of types Sa and later, there is indeed no difference in the ELG frequency between field and cluster environments, in accord with the conclusions of Biviano et al. (cf. Paper IV and references therein). A similar result has been obtained by Gavazzi et al. (1998) for galaxies of types Sa and later. These authors compared H$\alpha$ emission for volume-limited samples of cluster and supercluster field galaxies to the same magnitude limits in the Coma supercluster, and concluded that there was no significant difference between the two samples.
Table 1. Cluster galaxy survey sample

| CGCG  | UGC  | Type | $v_\odot$ (km s$^{-1}$) | CGCG  | UGC  | Type | $v_\odot$ (km s$^{-1}$) | CGCG  | UGC  | Type | $v_\odot$ (km s$^{-1}$) |
|-------|------|------|--------------------------|-------|------|------|--------------------------|-------|------|------|--------------------------|
| Abell 262 | 522-103 | SB... | 4039 | 540-048 | 540-044 | 6387 |
| 521-075 | SAO/a | 4340 | Abell 347 | 540-050 | 2568 | S0/a | 4752 |
| 521-077 | SAB... | 5819 | S0/a | 540-051 | 540-049 | 4704 |
| 521-079 | 1236 | S0: | 6002 | S0/a | 540-053 | 540-045 | 540-080 | 2674 | S0/Sb0 | 5015 |
| 522-008 | S0: | 6582 | E/S0 | 540-054 | 2574 | S0/a | 4704 |
| 522-009 | 1269 | E/S0 | 6373 | E/S0 | 540-055 | 2578 | E/S0/a | 4704 |
| 522-010 | 1272 | S0 | 6595 | S0/a | 540-056 | 4719 |
| 522-011 | ... | 5659 | S0/a | 540-057 | 2590 | S0/a | 4739 |
| 522-012 | S... | 5917 | S0/a | 540-059 | 5502 |
| 522-014 | 1277 | S0/a | 5065 | S0/a | 540-061 | 2598 | S0/a | 4504 |
| 522-015 | 1283 | E/S0 | 540-062 | 4798 | S0 | 5426 |
| 522-016 | ... | 10936 | S0: 540-063 | 2606 | E/S0 | 4888 |
| 522-017 | 1298 | S0 | 540-066 | 2613 | S0/a | 6014 |
| 503-033 | ... | 5195 | S0/a | 540-068 | 2614 | S0/a | 5252 |
| 502-022 | 1308 | E | 4407 | 540-072 | S0/a | 4234 |
| 502-023 | ... | 5766 | S0/a | 540-074 | 4969 |
| 503-040 | S... | 10608 | S0/a | 540-075 | 2624 | S0 | 5660 |
| 502-026 | SAO: | 5485 | S0/a | 540-077 | 5864 |
| 502-027 | 1336 | S0 | 540-079 | 7236 |
| 502-030 | ... | 5645 | S0/a | 540-080 | 4983 |
| 502-032 | 1339 | S0/a | 4969 | S0/a | 540-081 | 5631 |
| 502-032 | SB0 | 5750 | S0/a | 540-082 | 4850 |
| 502-034B | 1343 | S0: | 5859 | S0/a | 540-085 | 4370 |
| 502-034A | 1343 | S0: | 540-086 | 2644 | E | 4978 |
| 502-036 | S0/pec | 5880 | S0/a | 540-087 | 6468 |
| 502-037 | 1346 | S0: | 540-088 | 2651 | E | 7536 |
| 502-039 | 1348 | S0: | 4920 | 540-089 | 3342 |
| 502-040 | ... | 5018 | S0/a | 540-092 | 5059 |
| 502-043 | 1352 | S0 | 5799 | 540-095 | 2660 | E | 4965 |
| 502-044 | 1352 | S0: | 5165 | 540-096 | 5751 |
| 502-045 | ... | 5601 | 540-097 | 2661 | S0 | 5980 |
| 502-046 | 1353 | S0: | 5254 | Abell 400 | 540-097 | 8194 |
| 502-047 | 1358 | S0/a | 7380 | 540-098 | 2662 | E | 3815 |
| 502-048 | ... | 8116 | E/S0 | 540-099 | 5387 |
| 502-049 | S0/a | 7229 | E/S0 | 540-101 | 4500 |
| 502-052 | 1360 | S0/a | 6384 | 540-102 | 6413 |
| 502-053 | S0/a | 6861 | 540-104 | 5066 |
| 502-054 | S... | 7142 | 540-105 | 6090 |
| 502-057 | SB0/a | 6641 | 540-107 | 4266 |
| 502-061 | S0/a | 6097 | 540-108 | 4300 |
| 502-064 | 1388 | E/S0 pec | 6410 | 540-109 | 2139 |
| 502-065 | S0a | 7348 | 540-110 | 6767 | E/S0/a | 6749 |
| 502-068 | S... | 6830 | 540-111 | 2682 | E | 4432 |
| 502-072 | S0/a | 6770 | E/S0/a | 540-113 | 4173 |
| 502-076 | 1406 | S0/a | 8215 | 540-117 | 6585 |
| 502-080 | 1415 | S0/a | 8581 | 540-119 | 6421 |
| 502-083 | S0/a | 6652 | 540-120 | 4788 |
| 502-084 | 1434 | S0/a | 5487 | Abell 426 | 540-122 | 2708 | S0/a | 5394 |
| 502-085 | ... | 6296 | 540-123 | 2717 | E | 3798 |
| 502-092 | E/S0 | 1592 | 541-004 | 2725 | S0/a | 6192 |
| 502-092 | ... | 4792 | 541-007 | 2733 | E | 5331 |
| 502-092 | ... | 5355 | 541-012 | 4743 |
| 502-098 | ... | 2847 | 541-013 | 4179 |
| 502-099 | SB... | 5577 | 541-014 | 5580 |
| 502-101 | 1475 | E | 4209 | 540-046 | 2559 | S0/a | 5061 |
Table 1. continued

| CGCG | UGC | Type | \(v_C\) (km s\(^{-1}\)) | CGCG | UGC | Type | \(v_C\) (km s\(^{-1}\)) | CGCG | UGC | Type | \(v_C\) (km s\(^{-1}\)) |
|------|-----|------|----------------|------|-----|------|----------------|------|-----|------|----------------|
| 541-016B 2756  S0: | 181-028 ... | 15125 160-052 ... | 541-018 2762  E/S0 | 5442 181-029 ... | 6992 160-053 ... | 234-031 ... ... | 5792 181-033 4972  S0? | 7075 160-057 ... | 234-040 ... ... | 6047 181-034 ... | 6310 160-059 ... | 234-047 3659  E | 5944 181-035 4974  S0? | 7023 160-061A ... | 234-048 ... S0/a: | 5661 181-038 ... | 6657 160-061B ... | 234-053 ... S0: | 5895 181-040 5001  SBO/a | 1687 160-063 ... | 234-054 ... ... | 6003 181-041 ... | 12742 160-065 ... | 234-058 ... ... | 234-059 ... S0: | 5341 150-098 ... | 8010 160-068 8092 ... | 234-064 ... ... | 5748 150-101 ... | 7745 160-069 ... | 234-068 ... S0/a: | 6156 150-102 8017 ... | 7061 160-070 ... | 234-070 3695  E/S0 | 5795 150-104 ... | 6159 160-071 ... | 234-073 3696  E/S0 | 6150 150-106 ... | 7945 160-072 ... | 234-074 ... S0: | 4820 150-111 8026 S0/a | 7627 160-074 8097 S0/a | 234-075 3699  S0 | 5836 150-112 ... | 6413 160-076 ... | 234-077 ... S0: | 6108 150-113 8028 E/S0 | 8365 160-078 ... | 234-078 ... E/S0: | 5472 150-114 ... | 7033 160-079 ... | 234-080 ... SBO/a: | 6174 150-115 ... | 6202 160-080 ... | 234-081 3713  E/S0 | 6500 150-118 8038 ... | 7863 160-081 ... | 234-082 ... E/S0: | 5648 150-119 ... | 7495 160-082 ... | 234-083 ... E/S0: | 5747 160-015 ... S0: | 7356 160-083 ... | 234-084 ... E/S0: | 6310 160-016 ... | 7177 160-084 ... | 234-085 ... ... | 6158 160-017 8049 ... | 6989 160-085 ... | 234-086 ... E/S0: | 6393 160-018 ... | 7049 160-086 ... | 234-087 ... S0: | 4820 160-019 ... | 7115 160-087 ... | 234-088B 3719 ... ... | 160-020 ... | 4968 160-088 ... | 234-089 ... ... | 5894 160-021 8057 E/S0: | 6915 160-089 8100 E? | 234-091 3720  E | 5925 160-022 ... S0: | 6486 160-090 ... E/S0 | 234-095 ... E/S0: | 6102 160-023 ... | 6883 160-091 ... | 234-096 ... E/S0: | 5824 160-024 ... | 7506 160-092 ... | 234-097 3725  E/S0 | 6171 160-026 ... S0/a: | 7525 160-093 ... | 234-098 ... S0/a: | 5132 160-027 ... | 6297 160-094 ... | 234-101 ... E/S0: | 5487 160-028 8065 S0 | 7630 160-095 ... | 234-105 ... S0: | 6229 160-029 ... S0/a: | 6296 160-097 ... | 234-108 ... E/S0: | 5823 160-031 ... | 6849 160-098 8103 S0 | 7224 234-110 ... S0/a: | 160-032 ... S0/a: | 7581 160-100 ... | 234-113 ... 3758  E/S0 pec | 5678 160-033 ... | 6273 160-101 ... | 234-115 ... ... | 9988 160-034 ... | 8064 160-102 ... | 235-006 ... S0: | 5861 160-037 ... | 7463 160-104 ... | 235-007 ... ... | 14974 160-040 ... | 5475 160-106 ... | 234-008 ... SBO/a | 7171 160-041 ... | 7230 160-108 ... | 234-009 ... S0: | 6634 160-042 ... | 6087 160-109 8106 E | 234-011 ... E/S0: | 7213 160-044A 8072 E | 6775 160-111 ... E/S0 | 234-014 ... ... | 6781 160-044B 8072 E | 6302 160-112 ... | 234-015 ... ... | 7036 160-045 ... | 6356 160-113B ... | 234-018 4939 S0/a | 6379 160-046A ... | 7343 160-114 8110 E | 234-020 ... ... | 6465 160-046B ... | 7234 160-115 ... | 234-021 ... S0: | 6394 160-047 ... | 6118 160-116 ... | 234-022 ... S0/a: | 7062 160-048A ... E/S0: | 5861 160-117 ... | 234-024A 4924  E | 6948 160-048B ... | 6990 160-118 ... | 234-024B ... E/S0 | 5180 160-049 ... | 7237 160-119 ... | 234-027 ... ... | 7321 160-051 8080 S0/a | 7410 160-120 ... | 234-028 ... ... | 2780 160-052 ... | 8196 ... | 7095 ... | 7506 ... | 7675 ... | 7907 ... | 6697 ... | 6023 ... | 7145 ... | 8004 ... | 7660 ... | 6704 ... | 8430 ... | 5682 ... | 5916 ... | 7164 ... | 7972 ... | 5554 ... | 6336 ... | 7088 ... | 6650 ... | 7678 ... | 7980 ... | 5675 ... | 6812 ... | 4859 ... | 6841 ... | 7780 ... | 4670 ... | 6875 ... | 6790 ... | 4755 ... | 7299 ... | 6717 ... | 5848 ... | 8045 ... | 7224 ... | 6148 ... | 5978 ... | 8342 ... | 8009 ... | 6678 ... | 6900 ... | 9401 ... | 8071 ... | 6740 ... | 6392 ... | 6568 ... | 9902 ... | 6494 ... | 7268 ... | 7268 ... | 6781 ... | 11114 ... | 5737 ... | 7365 ... |
Table 1. continued.

| CGCG | UGC | Type | \(v_\odot\) (km s\(^{-1}\)) | CGCG | UGC | Type | \(v_\odot\) (km s\(^{-1}\)) | CGCG | UGC | Type | \(v_\odot\) (km s\(^{-1}\)) |
|------|-----|------|----------------|------|-----|------|----------------|------|-----|------|----------------|
| 160-121B | ... | ... | 6371 | 160-143 | ... | ... | 6828 | 160-167 | ... | ... | 8210 |
| 160-122 | ... | ... | 4634 | 160-144 | ... | ... | 5965 | 160-168 | ... | S0: | 7759 |
| 160-121A | ... | ... | 6811 | 160-145 | ... | ... | 6664 | 160-169 | ... | ... | 5965 |
| 160-123 | ... | ... | 8220 | 160-146 | 8133 | S0 | 7334 | 160-170 | 8154 | S0 | 5443 |
| 160-124 | ... | S0 | 8492 | 160-149 | ... | E/S0: | 5484 | 160-171 | ... | S0/a | 6917 |
| 160-125 | ... | SB:0/a: | 7208 | 160-151 | 8137 | S0 | 7387 | 160-174 | ... | ... | 5602 |
| 160-126 | ... | E/S0 | 6812 | 160-152 | ... | ... | 7556 | 160-175 | ... | E/S0: | 6358 |
| 160-128 | 8117 | E/S0 | 6012 | 160-153 | ... | ... | 5807 | 160-176B | ... | ... | 8167 |
| 160-129 | ... | E/S0: | 7521 | 160-155 | 8142 | E/S0 | 7887 | 160-177 | ... | E/S0: | 5939 |
| 160-131 | ... | ... | 5441 | 160-156 | ... | ... | 7072 | 160-181 | 8175 | E | 5908 |
| 160-133 | ... | S0: | 6363 | 160-157 | ... | E/S0: | 7764 | 160-182 | 8178 | E | 6909 |
| 160-134 | ... | ... | 7112 | 160-158 | ... | ... | 7188 | 160-184 | ... | ... | 7075 |
| 160-135 | ... | ... | 7997 | 160-161 | ... | E/S0: | 7572 | 160-187 | ... | ... | 7044 |
| 160-136 | 8122 | S0/a | 6925 | 160-162 | ... | S0/a: | 5580 | 160-189B | 8194 | ... | 7163 |
| 160-137 | ... | E/S0: | 8793 | 160-163 | ... | ... | 6872 | 160-190 | ... | ... | 7851 |
| 160-138 | ... | E/S0: | 6940 | 160-164B | ... | ... | 8619 | 160-192 | ... | S0/a: | 6307 |
| 160-141 | ... | E | 5012 | 160-165 | ... | E/S0 | 6211 | 160-193 | ... | ... | 7304 |
| 160-142 | ... | ... | 7665 | 160-166 | ... | ... | 7406 | 160-195 | 8206 | S0/a | 6655 |

Notes to the Table:
A total of 24 galaxies were not surveyed due to plate defects, viz. 9 galaxies on a defocussed region of Plate 15270 for Abell 1656 (CGCG nos. 159-106, 159-114, 159-119, 160-016, 160-029, 160-034, 160-035, 160-044A and 160-044B); 12 galaxies whose spectra were overlapped by adjacent stellar or galaxy spectra (CGCG nos. 159-106, 159-114, 159-119, 160-016, 160-029, 160-034, 160-044A and 160-044B); and 3 galaxies which lay outside the overlap region of the survey plane pair (CGCG nos. 503-033, 503-040 and 540-035).

Notes on double systems:
CGCG 522-034A and B: N and S components, \(m_p \sim 14.7\) and 15.1 respectively.
CGCG 415-043A and B: NW and SE components, \(m_p \sim 16.3\) and 16.3 respectively.
CGCG 541-016A and B: S and N components, \(m_p \sim 15.8\) and 15.8 respectively.
CGCG 234-088A and B: S and N components, \(m_p \sim 15.4\) and 16.6 respectively.
CGCG 181-024A and B: NE and SW components, \(m_p \sim 13.7\) and 14.5 respectively.
CGCG 160-046A and B: N and S components, \(m_p \sim 15.5\) and 15.9 respectively.
CGCG 160-048A and B: W and E components, \(m_p \sim 15.9\) and 16.2 respectively.
CGCG 160-061A and B: S and N components, \(m_p \sim 15.8\) and 16.1 respectively.
CGCG 160-113A and B: W and E components, \(m_p \sim 16.9\) and 16.8 respectively.
CGCG 160-121A and B: S and N components, \(m_p \sim 15.3\) and 15.7 respectively.
CGCG 160-164A and B: E and W components, \(m_p \sim 16.3\) and 16.3 respectively.
CGCG 160-176A and B: W and E components, \(m_p \sim 13.5\) and 15.2 respectively.
CGCG 160-189A and B: E and W components, \(m_p \sim 14.0\) and 16.5 respectively.

Explanations of the columns in Table 4:
Column 1. CGCG number (Zwicky et al. 1960–1968). The numbering of CGCG galaxies in field 160 (Abell 1656) which has a subfield covering the dense central region of the cluster, follows that of the listing of the CGCG in the SIMBAD database. The enumeration is in strict order of increasing Right Ascension, with galaxies of lower declination preceding in cases of identical Right Ascension.
Column 2. UGC number (Nilson 1973)
Column 3. Galaxy type taken from UGC or estimated from the PSS.
Column 4. Heliocentric velocity taken from the NASA Extragalactic Database (NED).

Using the prism survey data in this paper, we now compare ELG frequencies for E,S0,S0/a galaxies between field and cluster environments. We adopt the definitions of projected radial distance from the cluster centre, \(R\); local surface density, \(\Sigma\); and cluster type, \(CT\) given in Paper IV. For the latter parameter, \(CT\), cluster galaxies were taken as those surveyed galaxies with \(r \leq 1.0r_A\); field galaxies were either those surveyed galaxies with \(r > 1.5r_A\), or (for Abell 262, 347, 400 and 779) with \(r > 1.0r_A\). Clusters were ranked according to increasing mean space density of galaxies in the central regions of the cluster \((r \leq 0.5r_A)\) with the first rank for field galaxies. (For further discussion, cf. Paper IV).

If the frequency of ELGs varies systematically from field to cluster, we expect this frequency to show a dependence on one or more of the three parameters, \(R\), \(\Sigma\) and \(CT\). A Kendall rank test shows no significant correlation between the fraction of E,S0,S0/a galaxies detected in emission and each of \(R\), \(\Sigma\) and \(CT\) (significance levels of 0.0\(\sigma\), -1.1\(\sigma\), and -0.8\(\sigma\) respectively). Thus we confirm that there is no dependence of the frequency of ELGs among early type galaxies on
Table 2. Galaxies detected in Hα emission

| CGCG  | UGC  | R.A. (1950) | Dec. | r (rA) | m_p | Type | v⊙ (km s⁻¹) | Hα emission | Vis. | Conc. | Notes |
|-------|------|-------------|------|--------|-----|------|------------|-------------|------|------|-------|
| 522-011 |      | 1 46.4      | 34   | 43     | 0.8 | 15.4 | S0†        | 4014        | MS   | C    |       |
| 522-039 |      | 1 49.9      | 35   | 55     | 0.0 | 14.8 | E          | 4855        | W    | N    |       |
| 522-053 |      | 1 51.0      | 36   | 23     | 0.3 | 15.4 | S0/a:      | 5655        | W    | D    |       |
| 522-072 |      | 1 53.4      | 35   | 20     | 0.5 | 15.2 | S0:        | 5371        | M    | D    | *     |
| 539-031 |      | 2 24.4      | 41   | 47     | 0.2 | 15.0 | S0/a       | 5645        | S    | VC   | *     |
| 539-044 |      | 2 30.5      | 41   | 8      | 1.0 | 15.3 | pec        | 4920        | MS   | WD   |       |
| 415-020 |      | 2 51.0      | 6    | 4      | 0.9 | 15.3 | S0         | 7380        | W    | VD   |       |
| 415-033 |      | 2 53.8      | 4    | 25     | 1.2 | 15.2 | S0:        | 8116        | M    | N    |       |
| 415-038 |      | 2 54.3      | 6    | 0      | 0.2 | 15.3 | S0†        | 6384        | S    | N    |       |
| 415-043B|      | 2 55.3      | 5    | 35     | 0.2 | 15.3 | S0         | 6384        | D    |      |       |
| 415-050 |      | 2 56.6      | 5    | 56     | 0.3 | 15.0 | S0:        | 8215        | S    | N    |       |
| 415-052 |      | 2 57.5      | 5    | 36     | 0.6 | 15.3 | SA0/a:     | 6652        | W    | N    |       |
| 234-085 |      | 7 7.0       | 48   | 16     | 0.3 | 15.5 | ...        | 6158        | MW   | N    |       |
| 234-096 |      | 7 7.9       | 47   | 1      | 1.2 | 15.3 | E/S0       | 5824        | M    | C    |       |
| 234-113 |      | 7 11.9      | 49   | 42     | 1.0 | 15.7 | Sc†        | 9988        | W    | D    |       |
| 234-115 |      | 7 13.0      | 49   | 58     | 1.2 | 15.7 | ...        | W           | N    |      |       |
| 159-101 |      | 12 50.3     | 27   | 40     | 1.4 | 15.3 | Ir‡        | 7745        | S    | N    |       |
| 159-102 | 8017 | 12 50.4     | 28   | 39     | 1.3 | 14.5 | Sab†       | 7061        | M    | D    |       |
| 160-020 |      | 12 53.7     | 27   | 57     | 0.7 | 15.5 | Sa†        | 4968        | S    | C    |       |
| 160-026 |      | 12 54.1     | 27   | 33     | 0.8 | 15.5 | S0:a:      | 7525        | MW   | N    |       |
| 160-033 |      | 12 54.5     | 27   | 10     | 1.0 | 15.1 | E‡         | 6273        | MW   | N    | *     |
| 160-068 | 8092 | 12 56.2     | 27   | 51     | 0.4 | 14.2 | (R)SA0−?‡  | 7660        | W    | N    |       |
| 160-078 |      | 12 56.7     | 27   | 55     | 0.3 | 15.1 | E/S0       | 5554        | S    | N    | *     |
| 160-156 |      | 12 59.6     | 27   | 55     | 0.5 | 15.1 | S0 pec:‡   | 7188        | S    | N    | *     |
| 160-169 |      | 13 0.6      | 26   | 47     | 1.3 | 15.7 | S†         | 5965        | M    | N    |       |
| 160-189B | 8194 | 13 3.9      | 29   | 20     | 1.5 | 16.5 | S          | 7163        | W    | D    |       |
| 160-193 |      | 13 4.8      | 28   | 18     | 1.3 | 15.5 | Sc+†       | 7304        | S    | N    |       |

Notes on individual objects:
CGCG 522-011: = ARK 59 (Arakalian 1975). This high surface brightness elliptical blue object is a component of a triple system and is likely to be interacting with another component, CGCG 522-013 = V Zw 113 (“distorted blue Sc”, cf. Zwicky 1971; v⊙ = 4019 km s⁻¹).
CGCG 522-039: = NGC 708, the brightest galaxy in Abell 262. It has a radio jet (Bridle & Purley 1984), and also a double ionised gas component, one aligned with the stars of the galaxy and the other strongly decoupled, suggesting an external origin (Plena et al. 1998). Nuclear emission ratio, [NII]/Hα ≈ 2 (Miller & Owen 2002).
CGCG 522-053: = V Zw 144 (“blue fuzzy elliptical disk compact”, cf. Zwicky 1971).
CGCG 539-031: = MRK 1176. Markarian starburst galaxy paired with companion (Keel & van Soest 1992; Miller & Owen 2002).
CGCG 160-033: = ARK 395 (“Compact symmetrical blue object with envelope”, cf. Arakalian 1975)
CGCG 160-078: = MRK 58. A blue disk galaxy which shows a very asymmetric gas distribution (cf. Bravo-Alfaro et al. 2000). Type given by NED is SBa.
Explanations of columns in Table 2:

Columns 1 and 2: As columns 1 and 2 of Table 1.
Columns 3 and 4: Right Ascension and Declination (1950.0) of the galaxy centre taken from the CGCG.
Column 5: Radial distance in Abell radii (Abell 1958) of the galaxy with respect to the cluster centre. Adopted positions for the cluster centres and values of the Abell radii are given in Paper IV.
Column 6: CGCG photographic magnitude. For double galaxies, magnitude estimates for individual components obtained by eye from PSS are given in parentheses.
Column 7: As column 3 of Table 1. † indicates that types were taken from NED.
Column 8: As column 4 of Table 1.
Column 9: A visibility parameter describing how readily the Hα emission is seen on the plates according to a five-point scale (S strong, MS medium-strong, M medium, MW medium-weak, W weak).
Column 10: A concentration parameter describing the spatial distribution of the emission and contrast with the underlying continuum, on a five-point scale (VD very diffuse, D diffuse, N normal, C concentrated, VC very concentrated).
Column 11: Notes. An asterisk in this column indicates that a note on this galaxy appears below the Table.
Table 3. Galaxies detected in emission for different type classes.

| Type | Total | Compact ELGs | Diffuse ELGs | Percentage ELGs |
|------|-------|--------------|--------------|-----------------|
|      | $n_t$ | $n_t'$ | $n_{e,c}$ | $n_{e,d}$ | $n_{e,c}'$ | $n_{e,d}'$ | $p_e$ | $p_e'$ |
| E    | 39 (55) | 1 (2) | 0 (0) | 2.6 (3.6) |
| E-S0 | 82 (84) | 2 (2) | 0 (0) | 2.4 (2.4) |
| S0   | 127 (173) | 3 (8) | 2 (2) | 3.9 (5.8) |
| S0/a | 60 (67) | 5 (5) | 1 (1) | 10.0 (9.0) |
| Sa   | 55 (58) | 8 (9) | 8 (8) | 29.1 (29.3) |
| Sab  | 25 (27) | 3 (3) | 7 (8) | 40.0 (40.7) |
| Sc–Irr | 40 (40) | 10 (10) | 8 (8) | 45.0 (45.0) |
| Sh,Sc | 44 (45) | 7 (8) | 11 (11) | 40.9 (42.2) |
| Sc–Irr,Irr | 11 (13) | 1 (2) | 3 (3) | 36.4 (38.5) |
| pec | 21 (21) | 14 (14) | 2 (2) | 76.2 (76.2) |
| S... | 61 (69) | 12 (13) | 13 (13) | 41.0 (37.7) |
| ... | 105 (18) | 12 (2) | 1 (0) | 12.4 (11.1) |

Note to the Table: $n_t'$, $n_{e,c}'$, $n_{e,d}'$, and $p_e'$ for the various samples are obtained by including NED types, where available, for galaxies with indeterminate type.

either local surface density or cluster environment in accord with results of Biviano et al.

A Kendall rank test also shows no significant correlation between the fraction of E,S0,S0/a galaxies detected in compact emission and each of $R$, $\Sigma$ and $CT$ (significance levels of $-0.3\sigma$, $-0.3\sigma$, and $0.1\sigma$ respectively). This result is expected from the previous one, because most ELGs in the E,S0,S0/a sample have compact emission. However this result is in contrast to the previous finding (cf. Paper IV) of an enhancement of compact emission for cluster spirals.

In previous work, we have suggested that the enhancement of compact emission in cluster galaxies of types Sa and later is due to circumnuclear starbursts triggered by tidal interactions associated with sub-cluster merging and on-going processes of virialisation. With this scenario, one expects an enhancement of compact emission in the non-virialised late-type galaxy population. The degree of enhancement is likely to be related to the strengths of the varying gravitational fields in clusters of differing galaxy density and stage of relaxation.

If this scenario is correct, any corresponding enhancement of compact emission in early-type cluster galaxies may be less evident. As a cluster continues to form, and spirals are transformed into earlier type galaxies, any enhancement of circumnuclear starburst emission in early-type galaxies is likely to be masked by the increasing number of these galaxies in the cluster.

Accordingly, we attempt to test whether there is an enhancement of starburst emission in early-type galaxies in the clusters surveyed, using an alternative method described in the next section.

4 ENHANCEMENT OF STARBURST EMISSION IN CLUSTER EARLY-TYPE GALAXIES

In previous work, restricted to a sample of the surveyed cluster galaxies of types Sa and later, we have shown that compact emission can convincingly be identified as due to circumnuclear starburst emission, whereas diffuse emission originates from more normal star formation in the disks of the spiral galaxies. The compact emission was shown to be associated both with a tidal disturbance of the galaxy and also with the presence of a bar. For spirals in this sample, a strong association was also found between compact emission and the presence of a tidal companion, which suggests that much of this emission is caused by circumnuclear starbursts associated with local galaxy–galaxy interactions. However galaxies classified as peculiar show no tendency to have tidal companions, although a very high percentage (\~76 per cent) of these galaxies show compact emission (see Table 3). As discussed in Paper IV, a natural explanation of this latter result is that peculiar are predominantly on-going mergers, in which the companion is already indistinguishable from its merger partner, and the compact emission arises from the starburst induced by the merger.

However for early-type galaxies, the association between compact emission and star formation appears less likely. For example, in the Palomar spectroscopic survey of nearby galactic nuclei (PSSN; Ho et al. 1997), not a single elliptical galaxy shows emission attributable to star formation.

The above suggests that we might detect any enhancement of starburst emission in the early-type cluster galaxies by comparison of the fraction of detected early-type cluster ELGs which show HII emission, with the same fraction for a comparable field sample. We proceed to make this comparison as follows. First, we determine the expected fraction of early-type ELGs with HII emission from data for the field from the PSSN. This is done in section 4.2. Then, in section 4.2 we make a comparison between this expected fraction and the observed fraction for cluster early-type ELGs, using a compendium of published data. As will be seen, this comparison gives a modest indication of an enhancement of starburst emission in cluster early-type galaxies. Furthermore we show how this enhancement of emission can readily be explained by the effect of gravitational tidal interactions.

4.1 Expected emission from field data

The PSSN is based on high quality optical spectra of moderate resolution for the nuclei ($r \lesssim 200$ pc) of almost every bright galaxy ($B_T \leq 12.5$) in the northern sky ($\delta > 0^\circ$). Using standard nebular diagnostics, the probable ionisation mechanisms of the emission-line objects in the survey have been identified. These spectral classifications can be used to infer the likely origin of the compact emission detected in early-type galaxies by the present objective prism survey in the following way.

First, we select a sub-sample of the PSSN sample whose distribution in absolute magnitude approximately matches that of the CGCG galaxies in the prism survey. This match is important because the ionisation mechanism for emission-line objects in the PSSN has a strong dependence on absolute magnitude. In Figure 1 we show the distributions of absolute asymptotic B magnitudes corrected for internal and Galactic extinction, $M_B^*\sigma$ for galaxies in the prism survey and for a sub-sample of the PSSN restricted to $M_B^*\sigma \leq -18.5$. Values of $M_B^*\sigma$ for the prism survey galaxies were derived from CGCG magnitudes, $m_p$, converted to the $B_T$ system following Paturel, Bottinelli & Gouguenheim (1994).
Figure 1. Distribution in absolute magnitude, $M_B^0$, for galaxies in the prism survey (top) and in a sub-sample of the Palomar spectroscopic survey of nearby galactic nuclei (PSSN) restricted to $M_B^0 \leq -18.5$ (bottom). The dashed histogram shows the volume weighted distribution for the PSSN sub-sample.

Figure 2. Cumulative percentages of the volume weighted PSSN field galaxy sample (Ho et al. 1997) with HII emission, plotted against the combined equivalent width, $W_\lambda(H_\alpha + [NII])$. The cumulative percentages (with the integrated number of galaxies, $n$, increasing from right to left) are for all galaxies with equivalent width $\geq W_\lambda$.

Arrows in Figure 2 indicate the values of $W_\lambda$ at which the fraction of galaxies with equivalent width $\geq W_\lambda$ equals the fraction of galaxies detected in compact emission by the prism survey.
Table 4. Spectral classifications for galaxies with compact emission

| CGCG    | Type | Spectral type | Ref. |
|---------|------|---------------|------|
| Abell 262 |      |               |      |
| 521-074  | S; pec | HII            | 2    |
| 522-003  | pec    | HII            | 2    |
| 522-011  | S0†    | HII            | 2    |
| 522-020  | SBb    | Shrst          | 2    |
| 522-039  | E      | Sy2            | 2    |
| 522-058  | SBA    | Shrb           | 2    |
| 522-077  | SBB; pec | HII        | 2    |
| Abell 347 |      |               |      |
| 538-043  | pec    | SF             | 1    |
| 539-024  | SBb    | HII            | 3    |
| 539-025  | SB pec | SF             | 1    |
| 539-031  | S0/a   | SF             | 1    |
| Abell 400 |      |               |      |
| 415-050  | S0; Mix |               | 1    |
| Abell 426 |      |               |      |
| 540-064  | SBb    | Sy2            | 2    |
| 540-094  | Sbc    | HII            | 2    |
| 540-103  | pec:   | Sy2            | 2    |
| 541-009  | Sbc    | AGN            | 2    |
| Abell 569 |      |               |      |
| 234-056  | S pec  | HII            | 2    |
| 234-057  | pec    | SF             | 1    |
| 234-066  | pec:   | SF             | 1    |
| 234-071  | SB: pec | AGN           | 1    |
| 234-079A | S: pec | AGN            | 2    |
| 234-115  | ...    | SF             | 1    |
| Abell 779 |      |               |      |
| 181-023  | S      | Ab+            | 1    |
| 181-030  | SBa    | AGN;           | 2    |
| Abell 1367 |     |               |      |
| 97-026   | SBA pec | SF             | 1    |
| 97-068   | SBC pec | SF             | 1    |
| 97-079   | S...pec | SF             | 1    |
| 97-087   | Sd pec  | SF             | 1    |
| 97-114   | S0/a; pec | HII        | 2    |
| 97-125   | Sa: pec | SF             | 1    |
| 126-110  | Sab pec | Sy1            | 2    |
| 127-049  | SBab   | SF             | 1    |
| 127-052  | SA0    | Lin            | 1    |
| 127-055  | SAa    | SF             | 1    |
| 127-071  | S... pec | HII        | 2    |
| 127-095  | SBb    | HII            | 2    |
| Abell 1656 |     |               |      |
| 159-101  | Irr†   | HII            | 2    |
| 160-020  | Sa†    | HII            | 2    |
| 160-026  | S0/a; | HII            | 2    |
| 160-055  | SB:ab  | SF             | 1    |
| 160-064  | pec    | Shrst          | 2    |
| 160-067  | pec    | SF             | 1    |
| 160-068  | (R')SA0—?† | SF       | 1    |
| 160-075  | pec    | Shrb           | 2    |
| 160-078  | E/S0:  | Shrb           | 2    |
| 160-127  | pec    | SF             | 1    |
| 160-130  | pec:   | SF             | 1    |
| 160-148A | S pec  | Mix            | 1    |
| 160-156  | SA0†   | Sy             | 2    |
| 160-158  | S0 pec;† | Shrb       | 2    |

Table 4. continued.

| CGCG    | Type | Spectral type | Ref. |
|---------|------|---------------|------|
| 160-160 | pec  | HII           | 2    |
| 160-179 | S; pec | HII         | 2    |
| 160-180 | pec  | HII           | 2    |
| 160-193 | S... | Shrb          | 2    |

Explanation of the columns of the Table.

Column 1. CGCG number (Zwicky et al. 1960–1968). See notes to column 1 of Table 1 above.

Column 2. Galaxy type taken from papers III & IV, and this paper. † indicates that types were taken from NED.

Columns 3 & 4: Spectral classification taken from: 1. Miller & Owen (2002): SF – star-forming galaxy; Ab+ – predominantly absorption-line spectrum, although with slight emission of [NII] and sometimes [SII]; Sey – Seyfert; Lin – LINER; Mix – nuclear spectrum that of a Seyfert or LINER, with off-nuclear spectrum showing star formation. 2. NED: either NED galaxy classification (Shrb, Sy, Sy1, Sy2) or classification as HII or AGN emission from the line ratios of emission lines in the UZC Spectral Archive (Faldo et al. 1999).

Table 5. Percentages of galaxies with compact HII emission in clusters and the field.

| Type      | Cluster Total | % compact HII emission |
|-----------|---------------|------------------------|
| E,S0,S0/a |               |                        |
| Sa + later |               |                        |
| Note to the Table: p<sub>ce,c</sub> and p<sub>ce,f</sub> are the percentages of galaxies with compact HII emission and which both have compact HII emission and are disturbed, for cluster and field galaxies respectively. NED types for galaxies with otherwise indeterminate type have been included where available.

4.2 Comparison of expected and observed HII emission for early-type cluster galaxies

The above expected percentages of compact ELGs of different galaxy types with HII emission may be compared with actual percentages from spectroscopic data. In Table 4 we list spectral classifications for 54 compact ELGs in the 8 clusters surveyed. These represent 69% of the total of 78 compact ELGs which have a velocity within 3σ of the cluster mean. Spectral classifications were taken from Miller & Owen (2002) or derived from data given in NED. For these latter, the galaxy classification was either taken from NED, or, when not available, classification of the emission as either HII or AGN was made using emission line ratios in the UZC Spectral Archive (Faldo et al. 1999), following the method of Veilleux and Osterbrock (1987).

For the three type groups, E,S0,S0/a; Sa,Sab,Sb; and Sbc,Sc,Sc–Irr, restricted to galaxies within one Abell radius of the cluster centres (or within 0.5 Abell radii of each of the two subcluster centres in Abell 569), the observed percentages of galaxies with HII emission are 68% (n = 11), 80%...
are defined to be those outside 1
within 1
clusters is largely accounted for by an additional population E,S0,S0/a and Sa + later galaxies separately.

1367 and 1656 (cf. Paper IV). We make the comparison for no counterparts in the field. The number of these galaxies no
disturbed
of

sion in cluster galaxies is readily explained by gravitational
enhancement of HII emission for the early-type cluster galaxies with compact emission.

If this enhancement of HII emission in early-type cluster galaxies is real, what is its likely cause? Obviously, the simplest explanation is that previously suggested for cluster later types, viz. the effects of gravitational tidal interactions on the galaxies. For the present sample of cluster early-type galaxies (types E, S0 and S0/a), restricted to galaxies within one Abell radius of the cluster centres, there is a very strong correlation between the incidence of compact HII emission and a disturbed morphology for the galaxy (significance level of 8.2σ). Four out of nine disturbed galaxies show compact HII emission, while only 6 out of 270 undisturbed galaxies show this emission. This is a similar result to that found previously for cluster galaxies of types Sa and later, and indeed suggests that any enhancement of HII emission in cluster early-type spirals is due to gravitational tidal effects as is the case for later type cluster galaxies.

In Table 4 we compare the fractions of galaxies in the field and in clusters which have compact HII emission (pce,f and pce,c respectively) and the fractions which have compact HII emission and in addition are tidally disturbed (pce,d and pce,c,d respectively). Cluster galaxies are defined to be those within 1.0r(A) of the cluster centres (or within 0.5r(A) of each of the two subcluster centres in Abell 569), while field galaxies are defined to be those outside 1.0r(A) for the clusters Abell 262, 347, 400, 569 and 779, and outside 1.5r(A) for Abell 426, 1367 and 1656 (cf. Paper IV). We make the comparison for E,S0,S0/a and Sa + later galaxies separately.

First consider the later types. We find that the increase in the percentage of galaxies with compact HII emission in clusters is largely accounted for by an additional population of disturbed galaxies with compact HII emission – indeed there are no such galaxies in the field. This restates our earlier findings in Paper IV which focussed specifically on the later types.

For the early-type galaxies, again there is a population of disturbed galaxies with compact HII emission which have no counterparts in the field. The number of these galaxies (n = 4) is exactly that required to explain the observed excess of HII emission in cluster early type ELGs as determined from a comparison with the PSSN spectroscopic data for field galaxies (cf. section 4 above). Thus for early-types as well as later types, an enhancement of compact HII emission in cluster galaxies is readily explained by gravitational tidal interactions associated with cluster virialisation.2

5 CONCLUSIONS

In a series of papers (cf. Moss et al. 1988; Moss & Whittle 1993; Moss et al. 1998; Moss & Whittle 2000) we have undertaken an Hα survey of an essentially complete sample of 748 CGCG galaxies in 8 low-redshift clusters (viz. Abell 262, 347, 400, 426, 569, 779, 1367 and 1656). This paper has presented previously unpublished data for 383 mainly early-type galaxies and completes publication of data for the survey. The combined survey data show that emission detection increases as expected from earlier to later galaxy types (3% for E,E–S0; 6% for S0; 9% for S0/a; and 41% for types Sa and later).

A comparison of cluster and field early-type galaxies shows a similar frequency of emission detection. Together with the same result obtained for cluster and field galaxies of types Sa and later, these data confirm the inference of Biviano et al. (1997) that differences between the frequency of ELGs between clusters and the field can entirely be accounted for by the differing mix of galaxy morphological types in the two environments, while for a given morphological type there is no difference in the frequency of ELGs between clusters and the field. As noted by Biviano et al., this result is in disagreement with all or most previous studies. It is to be noted that this result has been obtained for galaxies with relatively strong emission (Wλ ≥ 20Å). Work is in progress to extend these results to fainter limits in equivalent width (cf. Sakai, Kennicutt & Moss 2001).

Although the incidence of emission does not vary between cluster and field environments, the survey has shown that the type of emission does vary. Detected emission is classified as ‘compact’ or ‘diffuse’, identified as circumnuclear starburst or AGN emission and disk emission respectively. In previous work, we have shown that for galaxies of types Sa and later, there is an enhancement of compact HII emission in cluster galaxies as compared to the field. This type of emission has been shown to be strongly correlated with a tidally disturbed morphology of the galaxy.

In the present work, a comparison of spectroscopic data for the cluster early-type ELGs with that for field galaxies from the PSSN (Ho et al. 1997) gives a modest indication (significance level ~ 2.8σ) for enhanced compact HII emission in early-type cluster ELGs as compared to the field. Moreover, the compact HII emission in the early-type cluster galaxies is strongly correlated with a disturbed galaxy morphology (significance level of 8.2σ).

For both early-type and later types, there is a population of disturbed galaxies with compact HII emission which have no counterparts in the field. This suggests that for cluster galaxies of all types, enhancement of compact HII emission can readily be explained as an enhancement of circumnuclear starburst emission due to gravitational tidal effects. As discussed previously (cf. Moss & Whittle 2000) these gravitational tidal effects are most likely to be associated with sub-cluster merging and other processes of on-going cluster virialisation.

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2 In Table 4 the percentage of early-type galaxies with compact HII emission in the field is numerically greater than in the cluster. However, as discussed above in section 4, this cluster-field difference is not statistically significant.
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