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# THE NUCLEAR ACTIVITY OF GALAXIES IN THE HICKSON COMPACT GROUPS

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## ABSTRACT

In order to investigate the nuclear activity of galaxies residing in compact groups of galaxies, we present results of our optical spectroscopic program made at Okayama Astrophysical Observatory. We have performed optical spectroscopy of 69 galaxies belonging to 31 Hickson compact groups (HCGs) of galaxies. Among them, three galaxies have discordant redshifts and, moreover, spectral quality is too poor to classify another three galaxies. Therefore, we describe our results for the remaining 63 galaxies. Our main results are summarized as follows: (1) We have found in our sample 28 active galactic nuclei (AGNs), 16 H II nuclei, and 19 normal galaxies showing no emission line. We used this HCG sample for statistical analyses. (2) Comparing the frequency distributions of activity types between the HCGs and the field galaxies whose data are taken from Ho, Filippenko, & Sargent (382 field galaxies), we find that the frequency of H II nuclei in the HCGs is significantly less than that in the field. However, this difference may be due to selection bias to the effect that our HCG sample contains more early-type galaxies than the field, because it is known that H II nuclei are rarer in early-type galaxies than in later ones. (3) Applying a correction to this morphological bias to the HCG sample, we find that there is no statistically significant difference in the frequency of occurrence of emission-line galaxies between the HCGs and the field. This implies that the dense galaxy environment in the HCGs does not affect the triggering of either the AGN activity and the nuclear starburst. We discuss some implications on the nuclear activity in the HCG galaxies.

*Key words:* galaxies: nuclei — galaxies: Seyfert — galaxies: starburst

## 1. INTRODUCTION

It is known that compact groups of galaxies provide the densest galaxy environment, rather than binary galaxies, loose groups of galaxies, and clusters of galaxies (Hickson 1982; Hickson et al. 1992). Therefore, frequent galaxy collisions are expected to trigger either some nuclear activity or intense star formation in their member galaxies (Hickson et al. 1989; Zepf, Whitmore, & Levison 1991; Zepf & Whitmore 1991; Zepf 1993; Verdes-Montenegro et al. 1998). Further, compact groups would evolve into other populations in the universe because they would be able to merge into one stellar system within a timescale shorter than the Hubble time (Hickson et al. 1992; Barnes 1989; Weil & Hernquist 1996). Indeed previous studies have shown possible evidence that galaxy collisions may trigger either the nuclear activity or starbursts in the HCGs; e.g., HCG 16 (Ribeiro et al. 1996; de Carvalho & Coziol 2000), HCG 31 (Iglesias-Páramo & Vílchez 1997a), HCG 62 (Valluri & Anupama 1996), HCG 90 (Longo, Grimaldi, & Ricther 1995), and HCG 95 (Iglesias-Páramo & Vílchez 1997b).

On the other hand, other statistical studies have shown that there may be no strong evidence for the unusually enhanced activity in the HCGs. Hickson et al. (1989) found that the far-infrared (FIR) emission is enhanced in the HCGs. However, later careful analysis of FIR data of HCGs showed that there is no firm evidence for the enhanced FIR emission in the HCGs (Sulentic & de Mello Rabaca 1993). Radio continuum properties of the HCG galaxies do not show evidence for the enhanced nuclear activity with respect to field spiral galaxies although the radio continuum emission from the nuclear region tends to be stronger than that from field spirals (Menon 1992, 1995).

More recently, Coziol et al. (1998) have shown from a spectroscopic survey for 17 HCGs (de Carvalho et al. 1997) that active galactic nuclei (AGNs) are preferentially located in the most early-type and luminous members in the HCGs. This result suggests possible relations among activity types, morphologies, and densities of galaxies in HCGs. Vílchez & Iglesias-Páramo (1998a) made an Hα-emission imaging survey for a sample of HCGs and found that over 85% of the early-type galaxies in their sample were detected in Hα (Vílchez & Iglesias-Páramo 1998b). However, they interpreted that the excess emission in Hα is attributed to photoionization by massive stars rather than AGNs. Therefore, it is still uncertain what kind of activity is preferentially induced in the nuclear regions of HCG galaxies.

In order to investigate the nuclear emission-line activity of HCG galaxies in detail, our attention is again addressed to an investigation of how frequent galaxy collisions are related to the occurrence of both nuclear activity and star formation activity in HCG galaxies. In this paper, we present results of our optical spectroscopic program for a sample of 69 galaxies belonging to 31 HCGs, which are randomly selected in the list of HCG (Hickson 1982). In the original catalog of HCG (Hickson 1982) 100 compact groups with 493 galaxies have entries. However, eight groups have now been dropped from the original sample because they do not have more than two galaxies whose redshifts are accordant (Hickson et al. 1989; Hickson 1993; see also Sulentic 1997). Therefore, our sample is selected from the remaining 92 HCGs.

## 2. OBSERVATIONS

We have performed optical spectroscopy of 69 galaxies in the 31 groups (see Table 1). The spectroscopic observations were made at the Okayama Astrophysical Observatory (OAO) 188 cm telescope with the new Cassegrain spectrograph and an SITe 512 × 512 CCD camera during a period

TABLE 1

JOURNAL OF OBSERVATIONS

| HCG | DATE | EXP.(s) | P.A. (deg) | TYPE Hickson | RC3 | Adopted |
|---|---|---|---|---|---|---|
| 7a ....... | 1996 Aug 19 | 1800 | 159 | Sb | (R')SB(r)a: | Sa |
| 10a ...... | 1996 Feb 21 | 1800 | 62 | SBb | SB(r)b | Sb |
| 10b ...... | 1997 Jan 07 | 1800 | 153 | E1 | $S0^-$: | S0 |
| 30a ...... | 1996 Feb 21 | 1800 | 124 | SBa | (R')SB(rs)$0^+$: | S0 |
| 30b ...... | 1996 Feb 23 | 1800 | 29 | Sa | (R')SAB(rs)$0^+$: | S |
| 31a ...... | 1997 Jan 09 | 1800 | 80 | Sdm | Pec | P |
| 31b ...... | 1997 Jan 09 | 1800 | 41 | Sm | S? | Sm |
| 31c ...... | 1997 Jan 09 | 860 | 41 | Im | S? | Im |
| 34a ...... | 1996 Feb 23 | 1800 | 84 | E2 | S0? | S0 |
| 37a ...... | 1996 Feb 22 | 1800 | 171 | E7 | Sb | Sb |
| 37b ...... | 1996 Feb 21 | 1800 | 77 | Sbc | S? | Sbc |
| 38a ...... | 1997 Jan 06 | 1800 | 340 | Sbc | S? | Sbc |
| 38b ...... | 1996 Feb 23 | 1800 | 85 | SBd | S? | Sd |
| 38c ...... | 1996 Feb 23 | 1800 | 85 | Im | S? | Im |
| 40a ...... | 1996 Feb 23 | 1800 | 185 | E3 | E | E |
| 40b ...... | 1996 Feb 23 | 1800 | 42 | S0 | SA(r)$0^-$: pec | S0 |
| 40c ...... | 1996 Feb 23 | 1800 | 122 | Sbc | SB(rs)b pec | Sb |
| 42a ...... | 1997 Jan 09 | 1800 | 134 | E3 | E3: | E |
| 42b ...... | 1997 Jan 09 | 240 | 66 | SB0 | SB(rs)$0^0$ | S0 |
| 42c ...... | 1997 Jan 09 | 1800 | 134 | E2 | E? | E |
| 44a ...... | 1996 Feb 21 | 1800 | 125 | Sa | SA(s)a pec | Sa |
| 44b ...... | 1996 Feb 22 | 1800 | 185 | E2 | E2 | E |
| 44c ...... | 1996 Feb 21 | 1800 | 130 | SBc | (R)SB(r)a | Sa |
| 44d ...... | 1996 Feb 21 | 1800 | 125 | Sd | SB(s)c pec | Sc |
| 47a ...... | 1996 Feb 21 | 1800 | 15 | SBb | SA(r): | Sb |
| 51a ...... | 1996 Feb 23 | 1800 | 358 | E1 | E | E |
| 51b ...... | 1996 Feb 23 | 1800 | 183 | SBbc | S? | Sbc |
| 51f ...... | 1996 Feb 23 | 1800 | 358 | S0 | S0? | S0 |
| 52a ...... | 1996 Feb 20 | 750 | 90 | SBab | SB? | Sab |
| 53a ...... | 1996 Feb 20 | 1800 | 93 | SBbc | SB? | Sbc |
| 57a ...... | 1996 Feb 25 | 1800 | 108 | Sb | Sab pec | Sab |
| 61a ...... | 1996 Feb 22 | 1800 | 159 | S0a | S0 | S0 |
| 61c ...... | 1996 Feb 21 | 1800 | 130 | Sbc | S | Sbc |
| 61d ...... | 1996 Feb 21 | 1800 | 50 | S0 | S? | S0 |
| 62a ...... | 1996 Feb 22 | 1800 | 130 | E3 | $S0^+$ | S0 |
| 62b ...... | 1996 Feb 22 | 1800 | 130 | S0 | $S0^0$ pec | S0 |
| 62c ...... | 1996 Feb 22 | 1800 | 173 | S0 | E+ | E |
| 67b ...... | 1996 Feb 21 | 900 | 21 | Sc | Sb | Sb |
| 68a ...... | 1996 Feb 22 | 1800 | 0 | S0 | S0 | S0 |
| 68b ...... | 1996 Feb 22 | 1800 | 0 | E2 | S0 | S0 |
| 68c ...... | 1996 Feb 21 | 1800 | 18 | SBbc | SB(r)b | Sb |
| 71a ...... | 1996 Feb 20 | 1800 | 23 | SBc | Scd: | Scd |
| 72a ...... | 1996 Feb 25 | 1800 | 102 | Sa | S0? | S0 |
| 73a ...... | 1996 Feb 25 | 1800 | 18 | Scd | SA(s)c | Sc |
| 79a ...... | 1996 Feb 22 | 758 | 63 | E0 | Sa pec | Sa |
| 79b ...... | 1996 Aug 15 | 1800 | 70 | S0 | S0? | S0 |
| 79c ...... | 1996 Aug 18 | 1800 | 34 | S0 | S0 pec | S0 |
| 79d ...... | 1996 Aug 18 | 1800 | 0 | Sdm | SB(s)c | Sc |
| 80a ...... | 1996 Feb 25 | 1800 | 64 | Sd | S? | Sd |
| 82a ...... | 1996 Aug 15 | 1800 | 37 | E3 | S0 | S0 |
| 82b ...... | 1996 Aug 19 | 1800 | 168 | SBa | SB0? | S0 |
| 87a ...... | 1996 Aug 18 | 1800 | 56 | Sbc | $S0^0$ pec | S0 |
| 87b ...... | 1996 Aug 15 | 1800 | 40 | S0 | S0? | S0 |
| 87c ...... | 1996 Aug 19 | 1800 | 90 | Sd | S? | Sd |
| 87d ...... | 1996 Aug 20 | 1800 | 40 | Sd | ... | Sd |
| 88a ...... | 1996 Aug 15 | 1800 | 132 | Sb | Sb | Sb |
| 88b ...... | 1996 Aug 15 | 1800 | 31 | SBb | SB(r)a pec: | Sa |
| 88c ...... | 1996 Aug 15 | 1800 | 31 | Sc | SAB(r)bc? | Sbc |
| 88d ...... | 1996 Aug 18 | 1800 | 71 | Sc | S? | Sc |
| 89a ...... | 1996 Aug 19 | 1800 | 57 | Sc | S? | Sc |
| 92a ...... | 1996 Aug 15 | 1800 | 137 | Sd | SA(s)d | Sd |
| 92b ...... | 1996 Aug 15 | 1800 | 22 | Sbc | SB(s)bc pec | Sbc |
| 92c ...... | 1996 Aug 18 | 1800 | 140 | SBa | SB(s)bc pec | Sbc |
| 92d ...... | 1996 Aug 15 | 1800 | 109 | SB0 | E2 pec | E |
| 92e ...... | 1996 Aug 18 | 1800 | 110 | Sa | ... | Sa |
| 93a ...... | 1996 Aug 19 | 1800 | 98 | E1 | $SA0^-$ | S0 |
| 93b ...... | 1996 Aug 19 | 1800 | 143 | SBd | SB(s)cd pec | Scd |
| 93c ...... | 1996 Aug 19 | 1800 | 98 | SBa | (R)SAB(s)0/a pec | S0/a |
| 96a ...... | 1996 Aug 19 | 480 | 90 | Sc | SA(r)bc pec | Sbc |

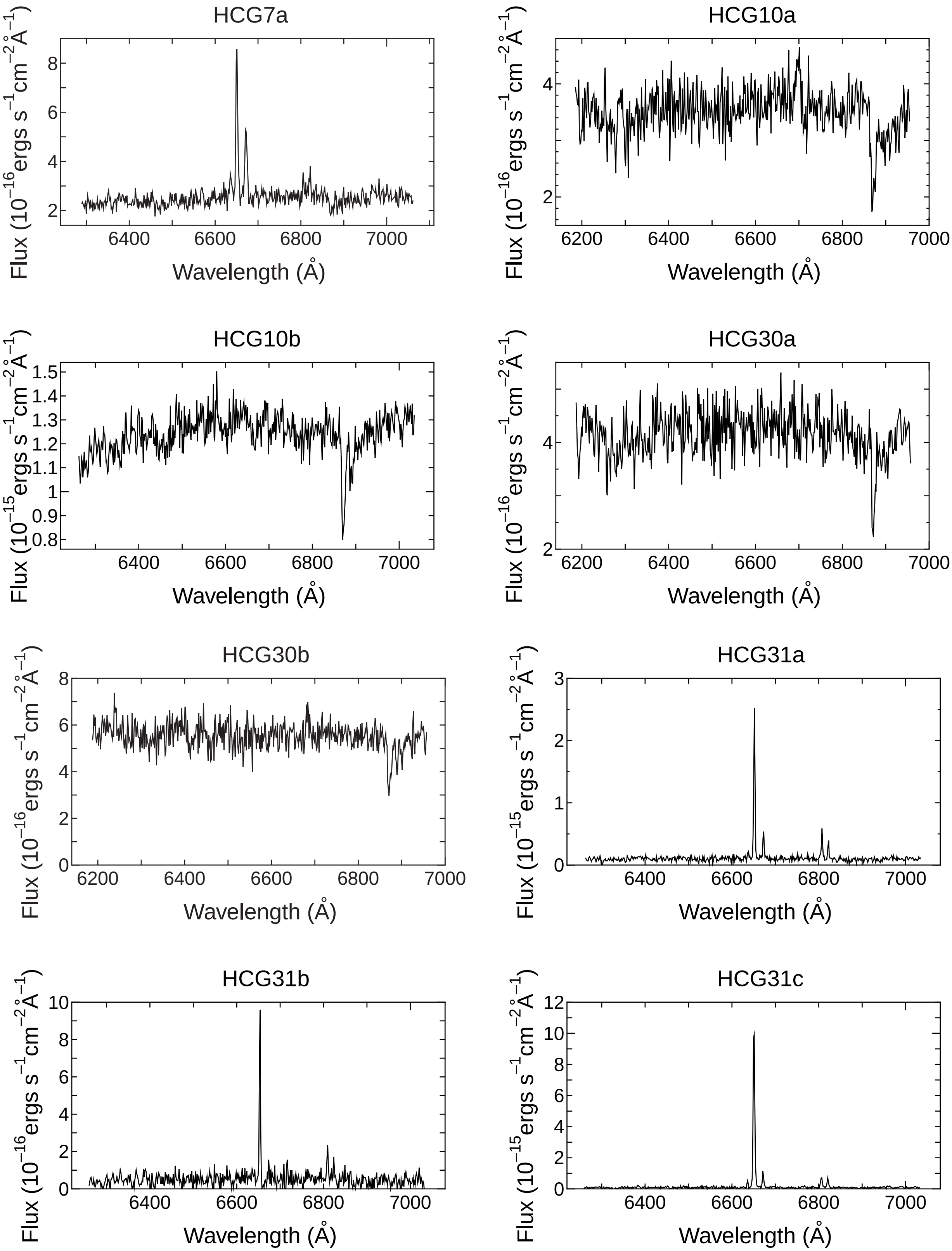


FIG. 1.—Nuclear spectra of the HCG galaxies

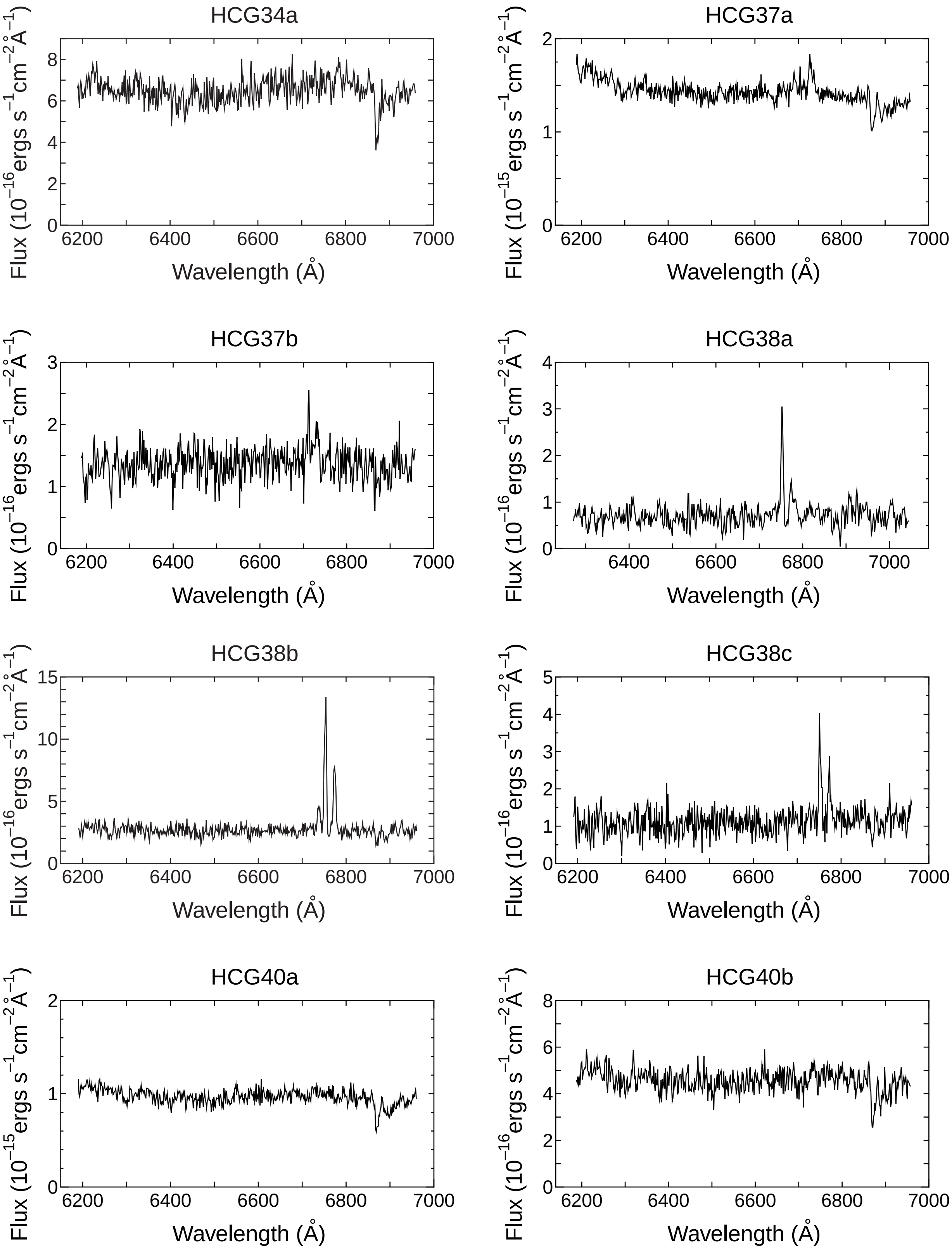


FIG. 1.—*Continued*

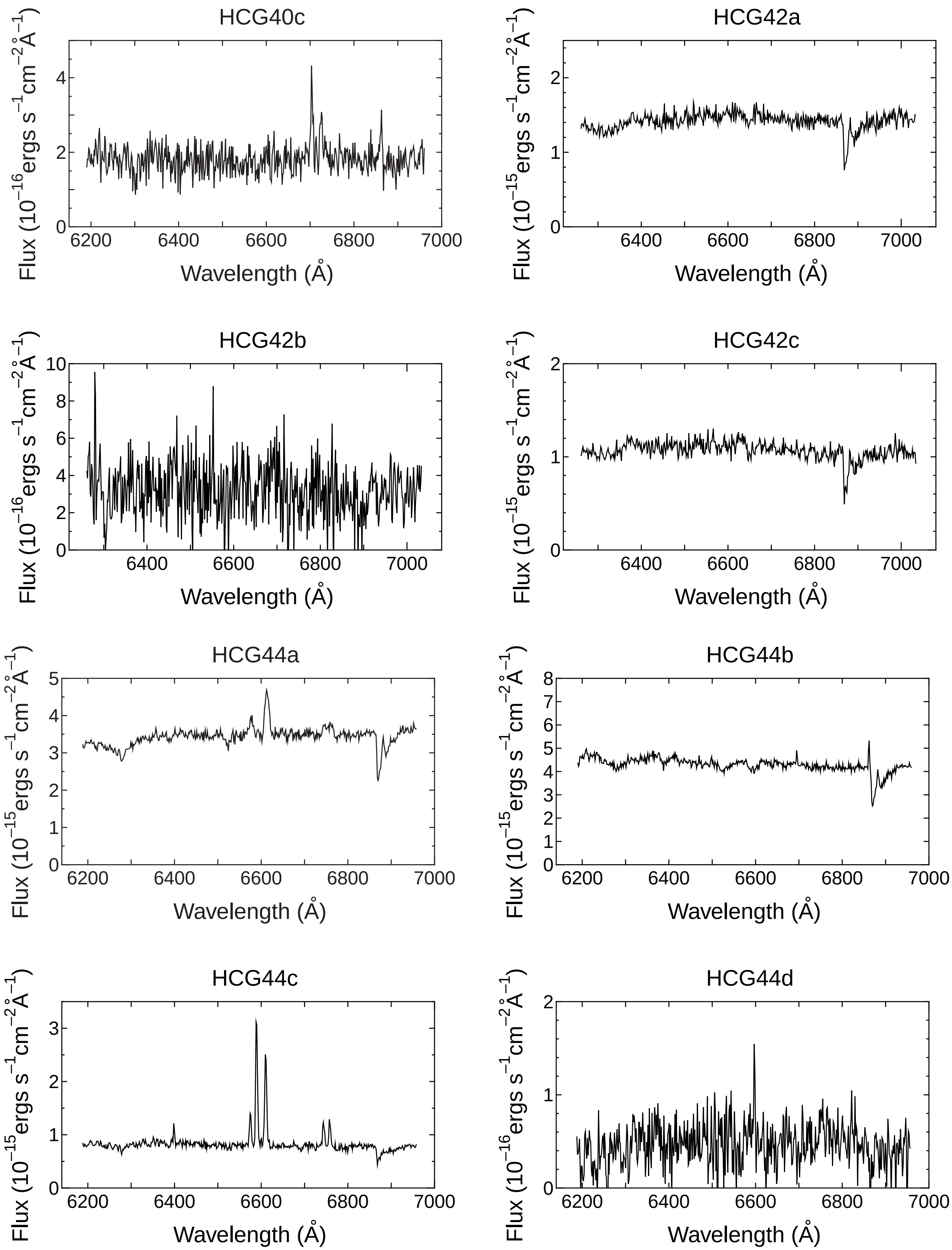


FIG. 1.—*Continued*

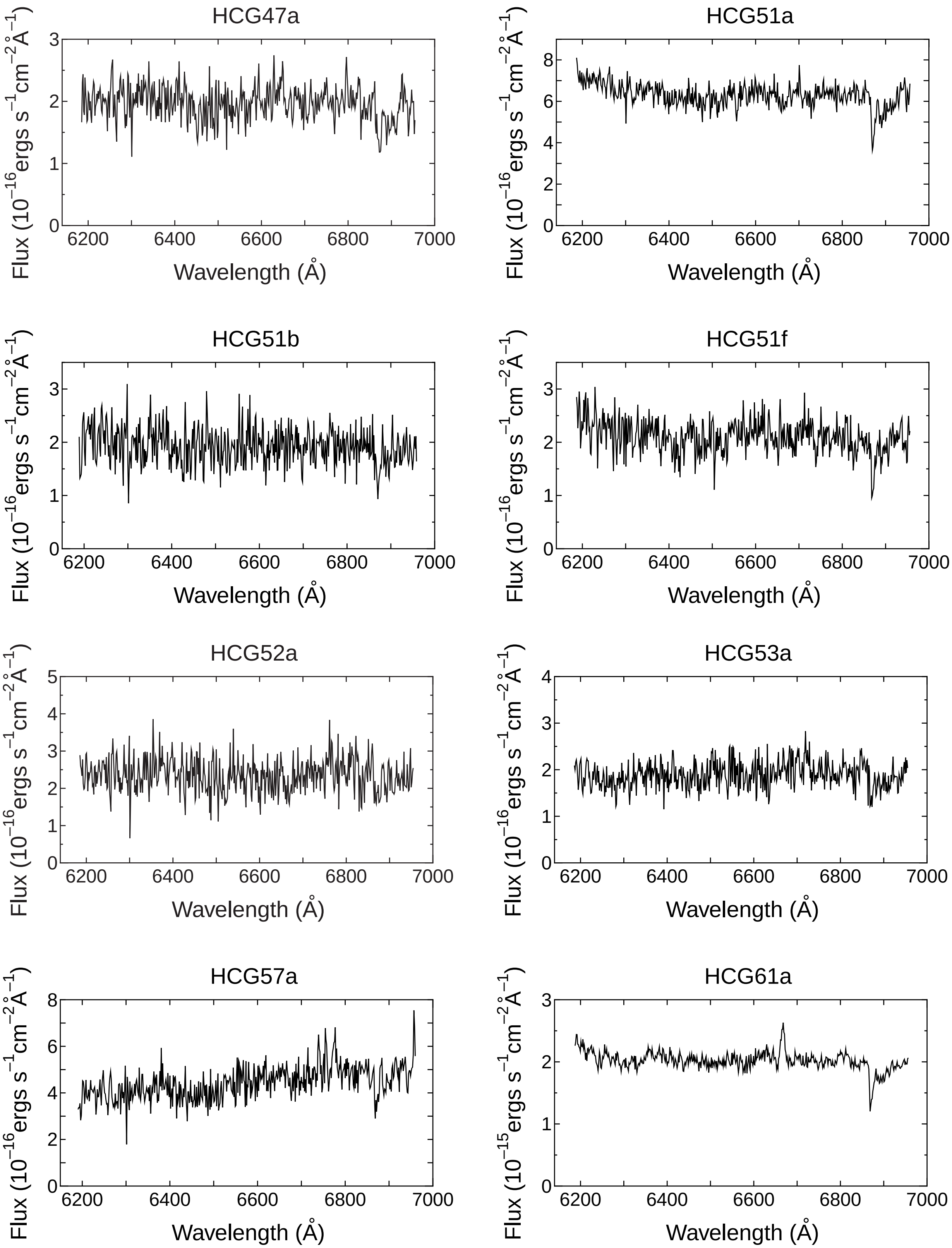


FIG. 1.—*Continued*

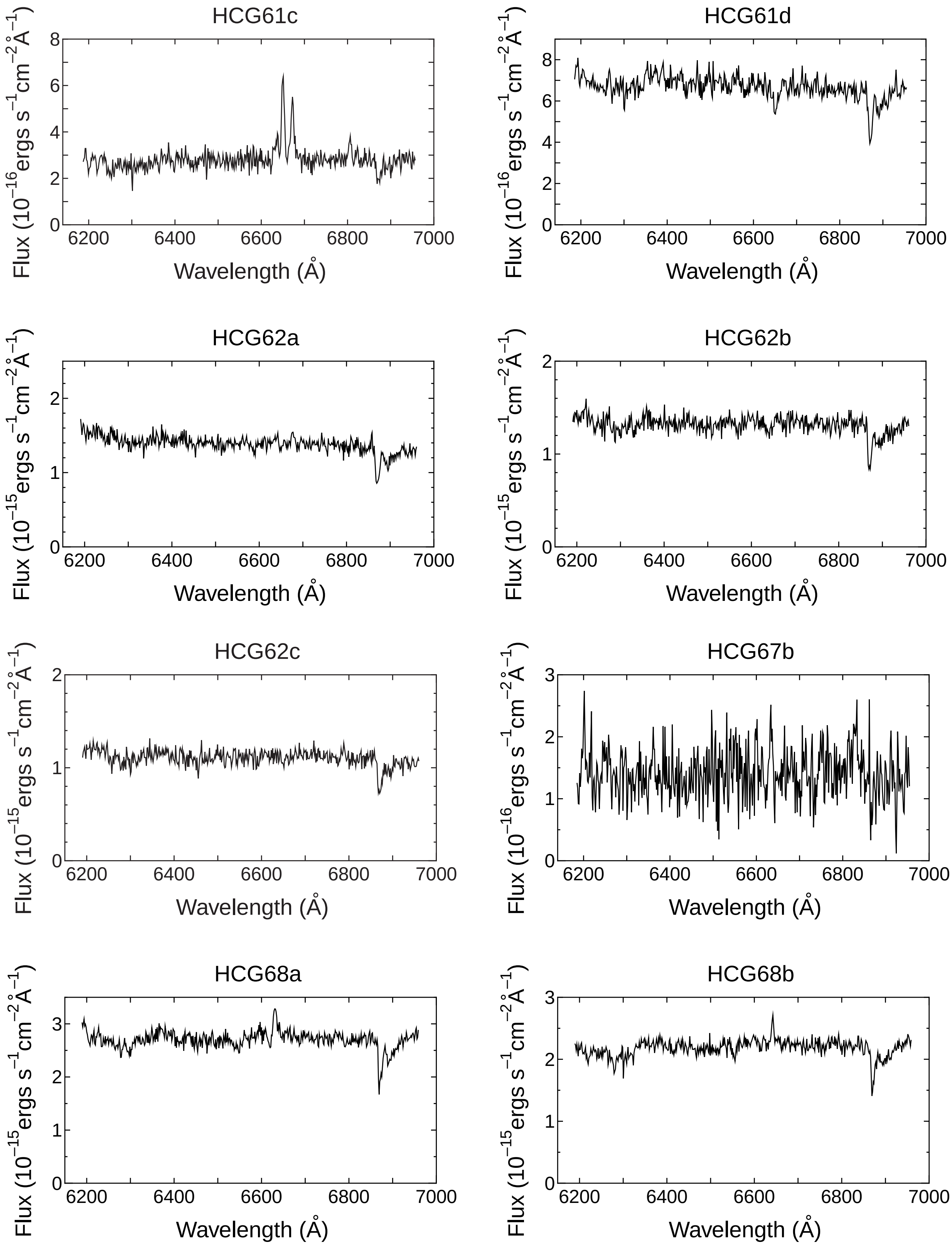


FIG. 1.—*Continued*

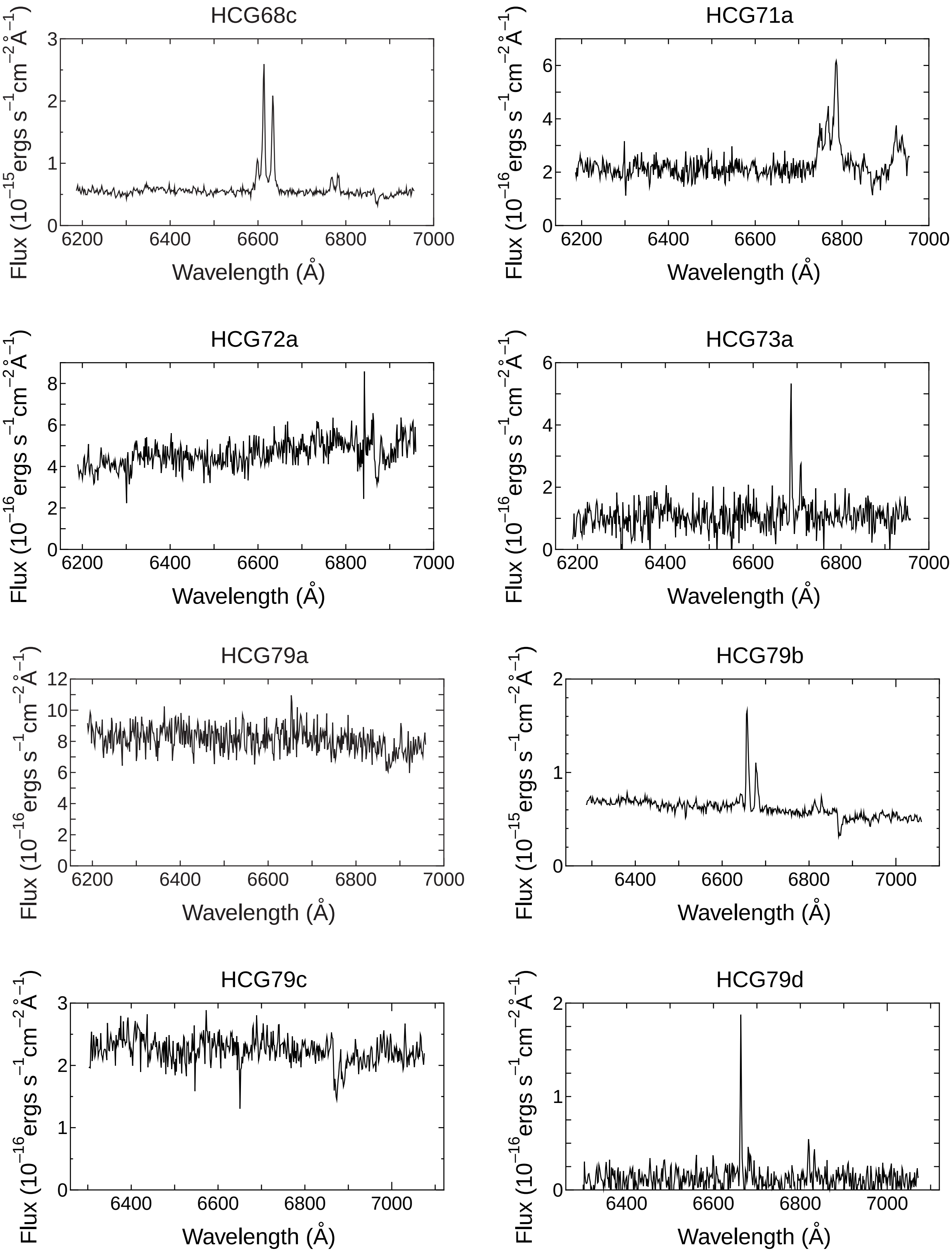


FIG. 1.—*Continued*

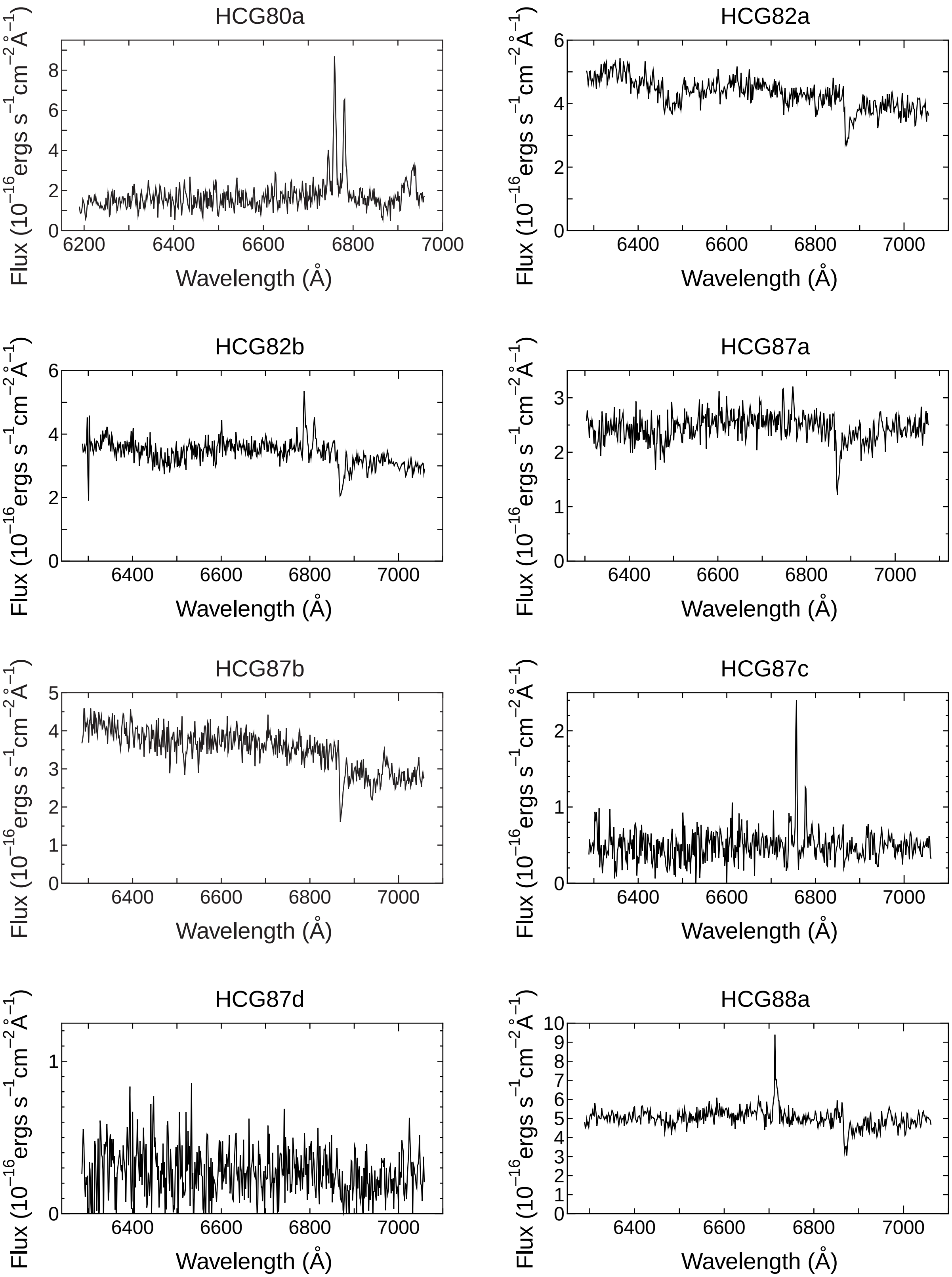


FIG. 1.—*Continued*

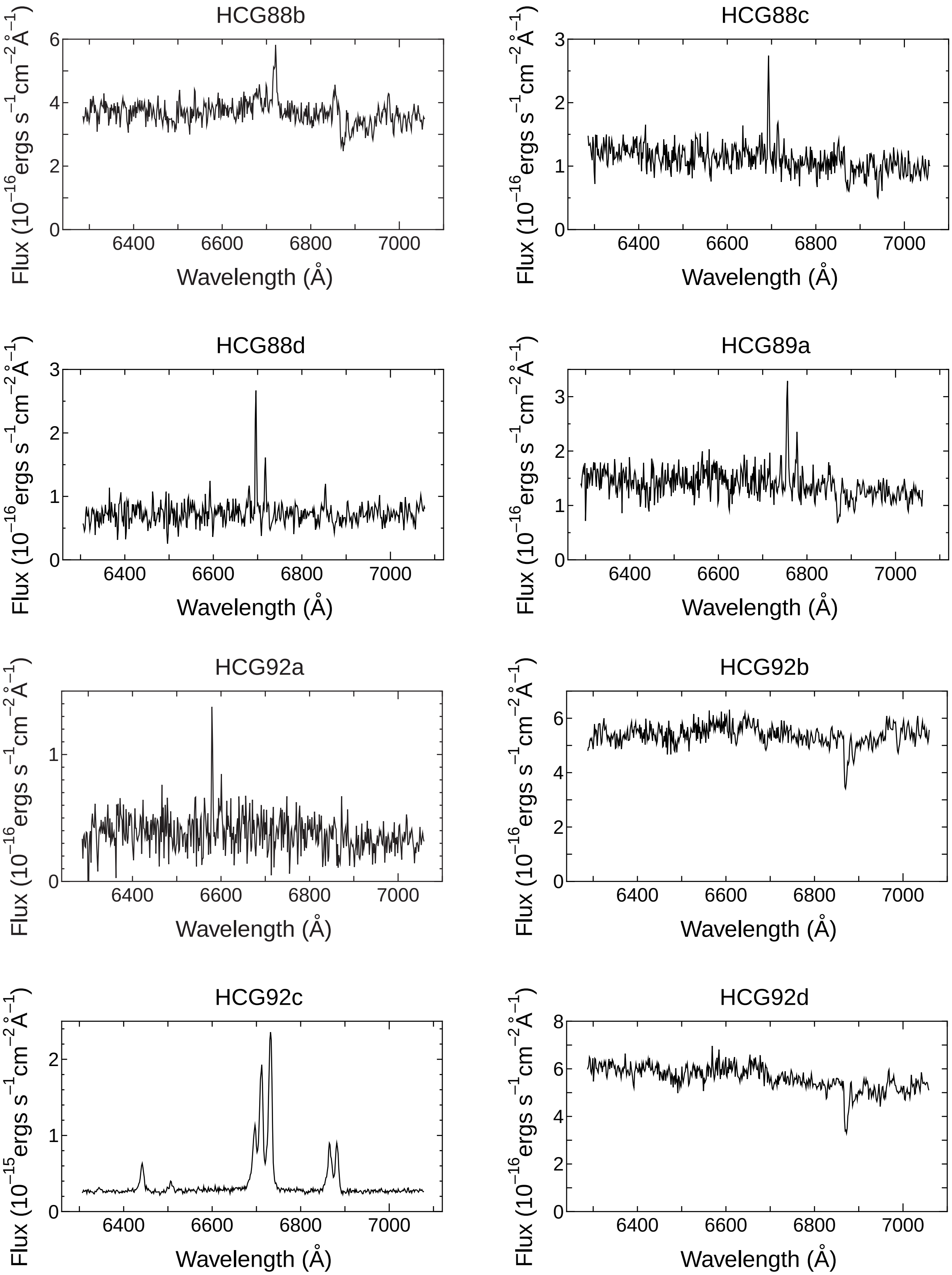


FIG. 1.—*Continued*

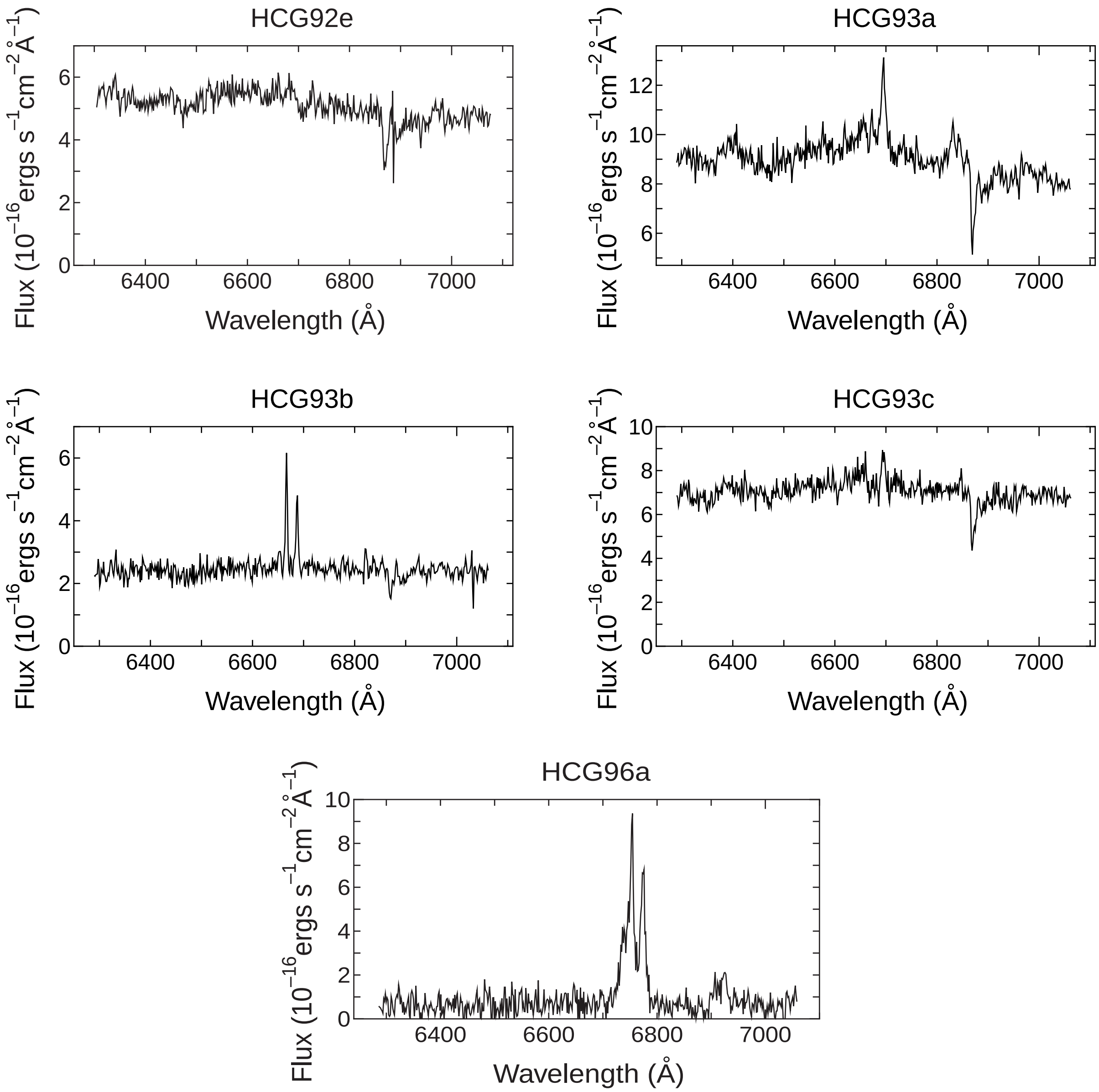


FIG. 1.—*Continued*

between 1996 February and 1997 January. The slit dimension was 1″.8 (width) × 5′ (length). Two-pixel binning was made along the slit, and thus the spatial resolution was 1″.75 per element. The 600 groove mm$^{-1}$ grating was used to cover 6300–7050 Å region with the spectral resolution of 3.4 Å ($\simeq$157 km s$^{-1}$ in velocity at 6500 Å). The observations were made under photometric conditions. The typical seeing during the runs was 2″.

The data were analyzed using IRAF.[1] We also used a special data reduction package, SNGRED (Kosugi et al. 1995), developed for OAO Cassegrain spectrograph data. The reduction was made with a standard procedure: bias subtraction, flat fielding with the data of the dome flats, and cosmic-ray removal. Flux calibration was obtained using standard stars available in IRAF. The nuclear spectra for individual galaxies were extracted with a 1″.8 × 1″.75 aperture. The extracted nuclear spectra are shown in Figure 1. A journal of the observations is given in Table 1. We also give morphological types of galaxies taken from Hickson (1993; see also Hickson, Kindle, & Huchra 1988; Mendes de Oliveira & Hickson 1994) and de Vaucouleurs et al. (1991) in Table 1.

## 3. RESULTS

### 3.1. *Classification of Emission-Line Activity*

In usual classification schemes for emission-line galaxies, some combinations of two emission-line intensity ratios (e.g., [O III] λ5007/Hβ versus [N II] λ6583/Hα) are often used (Veilleux & Osterbrock 1987). However, since our spectroscopic program was originally devoted to finding the

[1] The Image Reduction and Analysis Facility (IRAF) is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

kinematical peculiarity of HCG galaxies (Nishiura et al. 2000), our nuclear spectra only cover a wavelength range between 6300–7050 Å. Therefore, emission lines available for the classification of nuclear activities are [O I] λ6300, [N II] λλ6548, 6583, Hα, and [S II] λλ6717, 6731. Among several combinations between a couple of the emission lines listed above, the most reliable indicator to classify nuclear activities seems the [N II] λ6583/Hα ratio (hereafter [N II]/Hα). In fact, Ho, Filippenko, & Sargent (1997) showed from the spectroscopic analysis of more than 300 nearby galaxies that this ratio is useful in distinguishing between AGNs and H II nuclei; i.e., [N II]/Hα $\geq 0.6$ for AGNs while [N II]/Hα $< 0.6$ for H II nuclei. Therefore, applying this criterion, we classify the emission-line activity of our HCG galaxies. Galaxies without emission are referred as "Abs"; i.e., only stellar absorption features are seen in the optical spectra. For eight galaxies, we detected only [N II] line emission and did not detect Hα line emission (HCG 10a, 30b, 37a, 51b, 62a, 68a, 88a, and 93c). We classify them as AGNs. The emission-line flux data and the results of the classification are given in Tables 2 and 3, respectively.

As shown in Figure 1, some nuclei show evidence of Hα absorption. Since Hα absorption leads to an underestimation of the Hα emission, it would be better to subtract a template spectrum whose absorption spectral features are nearly the same as those of the concerned spectrum from the target galaxy spectrum (see, for example, Ho et al. 1997). Since, however, we do not have such a template database, we used the observed [N II]/Hα ratios in our classification.

In particular, in the case of very weak emission-line galaxies, the Hα emission may not be seen if the Hα absorption feature is strong. The most serious case may be post-starburst galaxies showing very strong Balmer absorption (e.g., Taniguchi et al. 1996 and references therein). Post-starburst galaxies have Hα absorption equivalent widths, EW(Hα) $\geq$ 3 Å. However, the galaxies with Hα absorption in our sample have EW(Hα) $\leq$ 2 Å; i.e., our sample contains no conspicuous poststarburst galaxy. We therefore expect that our emission-line classification is not affected by the effect of Hα absorption seriously.

Recently, Coziol et al. (1998) studied the nuclear activity of southern HCG galaxies. They obtained optical spectra of 82 bright galaxies in a sample of 17 HCGs (de Carvalho et al. 1997). Among the 82 galaxies, 40 galaxies are original HCG members identified by Hickson (1982). Although their sample is taken from the HCGs located in the southern hemisphere, 13 galaxies in their sample were also observed by us. Since they used the template subtraction method in their classification of nuclear activity, their classification seems to be more reliable than ours. In order to examine how our classification based on the [N II]/Hα ratio without absorption correction is reliable, we compare our results with those of Coziol et al. (1998). The basic data of the 13 HCG galaxies observed in common by both Coziol et al. (1998) and us are summarized in Table 4. We find that both studies give the same activity types for late-type galaxies. However, for early-type galaxies, although we have classified three galaxies (HCG 40a, 42a, and 87b) as absorption galaxies, they classified them AGNs (dwarf LINERs). These differences appear to be attributable to the fact that we did not apply the template subtraction method while they did. However, it is to be noted that none of the three galaxies are typical Seyfert nuclei, but dwarf LINER nuclei. Although our analysis may not miss typical Seyfert nuclei, it is safe to mention that about a half (e.g., $3/7 \simeq 43\%$) of early-type galaxies classified as absorption galaxies in our study are AGNs. This point will be taken into account in our later discussion.

Finally, we classified 63 of 69 galaxies we observed as 28 AGNs, 16 H II nuclei, and 19 no line emissions. Three of the remaining six galaxies are redshift-discordant galaxies (HCG 73a, 87d, and 92a). For the other three, the signal-to-noise ratio of their spectrum is too low to classify (HCG 34a, 42b, and 52a). We exclude these six galaxies from the sample in later statistical analyses.

### 3.2. *Nuclear Activity versus Group Properties*

Although the selection of HCGs was made homogeneously with the above criteria, it is known that the dynamical properties differ from HCG to HCG (Hickson et al. 1992). Therefore, it is interesting to compare the nuclear activity in the member galaxies with the dynamical properties of the groups.

As we mentioned previously, we adopt the [N II]/Hα intensity ratio as a measure of the nuclear activity. Since it is known that the nuclear activity type depends on the morphological types of host galaxies (e.g., Ho et al. 1997)—i.e., AGN favors early-type galaxies, while star formation activity favors later type ones—it is necessary to investigate relationships between the nuclear activity and the group properties for each morphological type. However, it is generally difficult to classify the morphology of galaxies that are interacting with their partner(s) (Mendes de Oliveira & Hickson 1994). Therefore, although we give detailed morphological types for the member galaxies in our sample in Table 1, we classify them broadly into the following three classes: (1) early-type galaxies (E/S0), (2) early-type spirals (S0a–Sbc), and (3) late-type spirals (Sc or later). In Figures 2–4, we show diagrams of [N II]/Hα against the number density of the groups $\rho_N$ (Hickson et al. 1992), the radial velocity dispersion of the groups $\sigma_r$ (Hickson et al. 1992), and the crossing time of the groups $t_c$ (Hickson et al. 1992), respectively. We adopt the null hypothesis that the [N II]/Hα ratio is correlated with each dynamical parameter and apply the Spearman-rank statistical test for all the correlations shown in Figures 2, 3, and 4. A summary of the statistical tests is given in Table 5. We find that there is no statistically significant correlation. Therefore, it is concluded that the nuclear activity of galaxies studied here has no physical relation to the dynamical properties of the groups. For disk galaxies in nearby HCGs, Iglesias-Páramo & Vílchez (1999) have found no clear correlations between the $L_{\mathrm{H}\alpha}/L_B$ ratio and the dynamical properties of the groups. Our results are consistent with their results.

### 3.3. *Comparison of the Nuclear Activity between the HCG Galaxies and Field Galaxies*

Our spectroscopic analysis shows that AGNs are found in almost half of the HCG galaxies, and star-forming activity is found in a quarter of the sample. An important question arises as whether or not these frequencies are unusual with respect to those in environments with fewer galaxy collisions. In order to examine this issue, we first make a control sample consisting of so-called field galaxies, and then we compare the nuclear activity between the HCG galaxies and the field galaxies.

TABLE 2

PROPERTIES OF LINE EMISSIONS

| | Hα | | | [N II] λ6548 | | | [N II] λ6583 | | | [S II] λ6717 | | | [S II] λ6731 | | | [O I] λ6300 | | | [O I] λ6364 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HCG | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] |
| 7a ....... | 6650.66 | 5.15 | 32.61 | 6635.91 | 5.15 | 5.42 | 6671.21 | 5.15 | 15.99 | 6806.19 | 4.33 | 3.40 | 6820.59 | 4.33 | 4.27 | | | | | | |
| | 0.09 | 0.14 | 2.01 | 0.09 | 0.14 | 0.48 | 0.09 | 0.14 | 1.41 | 0.37 | 0.57 | 1.15 | 0.37 | 0.57 | 1.31 | | | | | | |
| 10a ...... | | | | | | | 6698.58 | 13.46 | 14.76 | | | | | | | | | | | | |
| | | | | | | | 0.95 | 1.62 | 3.69 | | | | | | | | | | | | |
| 10b ...... | | | | | | | | | | | | | | | | | | | | | |
| 30a ...... | | | | | | | | | | | | | | | | | | | | | |
| 30b ...... | | | | 6647.68 | 6.72 | 2.79 | 6682.98 | 6.72 | 8.24 | | | | | | | | | | | | |
| | | | | 0.77 | 1.13 | 1.02 | 0.77 | 1.13 | 3.01 | | | | | | | | | | | | |
| 31a ...... | 6651.73 | 3.32 | 84.76 | 6636.98 | 3.32 | 4.97 | 6672.28 | 3.32 | 14.65 | 6807.60 | 2.85 | 14.38 | 6822.00 | 2.85 | 9.06 | | | | | | |
| | 0.02 | 0.03 | 1.96 | 0.02 | 0.03 | 0.38 | 0.02 | 0.03 | 1.11 | 0.07 | 0.10 | 1.14 | 0.07 | 0.10 | 0.92 | | | | | | |
| 31b ...... | 6653.34 | 2.74 | 27.80 | | | | | | | 6809.27 | 3.03 | 5.92 | 6823.67 | 3.03 | 3.92 | | | | | | |
| | 0.05 | 0.07 | 1.52 | | | | | | | 0.14 | 0.20 | 0.91 | 0.14 | 0.20 | 0.74 | | | | | | |
| 31c ...... | 6650.67 | 4.03 | 457.64 | 6635.92 | 4.03 | 12.87 | 6671.22 | 4.03 | 37.96 | 6806.30 | 4.41 | 31.54 | 6820.70 | 4.41 | 25.87 | 6383.93 | 4.61 | 7.05 | 6447.43 | 4.61 | 2.35 |
| | 0.02 | 0.03 | 7.45 | 0.02 | 0.03 | 1.38 | 0.02 | 0.03 | 4.08 | 0.09 | 0.14 | 2.26 | 0.09 | 0.14 | 2.04 | 0.52 | 0.75 | 2.51 | 0.52 | 0.75 | 0.84 |
| 34a ...... | 6762.39 | 8.62 | 3.50 | | | | 6782.94 | 8.62 | 6.62 | | | | | | | | | | | | |
| | 1.37 | 1.99 | 2.58 | | | | 1.37 | 1.99 | 3.45 | | | | | | | | | | | | |
| 37a ...... | | | | 6692.22 | 8.27 | 9.79 | 6727.52 | 8.27 | 28.90 | | | | | | | | | | | | |
| | | | | 0.53 | 0.83 | 2.10 | 0.53 | 0.83 | 6.19 | | | | | | | | | | | | |
| 37b ...... | 6712.35 | 2.77 | 3.58 | | | | 6731.07 | 8.82 | 4.53 | | | | | | | | | | | | |
| | 0.28 | 0.44 | 1.21 | | | | 1.43 | 2.17 | 2.41 | | | | | | | | | | | | |
| 38a ...... | 6752.59 | 5.62 | 13.51 | 6737.84 | 5.62 | 1.55 | 6773.14 | 5.62 | 4.58 | 6909.38 | 5.45 | 2.72 | 6923.78 | 5.45 | 1.71 | | | | | | |
| | 0.13 | 0.20 | 1.04 | 0.13 | 0.20 | 0.22 | 0.13 | 0.20 | 0.64 | 0.54 | 0.88 | 0.97 | 0.54 | 0.88 | 0.75 | | | | | | |
| 38b ...... | 6752.91 | 5.85 | 63.80 | 6738.16 | 5.85 | 12.03 | 6773.46 | 5.85 | 35.50 | 6911.67 | 5.23 | 4.08 | 6926.07 | 5.23 | 5.08 | | | | | | |
| | 0.08 | 0.13 | 3.10 | 0.08 | 0.13 | 0.77 | 0.08 | 0.13 | 2.26 | 0.39 | 0.64 | 1.24 | 0.39 | 0.64 | 1.41 | | | | | | |
| 38c ...... | 6751.78 | 5.58 | 13.89 | 6737.03 | 5.58 | 2.48 | 6772.33 | 5.58 | 7.31 | 6910.63 | 2.35 | 2.59 | 6925.03 | 2.35 | 1.15 | | | | | | |
| | 0.23 | 0.35 | 1.91 | 0.23 | 0.35 | 0.46 | 0.23 | 0.35 | 1.36 | 0.27 | 0.31 | 0.78 | 0.27 | 0.31 | 0.59 | | | | | | |
| 40a ...... | | | | | | | | | | | | | | | | | | | | | |
| 40b ...... | | | | | | | | | | | | | | | | | | | | | |
| 40c ...... | 6703.98 | 5.62 | 12.42 | 6689.23 | 5.62 | 2.47 | 6724.52 | 5.62 | 7.30 | | | | | | | | | | | | |
| | 0.25 | 0.36 | 1.82 | 0.25 | 0.36 | 0.46 | 0.25 | 0.36 | 1.35 | | | | | | | | | | | | |
| 42a ...... | | | | 6630.75 | 12.45 | 3.87 | 6666.05 | 12.45 | 11.41 | | | | | | | | | | | | |
| | | | | 2.37 | 3.80 | 2.52 | 2.37 | 3.80 | 7.42 | | | | | | | | | | | | |
| 44a ...... | 6592.53 | 3.86 | 6.44 | 6577.89 | 10.63 | 46.84 | 6613.19 | 10.63 | 138.18 | 6746.08 | 10.71 | 33.78 | 6760.48 | 10.71 | 37.79 | | | | | | |
| | 0.98 | 1.40 | 5.15 | 0.20 | 0.30 | 2.85 | 0.20 | 0.30 | 8.39 | 0.50 | 0.53 | 4.79 | 0.50 | 0.53 | 4.99 | | | | | | |
| 44b ...... | | | | | | | | | | | | | | | | | | | | | |
| 44c ...... | 6589.46 | 4.99 | 126.59 | 6574.71 | 4.99 | 32.14 | 6610.01 | 4.99 | 94.80 | 6743.86 | 5.25 | 25.92 | 6758.26 | 5.25 | 27.71 | | | | | | |
| | 0.05 | 0.08 | 4.49 | 0.05 | 0.08 | 1.28 | 0.05 | 0.08 | 3.78 | 0.12 | 0.19 | 2.29 | 0.12 | 0.19 | 2.38 | | | | | | |
| 44d ...... | 6597.17 | 2.94 | 3.72 | 6582.42 | 2.94 | 0.41 | 6617.72 | 2.94 | 1.20 | | | | | | | | | | | | |
| | 0.23 | 0.35 | 0.99 | 0.23 | 0.35 | 0.20 | 0.23 | 0.35 | 0.58 | | | | | | | | | | | | |
| 47a ...... | | | | 6760.87 | 3.73 | 0.88 | 6796.17 | 3.73 | 2.58 | | | | | | | | | | | | |
| | | | | 0.40 | 0.59 | 0.30 | 0.40 | 0.59 | 0.90 | | | | | | | | | | | | |
| 51a ...... | | | | | | | | | | | | | | | | | | | | | |
| 51b ...... | | | | 6727.71 | 9.60 | 1.42 | 6763.01 | 9.60 | 4.19 | | | | | | | | | | | | |
| | | | | 1.63 | 2.50 | 0.80 | 1.63 | 2.50 | 2.35 | | | | | | | | | | | | |
| 51f ...... | | | | | | | | | | | | | | | | | | | | | |
| 53a ...... | 6700.64 | 8.93 | 3.53 | 6685.89 | 8.93 | 1.83 | 6721.19 | 8.93 | 5.40 | | | | | | | | | | | | |

TABLE 2—*Continued*

| HCG | Hα | | | [N II] λ6548 | | | [N II] λ6583 | | | [S II] λ6717 | | | [S II] λ6731 | | | [O I] λ6300 | | | [O I] λ6364 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] | $\lambda_c$[a] | $\Delta\lambda$[b] | flux[c] |
| | 0.89 | 1.30 | 1.48 | 0.89 | 1.30 | 0.62 | 0.89 | 1.30 | 1.82 | | | | | | | | | | | | |
| 57a...... | 6755.24 | 6.18 | 9.19 | 6740.49 | 6.18 | 4.33 | 6775.79 | 6.18 | 12.79 | | | | | | | | | | | | |
| | 0.42 | 0.67 | 2.63 | 0.42 | 0.67 | 1.06 | 0.42 | 0.67 | 3.13 | | | | | | | | | | | | |
| 61a...... | 6644.47 | 2.41 | 5.39 | 6631.41 | 9.50 | 18.88 | 6666.71 | 9.50 | 55.69 | 6799.77 | 10.79 | 22.34 | 6814.17 | 10.79 | 21.74 | | | | | | |
| | 0.47 | 0.91 | 4.32 | 0.35 | 0.52 | 2.25 | 0.35 | 0.52 | 6.62 | 0.55 | 0.60 | 3.39 | 0.55 | 0.60 | 3.29 | | | | | | |
| 61c...... | 6650.69 | 7.73 | 28.93 | 6635.94 | 7.73 | 7.15 | 6671.24 | 7.73 | 21.09 | 6805.96 | 6.70 | 6.99 | 6820.36 | 6.70 | 2.68 | | | | | | |
| | 0.16 | 0.24 | 2.05 | 0.16 | 0.24 | 0.58 | 0.16 | 0.24 | 1.72 | 0.43 | 0.61 | 1.40 | 0.43 | 0.61 | 0.95 | | | | | | |
| 61d...... | | | | | | | | | | | | | | | | | | | | | |
| 62a...... | | | | 6641.17 | 6.90 | 4.38 | 6676.47 | 6.90 | 12.92 | | | | | | | | | | | | |
| | | | | 0.56 | 0.85 | 1.17 | 0.56 | 0.85 | 3.44 | | | | | | | | | | | | |
| 62b...... | | | | | | | | | | | | | | | | | | | | | |
| 62c...... | | | | | | | | | | | | | | | | | | | | | |
| 67b...... | 6613.54 | 6.33 | 2.44 | 6598.79 | 6.33 | 2.88 | 6634.09 | 6.33 | 8.49 | | | | | | | | | | | | |
| | 0.51 | 0.79 | 1.42 | 0.51 | 0.79 | 0.78 | 0.51 | 0.79 | 2.30 | | | | | | | | | | | | |
| 68a...... | | | | 6595.86 | 8.76 | 16.80 | 6631.16 | 8.76 | 49.56 | | | | | | | | | | | | |
| | | | | 0.56 | 0.84 | 3.50 | 0.56 | 0.84 | 10.32 | | | | | | | | | | | | |
| 68b...... | 6621.39 | 5.54 | 5.40 | 6606.64 | 5.54 | 8.25 | 6641.94 | 5.54 | 24.33 | | | | | | | | | | | | |
| | 0.31 | 0.45 | 2.61 | 0.31 | 0.45 | 1.46 | 0.31 | 0.45 | 4.32 | | | | | | | | | | | | |
| 68c...... | 6613.24 | 5.13 | 96.54 | 6598.49 | 5.13 | 25.35 | 6633.79 | 5.13 | 74.77 | 6768.02 | 6.56 | 18.23 | 6782.42 | 6.56 | 19.31 | | | | | | |
| | 0.05 | 0.08 | 3.66 | 0.05 | 0.08 | 1.05 | 0.05 | 0.08 | 3.09 | 0.17 | 0.26 | 1.72 | 0.17 | 0.26 | 1.81 | | | | | | |
| 71a...... | 6765.61 | 11.37 | 22.35 | 6750.86 | 11.37 | 15.33 | 6786.16 | 11.37 | 45.21 | | | | | | | | | | | | |
| | 0.19 | 0.24 | 1.67 | 0.19 | 0.24 | 0.75 | 0.19 | 0.24 | 2.20 | | | | | | | | | | | | |
| 72a...... | 6842.24 | 3.38 | 7.24 | 6827.49 | 3.38 | 2.26 | 6862.79 | 3.38 | 6.67 | | | | | | | | | | | | |
| | 0.42 | 0.61 | 3.20 | 0.42 | 0.61 | 1.02 | 0.42 | 0.61 | 3.00 | | | | | | | | | | | | |
| 73a...... | 6686.00 | 3.39 | 15.31 | 6672.69 | 3.55 | 2.16 | 6707.99 | 3.55 | 6.39 | | | | | | | | | | | | |
| | 0.12 | 0.17 | 1.71 | 0.29 | 0.43 | 0.58 | 0.29 | 0.43 | 1.70 | | | | | | | | | | | | |
| 79a...... | 6653.45 | 2.86 | 9.09 | 6638.70 | 2.86 | 1.87 | 6674.00 | 2.86 | 5.53 | | | | | | | | | | | | |
| | 0.28 | 0.44 | 3.14 | 0.28 | 0.44 | 0.78 | 0.28 | 0.44 | 2.31 | | | | | | | | | | | | |
| 79b...... | 6657.86 | 5.79 | 63.64 | 6643.11 | 5.79 | 9.63 | 6678.40 | 5.79 | 28.42 | 6814.39 | 6.47 | 8.36 | 6828.79 | 6.47 | 8.65 | | | | | | |
| | 0.11 | 0.16 | 3.96 | 0.11 | 0.16 | 0.91 | 0.11 | 0.16 | 2.70 | 0.31 | 0.47 | 1.49 | 0.31 | 0.47 | 1.53 | | | | | | |
| 79c...... | | | | | | | | | | | | | | | | | | | | | |
| 79d...... | 6663.08 | 3.12 | 5.62 | 6648.33 | 3.12 | 0.29 | 6683.63 | 3.12 | 0.85 | 6818.77 | 3.69 | 1.72 | 6833.17 | 3.69 | 1.11 | | | | | | |
| | 0.10 | 0.13 | 0.52 | 0.10 | 0.13 | 0.10 | 0.10 | 0.13 | 0.29 | 0.21 | 0.32 | 0.34 | 0.21 | 0.32 | 0.27 | | | | | | |
| 80a...... | 6759.43 | 5.77 | 39.60 | 6744.68 | 5.77 | 9.80 | 6779.98 | 5.77 | 28.90 | | | | | | | | | | | | |
| | 0.11 | 0.18 | 2.77 | 0.11 | 0.18 | 0.79 | 0.11 | 0.18 | 2.32 | | | | | | | | | | | | |
| 82a...... | | | | | | | | | | | | | | | | | | | | | |
| 82b...... | 6788.72 | 6.68 | 11.04 | 6773.97 | 6.68 | 2.14 | 6809.27 | 6.68 | 6.32 | | | | | | | | | | | | |
| | 0.29 | 0.47 | 1.70 | 0.29 | 0.47 | 0.43 | 0.29 | 0.47 | 1.28 | | | | | | | | | | | | |
| 87a...... | 6747.87 | 3.86 | 2.64 | 6733.12 | 3.86 | 0.87 | 6768.42 | 3.86 | 2.56 | | | | | | | | | | | | |
| | 0.31 | 0.46 | 0.78 | 0.31 | 0.46 | 0.25 | 0.31 | 0.46 | 0.75 | | | | | | | | | | | | |
| 87c...... | 6756.76 | 3.18 | 6.88 | 6742.01 | 3.18 | 1.00 | 6777.31 | 3.18 | 2.96 | | | | | | | | | | | | |
| | 0.10 | 0.15 | 0.72 | 0.10 | 0.15 | 0.16 | 0.10 | 0.15 | 0.47 | | | | | | | | | | | | |
| 88a...... | | | | 6679.15 | 7.99 | 7.66 | 6714.44 | 7.99 | 22.59 | | | | | | | | | | | | |
| | | | | 0.36 | 0.54 | 1.11 | 0.36 | 0.54 | 3.29 | | | | | | | | | | | | |
| 88b...... | 6700.00 | 2.75 | 2.45 | 6683.84 | 9.15 | 5.37 | 6719.14 | 9.15 | 15.83 | | | | | | | | | | | | |
| | 0.35 | 0.62 | 1.16 | 0.32 | 0.49 | 0.62 | 0.32 | 0.49 | 1.84 | | | | | | | | | | | | |

TABLE 2—*Continued*

| HCG | Hα $\lambda_c$[a] | Hα $\Delta\lambda$[b] | Hα flux[c] | [N II] λ6548 $\lambda_c$[a] | [N II] λ6548 $\Delta\lambda$[b] | [N II] λ6548 flux[c] | [N II] λ6583 $\lambda_c$[a] | [N II] λ6583 $\Delta\lambda$[b] | [N II] λ6583 flux[c] | [S II] λ6717 $\lambda_c$[a] | [S II] λ6717 $\Delta\lambda$[b] | [S II] λ6717 flux[c] | [S II] λ6731 $\lambda_c$[a] | [S II] λ6731 $\Delta\lambda$[b] | [S II] λ6731 flux[c] | [O I] λ6300 $\lambda_c$[a] | [O I] λ6300 $\Delta\lambda$[b] | [O I] λ6300 flux[c] | [O I] λ6364 $\lambda_c$[a] | [O I] λ6364 $\Delta\lambda$[b] | [O I] λ6364 flux[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 88c...... | 6693.22 | 3.29 | 5.84 | 6678.47 | 3.29 | 0.83 | 6713.77 | 3.29 | 2.44 | | | | | | | | | | | | |
| | 0.12 | 0.17 | 0.69 | 0.12 | 0.17 | 0.15 | 0.12 | 0.17 | 0.45 | | | | | | | | | | | | |
| 88d...... | 6696.14 | 3.40 | 7.37 | 6681.39 | 3.40 | 1.19 | 6716.69 | 3.40 | 3.50 | | | | | | | | | | | | |
| | 0.10 | 0.15 | 0.71 | 0.10 | 0.15 | 0.16 | 0.10 | 0.15 | 0.48 | | | | | | | | | | | | |
| 89a...... | 6755.68 | 4.38 | 8.94 | 6740.93 | 4.38 | 1.47 | 6776.23 | 4.38 | 4.33 | | | | | | | | | | | | |
| | 0.15 | 0.22 | 1.00 | 0.15 | 0.22 | 0.23 | 0.15 | 0.22 | 0.68 | | | | | | | | | | | | |
| 92a...... | 6579.86 | 2.92 | 3.21 | 6565.11 | 2.92 | 0.46 | 6600.41 | 2.92 | 1.36 | | | | | | | | | | | | |
| | 0.17 | 0.25 | 0.62 | 0.17 | 0.25 | 0.13 | 0.17 | 0.25 | 0.39 | | | | | | | | | | | | |
| 92b...... | | | | | | | | | | | | | | | | | | | | | |
| 92c...... | 6710.93 | 8.38 | 117.07 | 6696.18 | 8.38 | 58.12 | 6731.48 | 8.38 | 171.46 | 6866.47 | 9.19 | 57.59 | 6880.87 | 9.19 | 56.19 | 6441.80 | 9.33 | 33.00 | 6505.30 | 9.33 | 11.00 |
| | 0.05 | 0.10 | 4.18 | 0.05 | 0.10 | 1.53 | 0.05 | 0.10 | 4.51 | 0.18 | 0.21 | 3.58 | 0.18 | 0.21 | 3.54 | 0.44 | 0.64 | 4.91 | 0.44 | 0.64 | 1.64 |
| 92d...... | | | | | | | | | | | | | | | | | | | | | |
| 92e...... | | | | | | | | | | | | | | | | | | | | | |
| 93a...... | 6673.92 | 10.08 | 8.88 | 6659.17 | 10.08 | 11.27 | 6694.47 | 10.08 | 33.23 | 6830.10 | 8.87 | 13.94 | 6844.50 | 8.87 | 8.66 | | | | | | |
| | 0.32 | 0.46 | 2.21 | 0.32 | 0.46 | 1.13 | 0.32 | 0.46 | 3.33 | 0.41 | 0.51 | 1.91 | 0.41 | 0.51 | 1.62 | | | | | | |
| 93b...... | 6666.56 | 4.16 | 15.62 | 6651.81 | 4.16 | 3.48 | 6687.11 | 4.16 | 10.26 | 6821.91 | 4.17 | 3.23 | 6836.31 | 4.17 | 1.52 | | | | | | |
| | 0.07 | 0.11 | 0.93 | 0.07 | 0.11 | 0.25 | 0.07 | 0.11 | 0.72 | 0.33 | 0.49 | 0.84 | 0.33 | 0.49 | 0.59 | | | | | | |
| 93c...... | | | | 6659.36 | 6.92 | 3.92 | 6694.66 | 6.92 | 11.55 | | | | | | | | | | | | |
| | | | | 0.59 | 0.88 | 1.08 | 0.59 | 0.88 | 3.18 | | | | | | | | | | | | |
| 96a...... | 6753.33 | 8.95 | 52.54 | 6738.58 | 8.95 | 17.71 | 6773.88 | 8.95 | 52.23 | 6909.15 | 11.20 | 11.43 | 6923.55 | 11.20 | 16.83 | | | | | | |
| | 0.18 | 0.39 | 5.88 | 0.18 | 0.39 | 1.69 | 0.18 | 0.39 | 4.98 | 0.71 | 0.77 | 2.47 | 0.71 | 0.77 | 2.87 | | | | | | |

[a] The center wavelength and 1 $\sigma$ error of line spectrum in angstroms.
[b] The full width at half maximum and 1 $\sigma$ error of line spectrum in angstroms.
[c] The flux and 1 $\sigma$ error of line spectrum in the unit of $10^{-16}$ ergs $s^{-1}$ $cm^{-2}$.

TABLE 3

LINE RATIO AND DYNAMICAL PROPERTIES

| HCG | [N II]/Hα[a] | [S II]/Hα[b] | [O I]/Hα[c] | $\log \rho_N$ ($\mathrm{Mpc}^{-3}$) | $\log \sigma_r$ ($\mathrm{km\ s}^{-1}$) | $\log H_0 t_c$ | Activity Type |
|---|---|---|---|---|---|---|---|
| 07a ...... | 0.49 ± 0.07 | 0.24 ± 0.09 | | 4.00 | 1.95 | −1.40 | H II |
| 10a ...... | | | | 3.07 | 2.32 | −1.48 | AGN |
| 10b ...... | | | | 3.07 | 2.32 | −1.48 | Abs |
| 30a ...... | | | | 3.85 | 1.86 | −1.22 | Abs |
| 30b ...... | | | | 3.85 | 1.86 | −1.22 | AGN |
| 31a ...... | 0.17 ± 0.02 | 0.28 ± 0.03 | | 6.13 | 1.75 | −1.80 | H II |
| 31b ...... | | 0.35 ± 0.08 | | 6.13 | 1.75 | −1.80 | H II |
| 31c ...... | 0.08 ± 0.01 | 0.13 ± 0.01 | 0.02 ± 0.01 | 6.13 | 1.75 | −1.80 | H II |
| 34a ...... | 1.89 ± 2.39 | | | 5.41 | 2.50 | −2.44 | AGN? |
| 37a ...... | | | | 4.70 | 2.60 | −2.27 | AGN |
| 37b ...... | 1.26 ± 1.10 | | | 4.70 | 2.60 | −2.27 | AGN |
| 38a ...... | 0.34 ± 0.07 | 0.33 ± 0.15 | | 3.55 | 1.11 | 0.88 | H II |
| 38b ...... | 0.56 ± 0.06 | 0.14 ± 0.05 | | 3.55 | 1.11 | 0.88 | H II |
| 38c ...... | 0.53 ± 0.17 | 0.27 ± 0.14 | | 3.55 | 1.11 | 0.88 | H II |
| 40a ...... | | | | 5.54 | 2.17 | −2.12 | Abs |
| 40b ...... | | | | 5.54 | 2.17 | −2.12 | Abs |
| 40c ...... | 0.59 ± 0.19 | | | 5.54 | 2.17 | −2.12 | H II |
| 42a ...... | | | | 4.03 | 2.33 | −1.81 | Abs |
| 42b ...... | | | | 4.03 | 2.33 | −1.81 | ? |
| 42c ...... | | | | 4.03 | 2.33 | −1.81 | Abs |
| 44a ...... | 21.46 ± 18.45 | 11.11 ± 10.40 | | 4.24 | 2.13 | −1.65 | AGN |
| 44b ...... | | | | 4.24 | 2.13 | −1.65 | Abs |
| 44c ...... | 0.75 ± 0.06 | 0.42 ± 0.05 | | 4.24 | 2.13 | −1.65 | AGN |
| 44d ...... | 0.32 ± 0.24 | | | 4.24 | 2.13 | −1.65 | H II |
| 47a ...... | | | | 4.30 | 1.63 | 0.66 | Abs |
| 51a ...... | | | | 3.77 | 2.38 | −1.73 | Abs |
| 51b ...... | | | | 3.77 | 2.38 | −1.73 | AGN |
| 51f ...... | | | | 3.77 | 2.38 | −1.73 | Abs |
| 52a ...... | | | | 3.04 | 2.26 | −1.43 | ? |
| 53a ...... | 1.53 ± 1.15 | | | 3.58 | 1.91 | −1.14 | AGN |
| 57a ...... | 1.39 ± 0.74 | | | 3.64 | 2.43 | −1.69 | AGN |
| 61a ...... | 10.33 ± 9.51 | 8.17 ± 7.79 | | 4.48 | 1.94 | −1.60 | AGN |
| 61c ...... | 0.73 ± 0.11 | 0.33 ± 0.10 | | 4.48 | 1.94 | −1.60 | AGN |
| 61d ...... | | | | 4.48 | 1.94 | −1.60 | Abs |
| 62a ...... | | | | 4.69 | 2.46 | −2.16 | AGN |
| 62b ...... | | | | 4.69 | 2.46 | −2.16 | Abs |
| 62c ...... | | | | 4.69 | 2.46 | −2.16 | Abs |
| 67b ...... | 3.48 ± 2.98 | | | 3.91 | 2.32 | −1.76 | AGN |
| 68a ...... | | | | 4.52 | 2.19 | −1.79 | AGN |
| 68b ...... | 4.51 ± 2.98 | | | 4.52 | 2.19 | −1.79 | AGN |
| 68c ...... | 0.77 ± 0.06 | 0.39 ± 0.05 | | 4.52 | 2.19 | −1.79 | AGN |
| 71a ...... | 2.02 ± 0.25 | | | 3.76 | 2.62 | −2.04 | AGN |
| 72a ...... | 0.92 ± 0.82 | | | 4.33 | 2.42 | −2.00 | AGN |
| 73a ...... | 0.42 ± 0.16 | | | | | | H II |
| 79a ...... | 0.61 ± 0.46 | | | 6.49 | 2.14 | −2.43 | AGN |
| 79b ...... | 0.45 ± 0.07 | 0.27 ± 0.06 | | 6.49 | 2.14 | −2.43 | H II |
| 79c ...... | | | | 6.49 | 2.14 | −2.43 | Abs |
| 79d ...... | 0.15 ± 0.07 | 0.50 ± 0.16 | | 6.49 | 2.14 | −2.43 | H II |
| 80a ...... | 0.73 ± 0.11 | | | 4.78 | 2.43 | −2.16 | AGN |
| 82a ...... | | | | 3.43 | 2.79 | −2.07 | Abs |
| 82b ...... | 0.57 ± 0.20 | | | 3.43 | 2.79 | −2.07 | H II |
| 87a ...... | 0.97 ± 0.57 | | | 4.39 | 2.08 | −1.56 | AGN |
| 87b ...... | | | | 4.39 | 2.08 | −1.56 | Abs |
| 87c ...... | 0.43 ± 0.11 | | | 4.39 | 2.08 | −1.56 | H II |
| 87d ...... | | | | | | | ? |
| 88a ...... | | | | 3.49 | 1.43 | 0.94 | AGN |
| 88b ...... | 6.47 ± 3.83 | | | 3.49 | 1.43 | 0.94 | AGN |
| 88c ...... | 0.42 ± 0.13 | | | 3.49 | 1.43 | 0.94 | H II |
| 88d ...... | 0.47 ± 0.11 | | | 3.49 | 1.43 | 0.94 | H II |
| 89a ...... | 0.48 ± 0.13 | | | 3.67 | 1.74 | −0.84 | H II |
| 92a ...... | 0.42 ± 0.20 | | | | | | H II |
| 92b ...... | | | | 4.63 | 2.59 | −2.27 | Abs |
| 92c ...... | 1.46 ± 0.09 | 0.97 ± 0.10 | 0.28 ± 0.05 | 4.63 | 2.59 | −2.27 | AGN |
| 92d ...... | | | | 4.63 | 2.59 | −2.27 | Abs |
| 92e ...... | | | | 4.63 | 2.59 | −2.27 | Abs |
| 93a ...... | 3.74 ± 1.31 | 2.55 ± 1.03 | | 3.43 | 2.32 | −1.59 | AGN |
| 93b ...... | 0.66 ± 0.09 | 0.30 ± 0.11 | | 3.43 | 2.32 | −1.59 | AGN |
| 93c ...... | | | | 3.43 | 2.32 | −1.59 | AGN |
| 96a ...... | 0.99 ± 0.21 | 0.54 ± 0.16 | | 4.54 | 2.12 | −1.76 | AGN |

[a] [N II] λ6583/Hα. The error is 1 σ.

[b] [S II] (λ6717 + λ6731)/Hα. The error is 1 σ.

[c] [O I] λ6300/Hα. The error is 1 σ.

TABLE 4

COMAPARISON OF NUCLEAR ACTIVITIES BETWEEN OUR STUDY AND COZIOL ET AL. (1998)

| | | COZIOL ET AL. (1998) | | OUR STUDY | |
|---|---|---|---|---|---|
| HCG | TYPE ADOPTED | [N II]/Hα | Activity Type | [N II]/Hα | Activity Type |
| 40a ...... | E | 0.87 ± 0.06 | AGN | | Abs |
| 40b ...... | S0 | | Abs | | Abs |
| 42a ...... | E | 1.78 ± 0.04 | AGN | | Abs |
| 42c ...... | E | | Abs | | Abs |
| 62a ...... | S0 | 0.60 ± 0.01 | AGN | | AGN[a] |
| 62b ...... | S0 | | Abs | | Abs |
| 62c ...... | E | | Abs | | Abs |
| 87a ...... | S0 | 0.83 | AGN | 0.97 ± 0.57 | AGN |
| 87b ...... | S0 | 1.29 | AGN | | Abs |
| 87c ...... | Sd | 0.44 | H II | 0.43 ± 0.11 | H II |
| 88a ...... | Sb | 0.89 | AGN | | AGN[a] |
| 88b ...... | Sa | 1.91 | AGN | 6.47 ± 3.83 | AGN |
| 88d ...... | Sc | 0.32 | H II | 0.47 ± 0.11 | H II |

[a] We have not detected Hα but have detected [N II] λ6583.

Recently Ho, Filippenko, & Sargent (1995, 1997) made an extensive spectroscopic survey for nearby galaxies using the Palomar Observatory 5 m telescope. Their sample contains 486 galaxies with $B_T \leq 12.5$ and $\delta > 0°$ where $B_T$ is the apparent total $B$ magnitude and $\delta$ is the declination. In order to make a sample of field galaxies, we have omitted the following galaxies from their sample: (1) galaxies belong to the Virgo cluster, (2) binary/interacting galaxies, (3) HCG galaxies (HCG 44a = NGC 3190, HCG 44b = NGC 3193, HCG 44c = NGC 3185, HCG 61a = NGC 4169, HCG 68a = NGC 5353, and HCG 68b = NGC 5354), (4) NGC 1003 whose activity type is uncertain, and (5) the Hubble type is uncertain for five galaxies (NGC 63, 812, 2342, 7798, and UGC 3714). Excluding the above galaxies, we obtain a sample of 382 field galaxies, consisting of 167 AGNs, 174 H II nuclei, and 41 normal galaxies. This sample has no matching to the HCG sample in both apparent magnitude and morphology. Since the majority of the HCG galaxies are fainter than the field galaxies observed by Ho et al. (1997), it is difficult to obtain a magnitude-matched sample of field galaxies. However, when we compare the nuclear activity between the HCG galaxies and the field galaxies, we

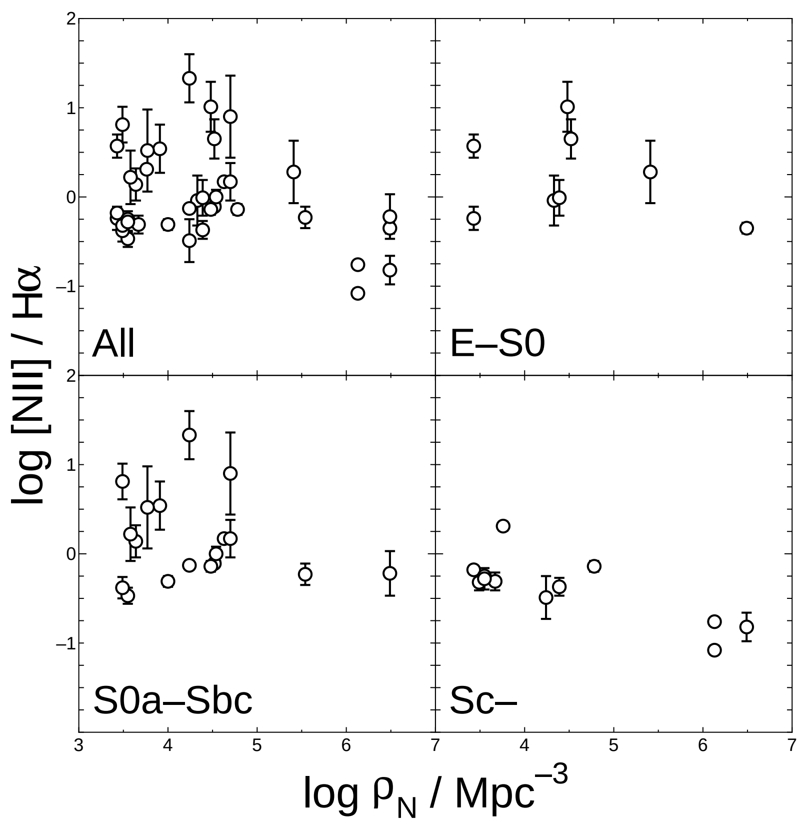


FIG. 2.—Correlations between the [N II]/Hα ratio and the number density of galaxies in the HCGs $\rho_N$. The results are shown for the entire sample (*top left*), E–S0 galaxies (*top right*), S0a–Sbc galaxies (*bottom left*), and Sc or later (*bottom right*).

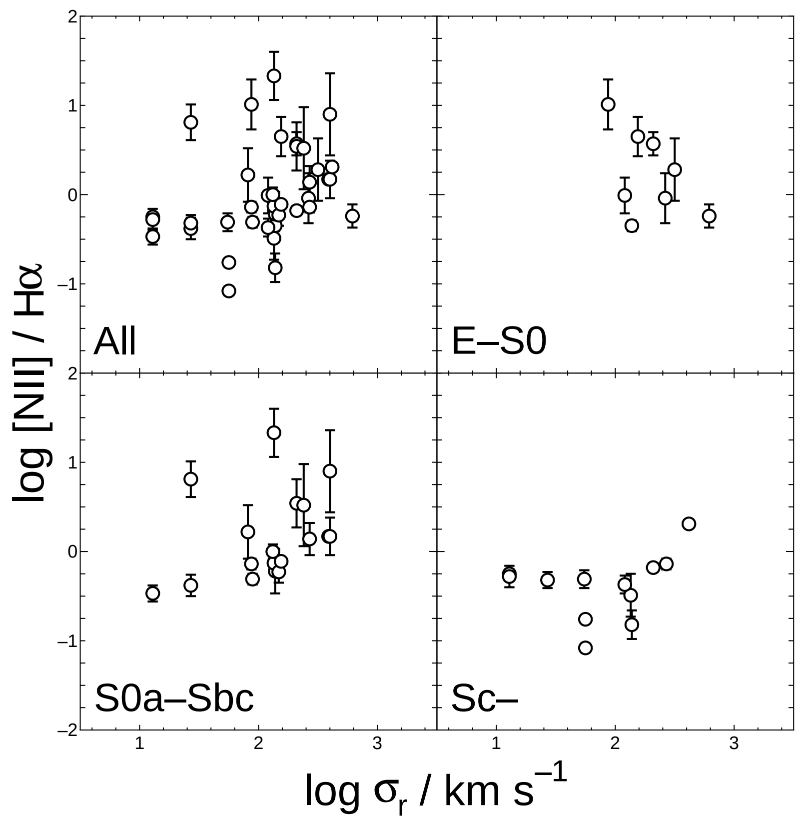


FIG. 3.—Correlations between the [N II]/Hα ratio and the radial velocity dispersion of galaxies in the HCGs $\sigma_r$. The results are shown for the entire sample (*top left*), E–S0 galaxies (*top right*), S0a–Sbc galaxies (*bottom left*), and Sc or later (*bottom right*).

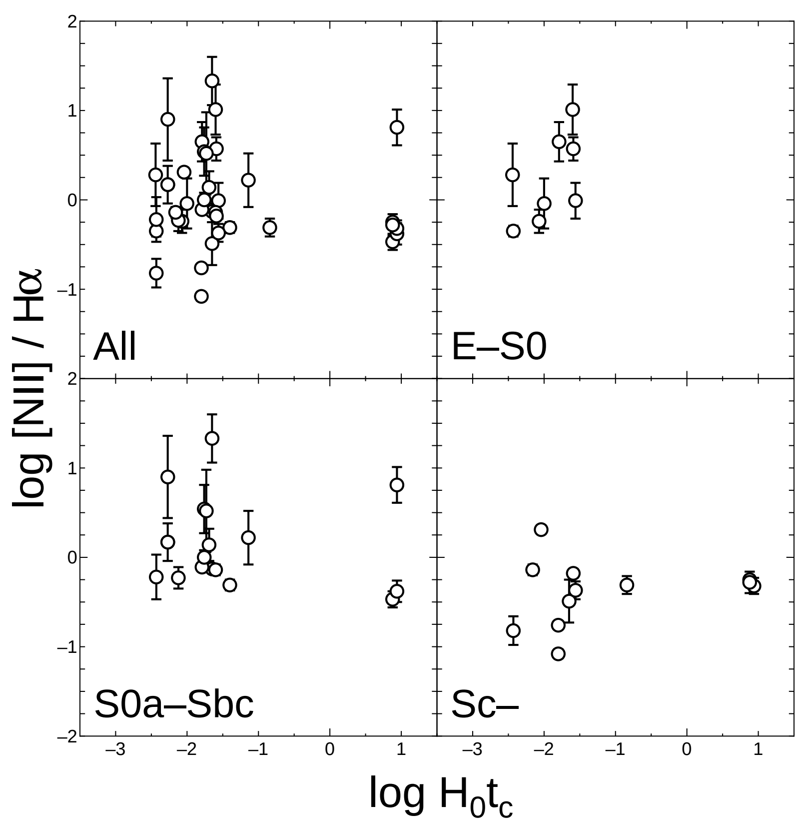


FIG. 4.—Correlations between the [N II]/Hα ratio and the crossing time of galaxies in the HCGs $t_c$. The results are shown for the entire sample (*top left*), E–S0 galaxies (*top right*), S0a–Sbc galaxies (*bottom left*), and Sc or later (*bottom right*).

TABLE 5

SUMMARY OF THE SPEARMAN RANK TEST FOR THE CORRELATIONS BETWEEN [N II]/Hα RATIO AND THE DYNAMICAL PROPERTIES OF THE HCGs[a]

| | log([N II] λ6583/Hα) | | |
|---|---|---|---|
| OBJECT | $\log \rho_N$ | $\log \sigma_r$ | $\log H_0 t_c$ |
| All .................. | 0.82 | 0.004 | 0.97 |
| E–S0 ............... | 0.43 | 0.93 | 0.07 |
| S0a–Sbc............ | 0.71 | 0.08 | 0.76 |
| Sc≤ ................ | 0.40 | 0.16 | 0.29 |

[a] The probability that rejects the null hypothesis.

will take account of the morphological difference between the HCGs and the fields.

In Figure 5, we show the frequency distributions of activity types for the HCGs (*top panels*) and for the field (*bottom panels*). Applying the $\chi^2$ test, we examine whether or not the frequency distributions of the activity types for the HCGs are significantly different from those for the field galaxies for the morphological samples of E–S0, S0a–Sbc, Sc or later, and all the galaxies (the total sample). We adopt the null hypothesis that the HCG galaxies and field galaxies come from the same underlying distribution of the activity types. The results of our statistical test are summarized in Table 6. Although the difference in the frequency distribution is not statistically significant for each morphological type, the difference for the total sample is significant in that the HCGs have fewer H II nuclei while having more absorption galaxies than the field galaxies. The H II nuclei and the absorption galaxies are found in 26% and 31% of the HCG galaxies, respectively. On the other hand, in the field the H II nuclei make up 46%, while the absorption galaxies make up only 11%, of the sample.

Taking into account that the nuclear activity type depends on the morphological types of host galaxies (e.g., Ho et al. 1997), we examine the difference in the morphological type distribution between the HCG galaxies and the field ones. In Figure 6, we show the frequency distributions of morphological types for each activity type and for the

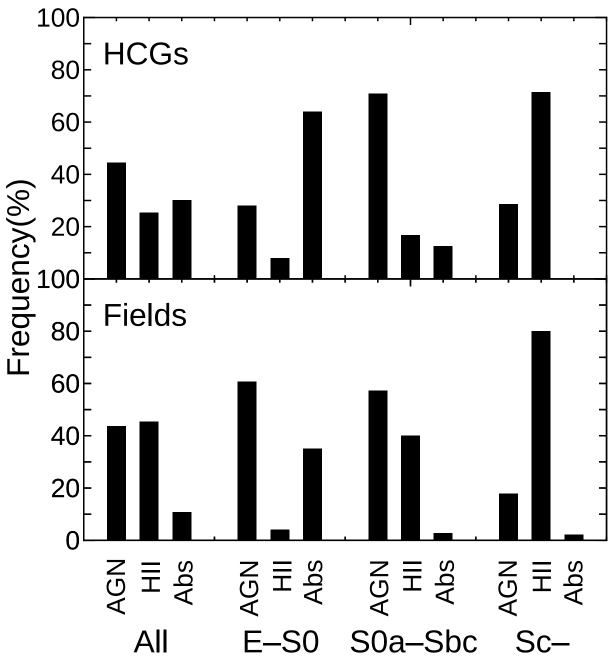


FIG. 5.—Comparison of frequency distributions of nuclear activity types between the HCGs and the field for the entire sample, E–S0 galaxies, S0a–Sbc galaxies, and Sc or later.

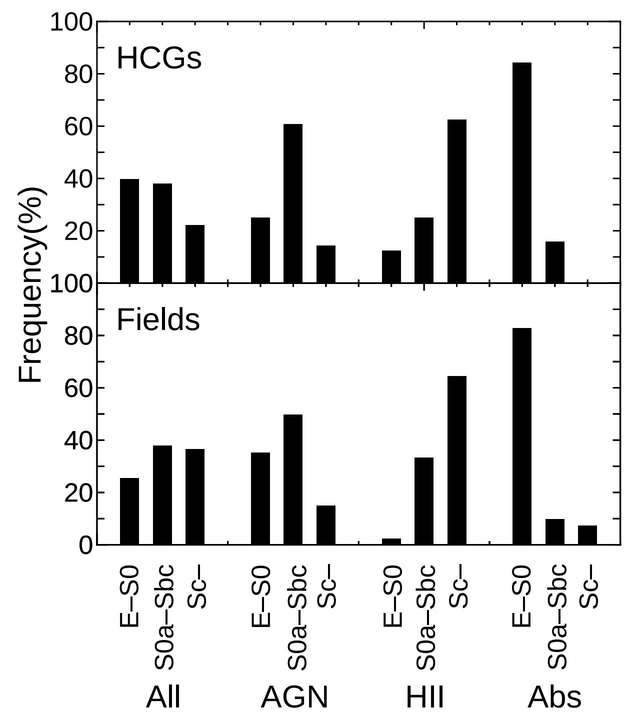


FIG. 6.—Comparison of frequency distributions of morphological types between the HCGs and the field for the entire sample, AGNs, H II nuclei, and absorption galaxies.

TABLE 6

FREQUENCY DISTRIBUTIONS OF NUCLEAR ACTIVITY TYPES BETWEEN THE HCGs AND THE FIELD[a]

| | ALL[b] | | E–S0 | | S0A–SBC | | SC≤ | |
|---|---|---|---|---|---|---|---|---|
| TYPE | HCGs | Field | HCGs | Field | HCGs | Field | HCGs | Field |
| AGN | 44.4 (28) | 43.7 (167) | 28.0 (7) | 60.8 (59) | 70.8 (17) | 57.2 (83) | 28.6 (4) | 17.9 (25) |
| H II | 25.4 (16) | 45.5 (174) | 8.0 (2) | 4.1 (4) | 16.7 (4) | 40.0 (58) | 71.4 (10) | 80.0 (112) |
| Abs | 30.2 (19) | 10.7 (41) | 64.0 (16) | 35.1 (34) | 12.5 (3) | 2.8 (4) | 0.0 (0) | 2.1 (3) |
| $P(\chi^2)$[c] | $3.93 \times 10^{-5}$ | | 0.01 | | 0.01 | | 0.55 | |

[a] Numbers in parentheses are the actual numbers.
[b] " All " means the total sample of E–S0, S0a–Sbc, and Sc≤ galaxies.
[c] The possibility that rejects the null hypothesis.

TABLE 7

FREQUENCY DISTRIBUTIONS OF THE MORPHOLOGICAL TYPES BETWEEN THE HCGS AND THE FIELD AS A FUNCTION OF NUCLEAR ACTIVITY[a]

| | ALL[b] | | AGN | | H II | | ABS | |
|---|---|---|---|---|---|---|---|---|
| TYPE | HCGs | Field | HCGs | Field | HCGs | Field | HCGs | Field |
| E–S0 ......... | 39.7 (25) | 25.4 (97) | 25.0 (7) | 35.3 (59) | 12.5 (2) | 2.3 (4) | 84.2 (16) | 82.9 (34) |
| S0a–Sbc...... | 38.1 (24) | 38.0 (145) | 60.7 (17) | 49.7 (83) | 25.0 (4) | 33.3 (58) | 15.8 (3) | 9.8 (4) |
| Sc≤ ........... | 22.2 (14) | 36.6 (140) | 14.3 (4) | 15.0 (25) | 62.5 (10) | 64.4 (112) | 0.0 (0) | 7.3 (3) |
| $P(\chi^2)$[c] .......... | 0.03 | | 0.51 | | 0.08 | | 0.41 | |

[a] Numbers in parentheses are the actual numbers.
[b] "All" means the total sample of AGN, H II, and absorption galaxies.
[c] The possibility that rejects the null hypothesis.

total sample. Applying the $\chi^2$ test, we examine whether or not the frequency distributions of the morphological types for our HCG galaxies are significantly different from those for the field galaxies for the nuclear activity type of AGN, H II, absorption, and the total sample. We adopt the null hypothesis that the HCG galaxies and field galaxies come from the same underlying distribution of the morphological types. The results of our statistical test are summarized in Table 7. Our HCG sample contains more E–S0 galaxies while fewer late-type spirals than the field. This leads to the underpopulation of H II nuclei in the HCG sample because H II nuclei favor such late-type spirals. However, the frequency of occurrence of AGNs in the HCGs is nearly the same as that in the field. A remarkable difference may be that the H II nuclei are found in E–S0 galaxies more frequently in the HCGs ($\simeq 13\%$) than in the field ($\simeq 2\%$). This result appears consistent with the finding by Zepf et al. (1991); there are a number of early-type galaxies with unusually blue colors, suggesting the enhanced star formation in early type galaxies.

We have found some interesting difference in the frequency distributions of the activity types between the HCGs and the field described above. However, since the frequency distribution of morphological types is different between the two samples, we cannot conclude that the differences are real. In order to check the effect of the difference in the morphological type distributions, we estimate the frequency of AGNs, H II nuclei, and absorption galaxies in the HCGs if the morphological type distribution in the HCGs is the same as that in the field. For example, we can estimate the expected number of AGNs in the HCGs as

$$N_{\rm AGN}^{\rm exp}({\rm HCG}) = N_{\rm E\text{–}S0} \times P_{\rm AGN,E\text{–}S0}({\rm Field}) + N_{{\rm S0}a\text{–}{\rm Sbc}} \times P_{{\rm AGN,S0}a\text{–}{\rm Sbc}}({\rm Field}) + N_{\rm Sc} \times P_{\rm AGN,Sc}({\rm Field}) ,$$

where $P_{x,y}$ (Field) is the probability that galaxies with the morphological type $y$ have the activity type $x$ in the field sample. We can also estimate both $N_{\rm HII}^{\rm exp}({\rm HCG})$ and $N_{\rm Abs}^{\rm exp}({\rm HCG})$ in a similar way. We also adopt the null hypothesis that the observed distribution is the same as the expected distribution and apply the $\chi^2$ test. The results are given in Table 8. We find that there is no statistical difference in the activity-type distributions between the HCGs and the field. Hence, we conclude that the nuclear activity in the HCGs is not different from that in the field under the assumption that the morphology-activity relation is the same between the HCGs and the field.

As mentioned in § 3.1, our spectral analysis may miss dwarf LINERs roughly in a half of early-type galaxies studied here. If we assume that a half of the early-type galaxies classified as "Abs" could be AGNs, our 63 HCG galaxies are classified into 36 AGNs, 16 H II nuclei, and 19 Abs. In this case, we obtain $P(\chi^2) = 0.50$. This means that the activity distribution of HCG galaxies is again indistinguishable from that of the field galaxies.

TABLE 8

COMPARISONS OF EXPECTED NUMBERS OF ACTIVITY TYPES WITH OBSERVATIONS FOR THE HCG SAMPLE[a]

| Type | Observations | Corrected Numbers[b] | Expected Numbers |
|---|---|---|---|
| AGN ...... | 44.4 (28) | 56.5 (35) | 49.2 (31) |
| H II........ | 25.4 (16) | 25.4 (16) | 34.9 (22) |
| Abs ........ | 30.2 (19) | 19.4 (12) | 15.9 (10) |
| $P(\chi^2)$[c]...... | 0.14 | 0.50 | |

[a] Numbers in parentheses are the actual numbers.
[b] Expected numbers assuming that we have taken AGN for Abs for half (3/7) of early-type galaxies.
[c] The possibility that rejects the null hypothesis.

## 4. DISCUSSION

Our main results are summarized here. (1) We have described the results of our spectroscopic program for a sample of 63 galaxies in the 28 HCGs. We have found in our sample 28 AGNs, 16 H II nuclei, and 19 normal galaxies that show no emission line. We used this HCG sample for statistical analyses. (2) Comparing the frequency distributions of activity types between the HCGs and the field whose data are taken from Ho, Filippenko, & Sargent (382 field galaxies), we find that the frequency of occurrence of H II nuclei in the HCGs is significantly less than that in the field. However, our HCG sample contains more early-type galaxies than the field, the above difference for the H II nuclei may be due to this morphology bias because it is known that H II nuclei are rarer in early-type galaxies than in later ones. (3) Correcting this morphological bias to the HCG sample, we find that there is no significant difference in the frequency of occurrence of emission-line galaxies between the HCGs and the field. This implies that the dense galaxy environment in the HCGs does not affect the triggering of either AGNs or nuclear starbursts. (4) Since our classification of nuclear activities is judged by the raw optical spectra, we may miss some less luminous AGNs, in particular in early-type galaxies. Even though this effect is taken into account, the distributions of activity types of HCG galaxies are indistinguishable from those of field galaxies.

Our finding seems surprising because it is widely accepted that galaxy interactions lead to either nuclear activity such as AGNs or nuclear starbursts or both (see for a review Shlosman, Begelman, & Frank 1990; Barnes & Hernquist 1992). Indeed, in 1980s several systematic observational investigations of interacting or binary galaxies suggested that galaxy collisions may raise both nuclear activity and intense star formation (e.g., Kennicutt & Keel 1984; Keel et al. 1985; Dahari 1985; Bushouse 1986, 1987), although the statistical significance was not so high (i.e., $\simeq$90%–95%; for recent papers, see De Robertis, Yee, & Hayhoe 1998; Taniguchi 1999). In addition, luminous and ultraluminous infrared galaxies are often detected in strongly interacting galaxies and merging galaxies (Sanders et al. 1988; for a review, see Sanders & Mirabel 1996). Numerical simulations of interacting or merging galaxies have shown that gas fueling driven by galaxy interaction occurs efficiently (e.g., Noguchi 1988; Olson & Kwan 1990a, 1990b; Mihos & Hernquist 1994b).

If tidal interactions lead to the formation of AGNs and/or nuclear starbursts, we would observe a large number of such active galaxies in the HCGs because the member galaxies are expected to have experienced many tidal interactions during the course of their dynamical evolution. Galaxy interactions affect the star formation activity in galactic disks because the effect of tidal interactions is much stronger in the outer parts than in the nuclear regions (e.g., Noguchi & Ishibashi 1986; see also Kennicutt et al. 1987). Indeed, some radio studies have revealed that a large fraction of HCG spirals are H I deficient (Williams & Rood 1987; Huchtmeier 1997). If a HCG contains several gas-rich spiral galaxies, the average star formation rate would be more enhanced than that in the field galaxies (e.g., Young et al. 1986). However, such excess has not yet been confirmed by *IRAS* observations (Sulentic & de Mello Rabaca 1993 and references therein). Although the deficiency of atomic hydrogen gas in HCG spirals implies that intense star formation is expected to occur in HCG galaxies, Moles et al. (1994) have concluded from optical and infrared observations that there are no strong starbursting galaxies in HCGs. These results indicate that frequent galaxy collisions are not always able to increase the star formation rate intensely. Although the lack of an enhancement of far-infrared emission may be partly attributed to the fact that the HCGs prefer early-type spiral galaxies as well as elliptical ones, it should be noted that roughly half of the galaxies in the HCGs are late-type spirals and irregular galaxies (Hickson et al. 1988; Mendes de Oliveira & Hickson 1994). Therefore, it is suggested that off-nuclear star formation activity is also not enhanced in the HCGs with respect to field galaxies.

Coziol et al. (1998) have shown from a spectroscopic survey for 17 HCGs (de Carvalho et al. 1997) that AGNs are preferentially located in the earliest type and most luminous members in the HCGs, suggesting a correlation between activity types, morphologies, and densities of galaxies in HCGs. They searched more possible member galaxies outside the original HCG members and then found the above interesting observational properties. However, our spectroscopic survey was made only for the original HCG members. Therefore, we do not think that our results are inconsistent with their results. An interesting point suggested by Coziol et al. (1998) is that AGNs are preferentially found in luminous, early-type galaxies. Verdes-Montenegro et al. (1998) showed from their $^{12}$CO($J$ = 1–0) emission survey for a large number of HCG galaxies that a number of early-type galaxies are detected in CO as well as in FIR. In addition, early-type galaxies with unusually blue colors are also found by Zepf et al. (1991). Although all these may be still circumstantial lines of evidence, it is suggested that the majority of early-type galaxies in the HCGs are affected by some environmental effect. One possible important effect is a merger between an early-type galaxy and a gas-rich galaxy, such as a late-type spiral or a small satellite galaxy, since galaxy mergers between unequal galaxies may lead to the formation of S0 galaxies (Bekki 1998).

The above arguments suggest that mere tidal interactions between galaxies are not responsible for the triggering of intense nuclear activities. Recently, instead of mere tidal interactions, minor mergers have been appreciated as a more important triggering mechanism both for nuclear starbursts (Mihos & Hernquist 1994a; Hernquist & Mihos 1995; Taniguchi & Wada 1996) and for Seyfert nuclei (De Robertis et al. 1998; Taniguchi 1999; see for an earlier indication Gaskell 1985). If this is the case, it is not surprising that the nuclear activities in the HCG galaxies are not significantly different from those in the field galaxies. Furthermore, if major mergers are more important to activate more luminous starbursts and AGNs (e.g., Sanders et al. 1988), it is suggested that most of the HCGs have not yet experienced such major mergers in the member galaxies. Since the dynamical relaxation timescale for the HCGs is shorter than the Hubble times, it is expected that each HCG will merge into one within a timescale of several gigayears (Hickson et al. 1992). Therefore, the HCG are expected to evolve either into luminous or ultraluminous infrared galaxies via multiple mergers (Xia et al. 1997; Taniguchi, Wada, & Murayama 1997; Taniguchi & Shioya 1998; Lípari et al. 2000; Borne et al. 2000) or into quasars (Sanders et al. 1988; Taniguchi, Ikeuchi, & Shioya 1999) or into ordinary-looking elliptical galaxies (Barnes 1989; Weil & Hernquist 1996; Nishiura et al. 1997).

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