THE ASTROPHYSICAL JOURNAL, 203:587–592, 1976 February 1

Hα EMISSION FROM THE DISKS OF SPIRAL GALAXIES

JUDITH G. COHEN
Kitt Peak National Observatory*
Received 1975 May 29; revised 1975 July 7

ABSTRACT

Observations of the amount of Hα emission from the disks of 53 galaxies have been made using large entrance apertures so that the maximum possible fraction of the total area of the galaxy is included. These observations reveal a relationship between $B - V$ color and Hα emission; for a given morphological type the bluer galaxies have more emission at Hα. The effect of the strong emission lines on the colors is not sufficient to produce this trend. Furthermore, the Hα emission comes from discrete H II regions ionized by starlight which are limited in the crudest approximation by the number of hot stars rather than the availability of gas. From the range in Hα emission, we obtain the ratio of hot stars to cooler stars corresponding to the observed range in $B - V$ color. We then compare this with a theoretical model by Searle, Sargent, and Bagnuolo which predicts $B - V$ color as a function of the stellar luminosity function in the galaxy. The two separate methods of determining the change in ratio of hot-to-cool stars agree well. We thus give further observational support to the models of Searle, Sargent, and Bagnuolo.

Subject headings: galactic: structure — galaxies: photometry — galaxies: stellar content — nebulae: general

I. INTRODUCTION

The amount of Hα emission produced in normal spiral disks is a function of the amount of gas present and the ionization equilibrium of the gas, usually determined by the available ultraviolet radiation from early-type stars. Radio studies of spirals (Oort 1974) have shown that, except in the central bulge, there is sufficient neutral hydrogen gas available along the arms so that the H II regions are ionization-bounded rather than density-bounded (Israel and van der Kruit 1974). Thus the amount of Hα emission in spiral disks is not limited by absence of gas in regions where hot stars are found, and is directly dependent on the number of O and early-B stars. To determine the variation in gas content and luminosity function (fraction of early-type stars) as a function of galaxy type, we have observed the emission at Hα (and [N II]) integrated over the disk of the galaxy for a sample of 53 galaxies, largely spirals and irregulars. The observations are described in § II. In § III, we discuss the implications of the relationship that we have observed between integrated Hα emission and $B - V$ color for galaxies of a given morphological type. We also compare the number of H II regions required to produce the observed emission with the number of H II regions in galaxies of various morphological types measured directly from photographs taken with Hα interference filters by Hodge (1969, 1974) and ourselves. The question of the ratio of Hα/[N II] in spiral disks is also discussed briefly. A summary of the important results is given in the last section.

* Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

II. OBSERVATIONS

Since we desire to observe the emission over the entire disk of the spiral galaxy, we selected galaxies with mean major diameters (D_g) (as listed in de Vaucouleurs and de Vaucouleurs 1964) less than 3′. In order to get a large fraction of the disk into the entrance aperture, we optimally desire a small telescope with large scale, but not so small that the limiting magnitude becomes excessively bright. We compromised on the 90 cm telescope, and the limiting V magnitude was thus 12.5. The number of spiral and irregular galaxies which satisfy these criteria is not very large, and we estimate that we have observed about 75 percent of the total available galaxies north of declination −25°. Because of these selection criteria, within each morphological class, our program is biased toward galaxies of high luminosity which tend to be brighter for a given angular size. A few bright ellipticals and lenticulars were also observed.

The observations were secured in three sessions at Kitt Peak National Observatory (KPNO) from 1974 February to 1975 January, and one trip to Cerro Tololo Inter-American Observatory (CTIO) in 1974 November using the two-channel Harvard scanner and the 90 cm telescopes.

Integrations were made at seven points spaced 50 Å apart from 6460 to 6760 Å. Unless the galaxy was unusually bright, a total integration time of 3 minutes per point was adopted. At KPNO the exit slit was 60 Å (1.829 mm), while an entrance slit of 2.205 mm (corresponding to 62″) was used. At CTIO, due to the different f ratio of their 90 cm telescope, an entrance aperture of 45″.5 (2.756 mm) was used with an exit slit of 80 Å in the first order (2.438 mm). The blurring in spectral purity at the exit slit, due to the filling of the entrance aperture, is 12 Å (mm of entrance aperture)$^{-1}$, so that the actual exit slits were about 110 Å at KPNO and 150 Å at CTIO. These numbers correspond well to the minimum full width of Hα seen, which was about 100 to 150 Å, respectively. This resolution is not sufficient to separate Hα from the [N II] line at 6584 Å, and any emission between 6560 and 6584 Å was measured. For galaxies with known redshifts observed at KPNO, an inference of the relative strength of Hα versus [N II] could sometimes be made from the profile of the observed emission. In a few cases at CTIO, we tried to observe Hβ emission. These scans covered the region from 5010 to 4770 Å with points 30 Å apart. The same entrance apertures were used as with Hα.

Every night we also observed with the scanner, at the same wavelengths, a few stars with known flux distributions on the system of Schild *et al.* (1971). Thus magnitudes at 6500 Å (denoted M_{6500}) of the part of the galaxy included in the entrance aperture were obtained.

In Table 1 we list the galaxies studied; their revised morphological type (with the DDO luminosity class, when available, in parentheses); $B - V$ colors; the ratio R = diameter of entrance aperture/D_g; M_{6500}; equivalent width of the emission at the redshifted Hα position; and estimates of the ratio of intensity of Hα/[N II]. A semicolon denotes measurements of greater uncertainty, while normally W_λ(Hα) should be accurate to the larger of ±5 Å or ±10 percent. For all but one of the ellipticals and lenticulars, W_λ(Hα) = 0, and this gives us confidence in the accuracy of our measurements. The first three columns of basic data are from de Vaucouleurs and de Vaucouleurs (1964, 1972).

Note that the emission widths in Table 1 are not corrected for the underlying stellar absorption of Hα. If the light is dominated by stars of spectral type later than G, we may expect the underlying absorption to be less than 5 Å (Tinsley 1967).

Although in all cases the entrance aperture was smaller than the major diameter of the galaxy, the eccentricity of the galaxy image ensures that the fraction of the disk which we observed was always greater than R^2. One might expect the fraction of total light observed to be considerably greater than R^2 because of the general decrease in surface brightness with radius and the low surface brightness of the area between the spiral arms in the outer part of the galaxy. To get an estimate of the fraction of light which we have included in our aperture, we use M_{6500}, a monochromatic magnitude determined from scanner integration at a point shortward of Hα. We need to convert this to a B magnitude, which will then compare to a B magnitude in which the whole galaxy is included in the aperture. At CTIO, using a *UBVR* filter photometer and a 2′ entrance aperture, we measured *UBVR* colors of 24 southern spirals (mostly not the same as the program galaxies). We used the relationship between $B - V$ and $V - R$ derived from these observations to correct M_{6500} to a B magnitude (which we call B_a). We then compared this B_a magnitude (including only the area of our scanner aperture) with the photoelectric B_0 for an aperture including the entire galaxy from de Vaucouleurs and de Vaucouleurs (1964). The difference $B_a - B_0$ indicates the fraction of the total light of the galaxy that was included in our entrance aperture. For the KPNO observations, for most spirals, R was in the range 0.3 to 0.7 (i.e., 0.1 to 0.6 of the area was included); but with only one exception, 50 percent or more of the total light was included. At CTIO, due to the smaller scale of their 90 cm telescope, R ranged from 0.2 to 0.4 (0.04 to 0.16 of the area was included), and 20 to 40 percent of the light was observed. For the ellipticals and lenticulars, the areas included and fraction of total light included are always greater than the spirals.

III. DISCUSSION

In Figure 1 we show Hα as a function of $B - V$ for the spiral galaxies observed from KPNO. The CTIO observations are omitted due to the smaller entrance aperture used and also the lower quality of the $B - V$ colors. We note the strong trend of decreasing $B - V$ color occurring with increasing Hα emission. The same trend is seen in Hα as a function of $U - B$, but there are fewer $U - B$ colors for the galaxies and they are more uncertain. This correlation of bluer $B - V$ colors with larger equivalent width of Hα emission is one of the principal results of this paper, and various explanations will be discussed below.

We first consider the possibility that the emission itself is directly influencing the $B - V$ colors, making them bluer. If we use the emission-line strengths for the Orion Nebula (Johnson 1968) (normalized to an Hα emission of 60 Å, the maximum observed in nearly all normal galaxies), and the transmission function for the B and V filters of the *UBV* system (Johnson *et al.* 1966), we may calculate the change in B and V colors due to emission lines for a galaxy with a given energy distribution in the continuum. The maximum effect, due mostly to the influence of the Balmer lines and λ5007 of [O III], is a decrease in $B - V$ of 0.04 mag, which is too small to explain the observed effect.

We also must consider the possibility that for a given galaxy type, $B - V$ is a function of the angle of inclination. If most of the Hα emission (and light) is coming from the disk rather than the central bulge, theoretically, for disks of radius 10 times that of the spherical bulge, one does not expect the bulge to vignette significantly the disk behind it until i reaches 75°. The maximum value of i, computed from the ratio of diameters along the major and minor axis given by the de Vaucouleurs' catalog, is 67° for the sample galaxies and the median value is 45°. The sample galaxies for a given morphological type show no noticeable correlation between $B - V$ color and angle of inclination. A correlation of color with i (with large scatter) was noted by Holmberg (1958) for a sample of 500 galaxies, but the effect is not large enough to be an annoyance to us.

We now consider the relative contribution of the

TABLE 1

Observations of Emission from Galactic Discs

NGC No.	Morphological Type (lum. class.)	B - V	R	M_{6500}	W_λ (Hα) (Å)	Hα/[N II]
Spirals						
2681	PSXT0	$0^{m}.74$	$0^{m}.37$		5	<0.5
2655	SXS0	0.86	0.28		9	<0.5
3166	SXT0	0.90	0.26		4	<1
1302	RBSR0	0.68	0.27*	$11^{m}.4$	2:	
2639	RSAR1	0.94	0.66	11.3	10	1
2782	SXT1p	0.64	0.47	11.7	38	>2
2196	PAS1 (I-II)	0.90	0.34*	12.1	3:	
1022	PSBS1	0.75	0.44*	12.2	23	
718	SXS1	0.81	0.51	11.6	0	
3504	RSXS2	0.77	0.46	11.2	53	1
2146	SBS2p	0.70	0.20		60	1.5
2775	SAR2 (II)	0.85	0.37		0	
7552	PSBS2	0.69	0.26*	11.1	20	
986	SBT2	0.82	0.25*	11.9	20	
1068	RSAT3	0.70	0.20		103	<1
1417	SXT3 (I-II)	0.81	0.44		16	1.5:
3982	SXR3	0.61[2]	0.51	11.4	45	
7496	SBS3	0.50	0.25*	12.6	32	
150	SBT3	0.72	0.27*	12.1	25	
278	SXT3	0.66	0.65	10.8	58	1.5
5248	SXT4 (I)	0.66	0.17	10.9	33	1
2964	SXR4 (II)	0.75	0.42	11.9	42	1
2268	SXR4	0.78	0.36	11.7	51	>3
5005	SXT4 (II)	0.84	0.22	10.3	12	1
7590	SAT4	0.64	0.30*	11.9	38	
1832	SBR4	0.78	0.41	12.6	21	1.5
3294	SAS5 (I)	0.55	0.32		43	<1
1084	SAS5 (I-II)	0.63	0.39		37:	<1
1637	SXT5	0.65	0.26		27	1.5:
961	SXT5 (I)	0.75	0.25		18	1
2525	SBS5 (II)	0.66	0.30*	12.6	13:	
2276	SXT5 (I)	0.59	0.43	12.6:	55	1.5
2976	SAS5p	0.67	0.24		28	2
922	SBS6p (II-III)	0.52	0.40*	12.6	56:	
1493	SBR6	0.52[1]	0.30*	13.1	12	
1559	SBS6	0.44	0.27*	11.8	18	
1385	SBS6 (I-II)	0.57	0.27*	11.9	45	
337	SBS7 (II-III)	0.46	0.31*	12.4	46	
625	SBS9	0.58[1]	0.26*	12.7	117	
Irregulars						
2537	IBS9p	$0^{m}.64$	$0^{m}.68$	$11^{m}.6$	24	>3
7764	IBS9	0.38	0.51*	13.1	51	
1569	IB9 (III-IV)	0.75	0.40	11.2	104	>3
3077	I0p	0.44	0.32		42	>3
5363	I0 (E7p)	1.05	0.40	10.2	5	1:
Ellipticals, Lenticulars						
3115	L	0.92	0.24		0	
1700	E	0.80	0.64		0	
2950	RLBR0	0.91	0.54	10.7	0	
3245	LAR0	0.88	0.47	10.8	0	
5846	E0	0.98	0.48	11.6	0	
5322	E3	0.89	0.39	11.6	0	
7507	E0	0.88	0.67*	11.0	5:	
1399	E0	0.85	0.41*	10.3	0	
584	E4	0.88	0.36*	10.9	0	

* Denotes CTIO observations.

[1] B - V color from UBVR photometry at CTIO (see § II).

[2] G. Grasdalen (private communication).

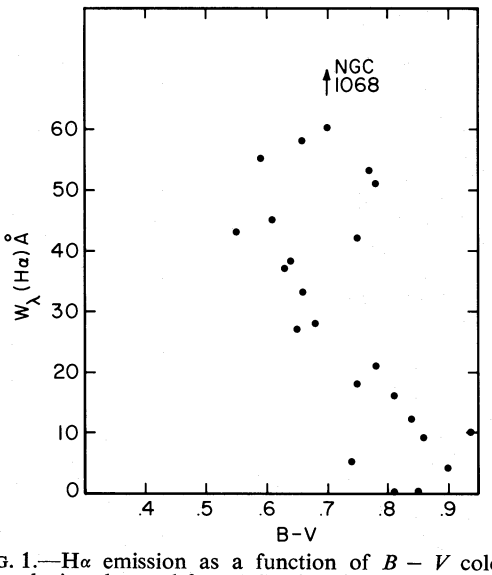

FIG. 1.—Hα emission as a function of $B - V$ color for spiral galaxies observed from KPNO.

central bulge and the disk (containing the arms) to the observed light. One indication can be obtained from M31, where a generous estimate of the size of the central bulge is a diameter of 15′ on the major axis (3.6 kpc if $m - M = 24.6$) and 9′ on the minor axis based on the photograph of M31 in Sandage (1961). Using the surface brightness measurements of de Vaucouleurs (1958) and Kinman (1965) in the B filter, we note that one-fifth of the total light in the B filter comes from the central bulge. If we observe with an aperture such that $R = 0.5$, then one-third of the observed light would come from the central bulge. Thus we see that the light of the disk dominates that of the central bulge even when an aperture is used whose diameter is half that of the galaxy.

Now we must show that the emission from the nucleus or nuclear bulge does not dominate over that from the disk. Peimbert (1968) has studied the emission from the nucleus of M51 within 10″ from the center of the galaxy. He finds that Hα and [N II] are in emission with Hα/[N II] ≈ 1/3 and a total emission equivalent width of about 30 Å. Since the inner 10″ of the galaxy contributes only 1/200 of the light of the nuclear bulge, the contribution of emission from the nucleus itself to our large aperture observations is negligible. Peimbert also asserts that the intensity of emission lines in the nucleus is controlled by the number of hot stars and not by the amount of gas.

The contribution of the nuclear bulge to the observed emission is more serious. In Table 2, we compare observations of Hα emission made at KPNO with apertures of 31″, 62″, and 125″ for three galaxies. The widths of the detected emission are given as well as the ratio of the flux observed in the continuum at 6710 Å in each aperture to that observed in the smallest aperture. It is apparent that the emission does not vary greatly with aperture size. This implies that the nuclear bulge contributes to the Hα emission in the same proportion as it does to the continuum. The source of ionization in the nuclear bulge is starlight, as any nonthermal activity in these galaxies is confined to the nucleus itself.

TABLE 2

OBSERVATIONS AT VARIOUS APERTURE SIZES

Galaxy	Equivalent Width of Hα (Å): Aperture Size			Flux Ratios: Aperture Size		
	31″	62″	125″	31″	62″	125″
NGC 3504.....	65	53	...	1.0	3.4	...
NGC 3982.....	47	45	...	1.0	2.7	...
NGC 5005.....	18	11	13	1.0	3.1	5.5

We next assert that the Hα emission which we see comes from discrete H II regions ionized by specific hot stars and that the contribution from any general uniform ionization of the interstellar medium must be small. In Table 3, we list the flux at Hα for the largest H II regions in various galaxies and for the Orion Nebula. These fluxes have been obtained from observational data in the references cited and are determined to within a factor of 3 using the distance scale of Sandage and Tammann (1974*b*), except for W49, for which no quantitative measurement of emission-line fluxes exists. Note that because we are looking at the disk from outside the galaxy, the reddening for any H II region will be small.

We also make use of the study by Hodge (1974) of the number of H II regions in spiral galaxies. The mean of his measurements is 52 H II regions per Sb galaxy and 95 H II regions per Sc galaxy. Furthermore, in most cases Hodge (1974) would not measure H II regions with diameters smaller than 10 pc. Thus these are large H II regions which we may take to be as bright as W49. Since most of our S5 galaxies are of luminosity class Sc I–II, we adopt a luminosity of $M_V = -21.2$ (Sandage and Tammann 1974*b*). We can then calculate that 100 such H II regions will produce approximately 4 Å of emission at Hα. If there are 10 H II regions the size of NGC 604, these H II regions will produce 5 Å of emission at Hα. The mean size of the three largest H II regions in Sc galaxies is comparable to the size of NGC 5471 rather than that of W49 (Sandage and Tammann 1974*a*), and one H II region of this size would contribute 10 Å of emission.

TABLE 3

Hα FLUXES FROM LARGE H II REGIONS

	Diameter (pc)	F(Hα) erg s^{-1}	Reference
Orion................	10	1×10^{36}	1
W49..................	19	5×10^{38}	2
30 Doradus...........	320	9×10^{39}	3
NGC 604 in M33.......	130	7×10^{39}	4
NGC 5471 in M101.....	640	1.5×10^{41}	4

REFERENCES.—(1) Reitmeyer 1965; (2) Mezger *et al.* 1967; (3) Faulkner 1967; (4) Searle 1971.

If the galaxy is less luminous than $M_V = -21.2$, fewer H II regions are required to produce a given equivalent width of Hα emission. We therefore conclude that it is possible to explain all the Hα flux by considering only the discrete H II regions. Using masses of the standard H II regions from the references to Table 3, we estimate that a mass of about 10^7 $M_\odot$ of ionized gas is required to produce 10 Å of emission. Thus the maximum mass of ionized gas we are seeing in normal spirals is 6×10^7 $M_\odot$.

The two galaxies in Table 1 with too much emission to be explained by reasonable numbers of H II regions are NGC 1068, a Seyfert galaxy, and NGC 1569, which de Vaucouleurs *et al.* (1974) have suggested recently had an explosive event similar to that in M82. In these cases, nonthermal emission may be important.

It is also not clear whether the Hα emission seen in a few S0 galaxies arises from discrete H II regions (i.e., gas outside the nucleus) or from gas in the nucleus, either ionized by starlight or by nonthermal processes. Perhaps the latter is to be preferred. We plan to obtain scans of the nuclei of these galaxies at Hα as soon as possible.

In many cases, these galaxies have been observed spectroscopically by Humason *et al.* (1956) or by Burbidge and Burbidge (1962, 1965). In those cases in which their remarks indicated the presence of nuclear emission, our observations indicate considerable Hα emission from the disk, with the single exception of NGC 5005, which has only weak emission from the disk. Also in the S0 NGC 2655, spectra by Burbidge and Burbidge (1965) reveal [N II] emission from the nucleus but no Hα, in accordance with our measurements. This may indicate that in the S0 galaxies the emission we see with large apertures arises only from the nuclear regions.

Because the underlying stellar absorption at Hβ is larger than that at Hα, the galaxy is not as bright, and the emission from H II regions is not as large, it is much more difficult to detect Hβ emission than Hα emission. Furthermore, since one must work in second order rather than first, a given exit slit corresponds to half the bandpass in angstroms that it would at Hα. Thus the Hβ scans are much noisier than the Hα scans. However, a definite detection of Hβ (and 5007 Å of [O III]) was obtained for NGC 625, NGC 7496, and NGC 7764, with W_λ in emission of 21, 7, and 12 Å, respectively. These correspond to a ratio of Hα/Hβ of 4.3 to 5.6. If we assume that the [N II] line is 1/7 that of the Hα (as in Orion) and correct our observed Hα for that, the ratio of Hα to Hβ becomes 3.7 to 4.9. If we then assume that in both cases there is 4 Å of underlying stellar absorption, we obtain ratios of Hα/Hβ of 4.3, 2.9, and 3.0, respectively, for the three galaxies. In Orion, the observed ratio of Hα/Hβ is 3.5 (Johnson 1968). Note that it is not fair to correct the Orion observed ratio for absorption, as most of the absorption is internal to the nebula and in the surrounding H I region, which would produce the same reddening even if the nebula were observed from above the disk of the galaxy. This agreement in the galactic Hα/Hβ with that of Orion gives us further confidence that the emission we are observing arises from discrete H II regions. Note that if [N II]/Hα had been made larger than $\frac{1}{2}$, we would expect less Hβ than is observed. Since [N II]/Hα > 1 is characteristic of galactic nuclei (Burbidge and Burbidge 1962), we also have further support for the idea that most of the emission we see arises from discrete H II regions in the spiral disk, not in the nucleus. The crude wavelength resolution of the scans does not allow us to infer the ratio of emission at Hα to that of [N II] directly.

We are therefore led to the conclusion that the effect seen in Figure 1 is an intrinsic property of the galaxy related to the properties of the H II regions within the galaxy. The amount of Hα emission is not very sensitive to physical conditions in the gas such as electron temperature, and is dependent on the mean value of N_e^2. If we ignore density fluctuations, in the crudest approximation the amount of Hα emission depends on the ionizing flux from the hot stars. Because of their larger luminosities, the hottest O stars cause most of the ionization and dominate the contribution of the cooler O stars and early-B stars. The stars most efficient at photoionizing the gas are approximately the same from galaxy to galaxy, as scans of various H II regions in external galaxies by Smith (1975) show that the ratio of He I (5876 Å) to Hα is almost constant. Thus the effect seen in Figure 1 is caused by a variation in the luminosity function of the stars within the galaxy. If we assume that the luminosity function for the O and early-B stars *only* has a constant shape and is merely scaled up or down in number relative to the cooler stars, we may assert that the galaxies with bluer $B - V$ colors have a larger proportion of blue to red stars, and hence a larger relative number of O and early-B stars capable of ionizing the gas to form H II regions. Among the class of evolutionary models which can reproduce the observed colors of galaxies are those of Searle *et al.* (1973). They use a varying formation rate for massive stars of the form mass$^{-\alpha}$ $\exp(-\beta t_{10})$, where t_{10} is the time since the formation of the galaxy in units of its present age, and they have succeeded in reproducing the present range of colors of Sc galaxies with $\alpha = 2.45$. To go from $B - V = 0^m.55$ to $B - V = 0^m.75$ (the range for our S5 galaxies) using their models, we must use $\beta = 2$ to $\beta = 4.5$. They would therefore predict a range of 12 in the ratio of recently formed massive stars to cooler stars. Our observed ratio for W(Hα) over the range of $B - V$ from $0^m.55$ to $0^m.75$ is 6. If we restrict the range of $B - V$ to $0^m.15$ to allow for the effect of emission on the colors, the agreement is even better. The relative agreement between these two completely independent estimates, one observational and one theoretical, of the ratio of massive stars to cool stars in Sc galaxies over this range in $B - V$ is very pleasant.

An attempt by Hills (1973) to discuss from a theoretical point of view the same problem, namely the rate of production of ionizing radiation and the resulting Hα emission in galaxies, fails to take into account the variation of the stellar luminosity function from galaxy to galaxy. His average predicted Hα emission for spiral galaxies of various morphological types is in fair agreement with the averages of the entries for each type in Table 1.

IV. SUMMARY

The observations of Hα + [N II] and Hβ emission in spiral disks reported in this work have several important implications. We find a correlation between the amount of emission at Hα and the $B - V$ color of the galaxy for a given morphological type in the sense that the bluer the galaxy, the larger the Hα emission. We have shown that the emission itself does not sufficiently directly affect the $B - V$ colors to produce the observed correlation. Furthermore, inclination effects are not responsible for this correlation, nor for the range in $B - V$ color. We have also shown that at least two-thirds of the observed light will come from the disk rather than the central bulge, even if we observe with an aperture such that its diameter is only half that of the galaxy. Using photographic surveys by Hodge (1974), who counted the number of H II regions in various galaxies, and the amount of emission from known large H II regions in our Galaxy and its neighbors, we calculate that all the Hα emission in normal spiral galaxies can be accounted for by emission from ordinary H II regions of reasonable size and number.

We therefore assert that this range of Hα emission is a result of varying proportions of O and B stars capable of photoionizing the gas relative to cooler stars. This variation in the proportion of O and B stars occurs over most of the galaxy outside the nucleus. Due to the lack of strong variation of Hα emission with aperture size, it probably occurs in the nuclear bulge as well as in the disk. Furthermore, the theoretically predicted change in the relative number of early-type stars for a given range in $B - V$ calculated by Searle *et al.* (1973) from a study of the $B - V$ colors agrees well with the range implied from the observed Hα ratio.

Since we have shown that the $B - V$ color of a galaxy depends on the number of O and early-B stars, most of which are young with relatively short main-sequence lifetimes, we may crudely use the $B - V$ color as an indication of the extent of recent star formation as compared with that in the past. If we hypothesize that density waves cause star formation (Roberts *et al.* 1975) and that these may be excited by close approaches of another galaxy, we might expect a difference in the distribution of $B - V$ colors for galaxies inside and outside clusters. A study was made of the distribution in $B - V$ color of S4 and S5 galaxies in de Vaucouleurs and de Vaucouleurs (1964). The Palomar Sky Survey plates were checked for each galaxy to determine whether it is in a cluster. There is no apparent difference in the $B - V$ color distributions for galaxies in and out of clusters, but the test should be repeated with a larger sample of galaxies.

It would also be interesting to survey integrated [O III] emission at λ5007 to study the variation in physical properties of the gas from galaxy to galaxy, as the amount of [O III] emission is more dependent on the temperature and degree of ionization of the gas than is Hα.

We thank A. Gomez for significant help in obtaining the observations, and G. Grasdalen for measuring a galaxy in the *UBV* system.

REFERENCES

Burbidge, E. M., and Burbidge, G. R. 1962, *Ap. J.*, **135**, 694.
———. 1965, *Ap. J.*, **142**, 634.
de Vaucouleurs, G. 1958, *Ap. J.*, **128**, 465.
de Vaucouleurs, G., and de Vaucouleurs, A. 1964, *Reference Catalogue of Bright Galaxies* (Austin: University of Texas Press).
———. 1972, *Mem. R.A.S.*, **77**, 1.
de Vaucouleurs, G., de Vaucouleurs, A., and Pence, W. 1974, *Ap. J. (Letters)*, **194**, L119.
Faulkner, D. J. 1967, *M.N.R.A.S.*, **135**, 401.
Hills, J. G. 1973, *Astr. and Ap.*, **28**, 63.
Hodge, P. W. 1969, *Ap. J.*, **156**, 847.
———. 1974, *Ap. J. Suppl.*, **27**, 113.
Holmberg, E. 1958, *Medd. Lund Obs.*, **54**, Series 2, No. 136.
Humason, M. L., Mayall, N. U., and Sandage, A. R. 1956, *A.J.*, **61**, 91.
Israel, F. P., and van der Kruit, P. C. 1974, *Astr. and Ap.*, **32**, 363.
Johnson, H. L., Mitchell, R. I., Iriarte, B., and Wisniewski, W. Z. 1966, *Comm. Lunar and Planet. Lab.*, **4**, No. 63, p. 99.
Johnson, H. M. 1968, in *Nebulae and Interstellar Matter*, ed. B. M. Middlehurst and L. H. Aller (Chicago: University of Chicago Press).
Kinman, T. D. 1965, *Ap. J.*, **142**, 1376.
Mezger, P. G., Schraml, J., and Terzian, Y. 1967, *Ap. J.*, **150**, 807.
Oort, J. H. 1974, in *Proc. IAU Symposium No. 58*, ed. J. R. Shakeshaft (Dordrecht: Reidel), p. 375.
Peimbert, M. 1968, *Ap. J.*, **154**, 33.
Reitmeyer, W. L. 1965, *Ap. J.*, **141**, 1331.
Roberts, W. W., Roberts, M. S., and Shu, F. 1975, *Ap. J.*, **196**, 381.
Sandage, A. 1961, *The Hubble Atlas of Galaxies* (Washington: Carnegie Institution of Washington).
Sandage, A., and Tammann, G. A. 1974*a*, *Ap. J.*, **190**, 525.
———. 1974*b*, *ibid.*, **194**, 559.
Schild, R., Peterson, D. M., and Oke, J. B. 1971, *Ap. J.*, **166**, 95.
Searle, L. 1971, *Ap. J.*, **168**, 327.
Searle, L., Sargent, W. L. W., and Bagnuolo, W. G. 1973, *Ap. J.*, **179**, 427.
Smith, H. E. 1975, *Ap. J.*, **199**, 591.
Tinsley, B. M. 1967, *Pub. Dept. of Astr., University of Texas at Austin*, Series 2, **1**, No. 15.

JUDITH G. COHEN: Kitt Peak National Observatory, P.O. Box 26732, Tucson, AZ 85726