THE ASTROPHYSICAL JOURNAL, 341:679–684, 1989 June 15

INFRARED EMISSION FROM COMPACT GROUPS OF GALAXIES

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Received 1988 August 30; accepted 1988 December 1

ABSTRACT

A search of the *IRAS* Point Source Catalog, Version 2 has revealed infrared sources within 1′ of the optical centers of 54 galaxies in Hickson's catalog of compact groups of galaxies. The 60 μm luminosity function for these galaxies has the same shape as the luminosity function of the *IRAS* bright galaxy sample. The space density of *IRAS* galaxies in compact groups is 60 times smaller than the space density of *IRAS* bright galaxies, indicating that of order 1% of all bright *IRAS* galaxies are in compact groups. The infrared emission from these galaxies is compared with the emission from samples of isolated galaxies by Keel *et al.* and cluster galaxies studied by Bicay and Giovanelli. The fractional distribution of the ratio of far-infrared to optical luminosity of compact group galaxies is significantly larger than that of the isolated galaxies and comparable to that of the cluster galaxies. These results indicate that infrared emission is enhanced in the compact group galaxies, probably because of interactions. We also report an upper limit to the 2–10 keV X-ray flux of compact groups in our sample of $3 \times 10^{41} h^{-2}$ ergs^{-1}, from the *HEAO 1* A-2 experiment.

Subject headings: galaxies: clustering — galaxies: interactions — galaxies: X-rays — infrared: sources

I. INTRODUCTION

Strong infrared radiation from galaxies arise from several causes. In normal spiral galaxies, infrared radiation is produced by newly born stars which excite the surrounding parental gas and dust clouds (Becklin 1987). The infrared therefore provides information on the distribution, energetics, and rate of star formation in these galaxies. Active galaxies, on the other hand, contain a compact nonthermal nuclear component which is also a strong source of infrared radiation. By comparing optical and infrared data one can learn about the nature and extent of this activity. Extremely luminous far-infrared sources may be produced by collisions of molecular clouds in interacting galaxies (Harwit *et al.* 1987).

Collisions or tidal interactions between galaxies may trigger star formation by compression of gas in gas-rich galaxies (Norman 1988*a*, *b*). Also, interactions may promote nuclear activity by providing a source of fuel for the nonthermal source. Interacting galaxies, or galaxies with close companions, might thus be expected to have a high probability of strong infrared emission. The environment of a galaxy is therefore an important factor in the development of infrared emission in galaxies.

Infrared emission from normal spiral galaxies has been studied in some detail (Soifer *et al.* 1987 and references therein). In addition, the infrared properties of galaxies in clusters have been considered by Bicay and Giovanelli (1987). This paper presents a study of infrared emission in galaxies in high-density environments. The sample selection and observational data are presented in § II and the infrared luminosity function is discussed in § III. In § IV we compare the infrared properties of this high-density sample with a sample of isolated galaxies and cluster galaxies. The results are summarized and discussed in § V. We also describe the results of a search of the *HEAO 1* A-2 data base for X-ray emission from galaxies in our sample.

II. SAMPLE SELECTION AND DATA

We choose as our sample the homogeneous catalog of 100 compact groups of galaxies identified by Hickson (1982). This catalog contains the densest systems of galaxies known, with space densities ranging from 10^3 to 10^6, up to four orders of magnitude higher than typical densities in the centers of rich clusters. The catalog contains 463 galaxies, of which 53% are classified as spiral or irregular, 23% as elliptical, and 24% as S0 (Hickson, Kindl, and Auman 1988). Many of these galaxies are interacting and provide a good sample of galaxies in dense environments. Evidence for high physical density of these groups is summarized by Hickson and Rood (1988), and some morphological and dynamical properties of the groups are discussed by Hickson, Kindl, and Huchra (1988*a*).

The *IRAS* Point Source Catalog (PSC, 1985) was searched for sources within 1′ of the optical centers of galaxies in the groups. Fifty-four such infrared sources were found. Table 1 lists the group identification, optical and *IRAS* positions and separation, blue magnitude, and fluxes at 60 and 100 μm for each source and corresponding galaxy. Fluxes for galaxies 16a, 16c, and 16d are reprocessed *IRAS* fluxes (B. T. Soifer, private communication). Galaxies 9a and 11a have redshifts that differ from other group members by more than 1000 km s^{-1} and were not included in the analysis. These are considered to be foreground or background galaxies projected on the groups by chance (Hickson, Kindl, and Huchra 1988*b*). Also excluded are galaxies 14b and 79a which are elliptical and 56c which is an S0 galaxy. The rest of the galaxies are spiral. The symbols " L" and ":" following *IRAS* fluxes in Table 1 indicate respectively an

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TABLE 1

OBSERVATIONAL DATA FOR COMPACT GROUPS

No.	Optical Position		*IRAS* Position		Sep. (″)	B_T (mag)	$F_{60\,\mu m}$ (Jy)	$F_{100\,\mu m}$ (Jy)
2b	$00^h28^m43^s.7$	+08°11′57″	28 $45^s.0$	11′40″	25	14.39	3.694	5.455
4a	00 31 43.7	−21 42 51	31 43.1	42 53	9	13.50	3.898	7.780
7a	00 36 39.7	+00 35 21	36 40.7	35 33	20	12.98	3.231	5.989
7c	00 37 01.2	+00 35 06	37 00.8	35 09	6	12.60	0.602	2.043
9a	00 51 53.6	−23 49 25	51 52.7	49 15	20	14.89	0.583:	1.266
11a	01 24 10.8	−23 29 07	24 10.7	29 33	32	12.97	0.412L	1.235
14b	01 57 22.7	−07 19 42	57 22.2	19 43	7	14.17	0.789:	1.786
16a	02 06 57.4	−10 22 20	06 56.7	22 21	11	12.76	5.39	11.4
16c	02 07 11.3	−10 22 56	07 10.5	23 02	13	13.10	12.29	19.03
16d	02 07 15.6	−10 25 11	07 15.9	25 10	5	13.42	12.2	12.15
19b	02 40 18.0	−12 38 24	40 18.9	38 15	16	15.24	0.402L	1.155
21a	02 42 58.4	−17 55 08	42 59.6	54 57	21	14.13	1.054	2.994
23d	03 04 29.8	−09 49 17	04 28.3	49 30	26	16.00	0.559	1.000L
23b	03 04 44.1	−09 47 06	04 44.3	46 53	13	14.42	1.375	3.784
25a	03 18 10.5	−01 17 20	18 10.2	17 14	7	13.86	0.646	1.098L
25c	03 18 10.6	−01 10 55	18 10.9	10 56	5	15.35	0.672	1.486
26a	03 19 34.1	−13 49 45	19 34.1	49 37	8	16.10	0.572	1.433
31c	04 59 08.9	−04 19 46	59 09.0	19 51	6	12.50	4.015	5.426
33c	05 07 50.3	+17 57 31	07 51.7	57 35	22	16.40	0.646	1.758L
34b	05 19 08.5	+06 37 44	19 08.4	37 55	11	16.56	1.327	35.920L
37b	09 10 33.0	+30 12 24	10 33.4	12 22	7	14.50	0.557	1.914
38b	09 25 00.7	+12 30 19	25 00.8	30 18	2	14.76	1.399	3.034
40e	09 36 24.7	−04 37 52	36 24.7	37 33	20	16.69	0.564L	3.691
44c	10 14 53.3	+21 56 19	14 51.7	56 27	25	12.55	1.550	3.531
44d	10 15 02.5	+22 07 25	15 02.9	07 19	9	13.09	0.891	2.556
44a	10 15 20.6	+22 04 55	15 21.2	04 51	9	11.52	3.435	9.925
47a	10 23 05.9	+13 58 17	23 06.9	58 21	15	14.61	0.727L	1.527
48b	10 35 27.9	−26 51 41	35 27.8	51 42	2	14.63	0.864	1.905
56c	11 29 51.8	+53 13 25	29 52.4	13 45	21	15.37	0.750	1.314L
57d	11 35 18.6	+22 15 45	35 17.9	16 00	18	14.51	0.430:	1.319
58a	11 39 36.3	+10 33 18	39 35.8	33 24	10	13.56	3.132	6.724
59d	11 45 56.1	+13 00 28	45 54.9	00 05	29	15.80	3.425	3.665
61c	12 09 59.0	+29 26 48	09 58.9	26 47	2	13.53	5.328	10.740
63d	12 59 19.6	−32 30 23	59 21.5	30 37	32	16.79	1.153	3.102
67b	13 46 22.0	−06 56 51	46 22.1	56 53	3	13.89	0.860	2.798
68c	13 51 14.8	+40 36 32	51 12.9	36 40	30	11.93	2.243	8.252
69b	13 53 15.3	+25 17 38	53 15.3	17 41	6	15.59	2.151	2.833
71b	14 08 46.0	+25 45 16	08 43.9	45 24	32	14.90	1.541	2.939
73a	15 00 29.1	+23 31 41	00 27.4	32 07	33	13.30	0.820	2.560
75e	15 19 20.3	+21 21 26	19 21.0	21 19	12	16.36	0.410L	1.020
78a	15 48 04.7	+68 22 19	48 04.0	22 16	11	14.35	0.805	2.107
79a	15 57 00.0	+20 53 43	57 00.3	53 53	14	14.35	1.024	2.102
80a	15 58 50.7	+65 22 22	58 49.4	22 23	19	14.76	2.201	4.896
82c	16 26 26.6	+32 55 13	26 26.0	55 11	9	14.78	0.996	2.017
88a	20 49 56.5	−05 54 00	49 55.9	54 08	12	13.18	0.470L	2.223
90a	21 59 07.6	−32 06 42	59 07.0	06 42	9	12.36	5.848	12.410
90d	21 59 11.6	−32 14 09	59 12.0	14 02	9	12.81	3.434	7.764
91a	22 06 17.1	−28 03 20	06 17.1	03 18	3	12.62	2.101	5.026
91b	22 06 26.0	−27 58 38	06 16.5	58 31	8	14.63	1.994	3.232
92c	22 33 46.3	+33 42 57	33 46.5	42 44	13	13.33	0.637:	2.887
93b	23 12 48.0	+18 46 08	12 47.6	46 09	6	13.18	1.838	4.520
95d	23 16 59.3	+09 13 44	17 00.6	13 32	19	16.14	0.917	2.295
96a	23 25 24.7	+08 30 10	25 24.7	30 14	4	13.53	5.469	8.192
100a	23 58 46.3	+12 49 57	58 46.6	49 57	4	13.66	2.066	4.171

upper limit or a moderate quality measurement as in the *IRAS* catalog.

The distribution of separations between optical and infrared positions is shown in Figure 1. All sources fall within 33″ of the optical centers of the associated galaxies. This is less than 2.4 standard deviations of the *IRAS* position uncertainty.

From these data luminosities were computed using $H = 100$ km s^{-1} Mpc^{-1} and $q_0 = 0.5$. These are listed in Table 2. The column headings are as follows. (1) group identification; (2) group redshift (Hickson, Kindl, and Huchra 1988*a*); (3) log optical luminosity from the formula

$$\log(L_{\rm op}) = 0.4(K - B_T + M_\odot) + \log(L_\odot) + 2\log(D) + 10.0\,,$$

where K is the K-correction computed as in Pence (1976), B_T is the galaxy blue magnitude on the de Vaucouleurs system determined by Hickson, Kindl, and Auman (1988), $M_\odot = 5.48$, $L_\odot = 3.826 \times 10^{26}$ W, and D is the luminosity distance defined by

$$D = \frac{2c}{H}\,(1 + z - \sqrt{1 + z})\,,$$

where z is the group redshift, c is the speed of light, and H is the Hubble constant (no attempt was made to correct for color differences between the galaxy and the Sun); (4) log blue spe-

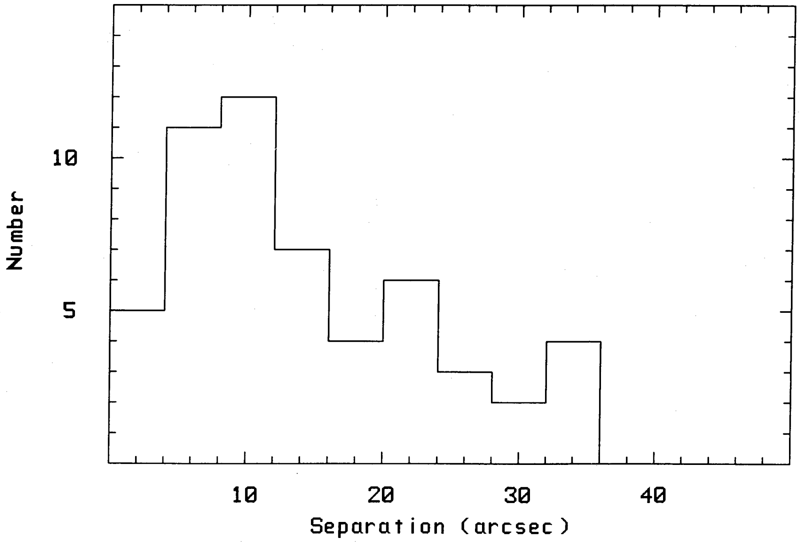

FIG. 1.—Separations between *IRAS* positions and the optical centroids of the corresponding galaxy images. Position errors are small enough to allow positive identification of the *IRAS* galaxy from position alone in all but a few cases.

cific luminosity from the formula

$$\log (L_b) = 0.4(K - B_T) + 2 \log (D) + 23.72 ;$$

(5) log 60 μm specific luminosity from the formula

$$\log (L_{60\ \mu\mathrm{m}}) = \log (f_{60\ \mu\mathrm{m}}) + 2 \log (D) + 17.08 ;$$

(6) log "in band" far-infrared luminosity calculated from the formula

$$\log (L_{\mathrm{fir}}) = \log (\mathrm{FIR}) + 2 \log (D) + 46.08 ,$$

where $\mathrm{FIR} = 1.26 \times 10^{-14}\ (2.58 f_{60\ \mu\mathrm{m}} + f_{100\ \mu\mathrm{m}})$; (7) log extrapolated (1–500 μm) far-infrared luminosity from the formula

$$\log (L_{\mathrm{ir}}) = \log (L_{\mathrm{fir}}) + 0.1604 - 0.2894R + 1.1733R^2 - 1.1053R^3 + 0.6119R^4 ,$$

where $R = f_{100}/f_{60\ \mu\mathrm{m}}$ and the numerical coefficients were determined by a least-squares fit to the data of Table B.1 in *Cataloged Galaxies and Quasars Observed in the IRAS Survey;* (8) the difference of columns (7) and (3). The letter "L" indicates numbers based on upper limits to infrared fluxes.

III. THE INFRARED LUMINOSITY FUNCTION

The 60 μm infrared luminosity function for our sample was calculated from the formulae

$$\phi = \frac{4\pi}{\Omega} \sum \frac{1}{V_m}$$

$$\sigma_\phi = \frac{4\pi}{\Omega} \left(\sum \frac{1}{V_m{}^2} \right)^{-1/2} ,$$

where Ω is the effective area of the survey (Hickson, Kindl, and Auman 1988) and V_m is the volume beyond which the 60 μm flux falls below the *IRAS* catalog flux limit. Our luminosity function is plotted in Figure 2. The solid line shows a fit to the *IRAS* bright galaxy sample (Soifer *et al.* 1987) 60 μm luminosity function, consisting of power laws with indices of -0.8 for $\log (L_{60\ \mu\mathrm{m}}) < 3.7 \times 10^{36} h^{-2}$ and -2.0 for $\log (L_{60\ \mu\mathrm{m}}) > 3.7 \times 10^{36} h^{-2}$, where h is the Hubble constant in units of 100 km s^{-1}. The shape of the compact group galaxy luminosity function is consistent with these power laws, but at a space density about 60 times lower than the *IRAS* bright galaxy sample.

The break in our compact luminosity function occurs at about the same luminosity as the *IRAS* bright galaxy sample. That sample was selected on the basis of 60 μm flux density, and therefore contains galaxies with greater than average infra-

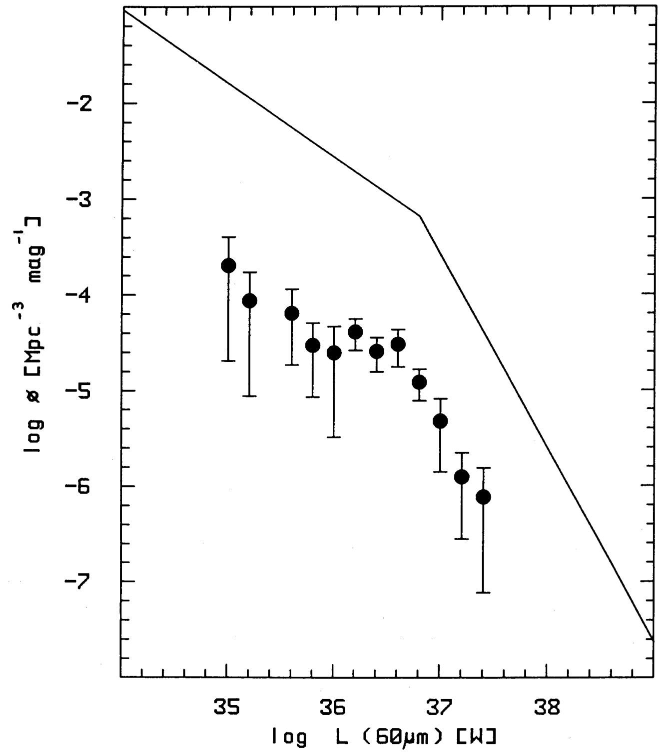

FIG. 2.—Infrared (60 μm) luminosity function for compact group galaxies. The solid line is a two power-law fit to the luminosity function for *IRAS* bright galaxies derived by Soifer *et al.* (1987) and described in the text.

TABLE 2

COMPACT GROUP GALAXY DATA

No. (1)	z (2)	log L_{op} (W) (3)	log L_b (W/Hz) (4)	log $L_{60\,\mu m}$ (W/Hz) (5)	log L_{fir} (W) (6)	log L_{ir} (W) (7)	log L_{ir}/L_{op} (8)
02b	0.014	36.29	21.24	23.92	36.63	36.77	0.48
04a	0.027	37.21	22.16	24.49	37.25	37.40	0.19
07a	0.014	36.85	21.80	23.85	36.59	36.74	−0.11
07c	0.014	37.00	21.95	23.12	35.99	36.21	−0.79
16a	0.013	36.88	21.83	24.01	36.78	36.94	0.06
16c	0.013	36.73	21.68	24.37	37.08	37.22	0.49
16d	0.013	36.61	21.56	24.36	37.02	37.18	0.57
19b	0.014	35.94	20.89	22.94L	35.78L	35.97L	0.03L
21a	0.025	36.90	21.84	23.86	36.69	36.89	−0.01
23b	0.016	36.40	21.35	23.60	36.43	36.62	0.22
23d	0.016	35.77	20.71	23.21	35.95L	36.10L	0.33L
25a	0.021	36.85	21.80	23.50	36.23L	36.37L	−0.48L
25c	0.021	36.26	21.20	23.51	36.29	36.46	0.20
26a	0.032	36.31	21.26	23.80	36.61	36.78	0.47
31c	0.014	37.00	21.95	23.91	36.61	36.75	−0.26
33c	0.026	36.01	20.96	23.68	36.50L	36.69L	0.68L
34b	0.031	36.10	21.04	24.14	37.71L	39.19L	3.09L
37b	0.023	36.67	21.61	23.50	36.38	36.60	−0.06
38b	0.029	36.77	21.72	24.12	36.89	37.06	0.28
40e	0.023	35.77	20.72	23.49L	36.55L	36.92L	1.15L
44a	0.005	36.45	21.39	22.89	35.73	35.92	−0.52
44c	0.005	36.03	20.98	22.55	35.33	35.50	−0.53
44d	0.005	35.82	20.76	22.31	35.14	35.34	−0.48
47a	0.032	36.92	21.87	23.91L	36.68L	36.83L	−0.09L
48b	0.009	35.83	20.77	22.92	35.70	35.86	0.03
57b	0.031	36.92	21.86	23.64	36.49	36.70	−0.22
58a	0.021	36.96	21.91	24.17	36.94	37.10	0.14
59d	0.014	35.67	20.62	23.83	36.49	36.65	0.98
61c	0.013	36.56	21.50	23.99	36.76	36.91	0.35
63d	0.024	35.81	20.75	23.87	36.69	36.88	1.08
67b	0.025	36.97	21.92	23.75	36.62	36.83	−0.14
68c	0.008	36.76	21.71	23.19	36.08	36.32	−0.45
69b	0.029	36.46	21.41	24.31	37.00	37.14	0.68
71b	0.031	36.78	21.72	24.20	36.96	37.11	0.33
73a	0.019	36.99	21.93	23.51	36.37	36.58	−0.41
75e	0.042	36.49	21.44	23.89L	36.70L	36.87L	0.38L
78a	0.030	36.98	21.93	23.91	36.72	36.91	−0.08
80a	0.031	36.83	21.78	24.37	37.15	37.32	0.49
82c	0.036	36.94	21.89	24.16	36.92	37.08	0.13
88b	0.020	37.06	22.01	23.35L	36.28L	36.55L	−0.52L
90a	0.009	36.67	21.62	23.68	36.45	36.61	−0.07
90d	0.009	36.48	21.43	23.44	36.23	36.40	−0.09
91a	0.024	37.45	22.40	24.11	36.91	37.08	−0.37
91b	0.024	36.65	21.60	24.09	36.81	36.96	0.31
92c	0.022	37.08	22.02	23.51	36.46	36.74	−0.34
93b	0.017	36.92	21.86	23.75	36.55	36.73	−0.19
95d	0.039	36.49	21.43	24.19	36.99	37.17	0.68
96a	0.029	37.27	22.22	24.71	37.42	37.56	0.29
100a	0.018	36.80	21.74	23.86	36.63	36.78	−0.01

red emission. The similarity of the luminosity functions for the two samples indicates that many compact group galaxies also have enhanced infrared emission compared to normal galaxies, and that these galaxies are as luminous in the infrared as typical *IRAS* bright galaxies. The difference in normalization of the two luminosity functions indicates that the space density of compact group *IRAS* galaxies is about 60 times lower than the space density of the *IRAS* bright galaxies, *i.e.*, *of order 1% of the luminous IRAS galaxies are in compact groups.* To check this result we subsequently examined positions and identifications of the 324 galaxies comprising the *IRAS* bright galaxy sample (Soifer *et al.* 1987) and found three galaxies that are also in our compact group sample (16a, 61c, and 96a), in good agreement with the above estimate.

IV. A COMPARISON OF GALAXIES IN DIFFERING ENVIRONMENTS

In order to compare the properties of spiral galaxies in our sample with those of galaxies in less-dense environments, we have considered the control sample of noninteracting spiral galaxies discussed by Keel *et al.* (1985) selected because they have no close companions.

A powerful test of the similarity of the compact group and isolated galaxy sample is provided by the fractional infrared-to-optical ratio functions of the samples. These were computed using the methods of survival analysis as discussed by Schmitt (1985). Specifically, we have used the Kaplan-Meier estimator to compute the fractional ratio functions. This procedure utilizes upper limits on undetected galaxies as well as the detec-

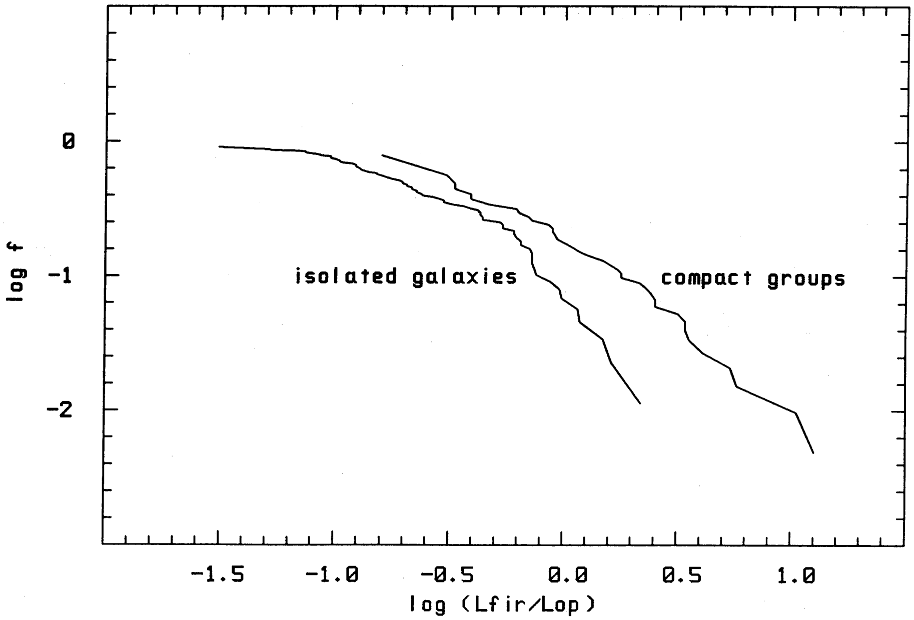

FIG. 3.—Fractional infrared-to-optical luminosity function. The curves show the fraction *f* of galaxies that have a ratio of far-infrared to blue luminosity equal to or greater than the value on the abscissa, for compact group and isolated galaxy samples. Galaxies in compact groups have significantly higher infrared emission.

tions. The Kaplan-Meier estimator for the two samples are shown in Figure 3. The median log $(L_{\rm fir}/L_{\rm op})$ for all 211 spiral galaxies in the compact groups and for the 95 isolated spiral galaxies, computed using upper limits, are 0.00 and -0.92, respectively. On the νf_ν flux system used by Soifer *et al.* (1987), the median values of log $(f_{\rm FIR}/f_b)$ are 0.27 and -0.65 for the compact group and isolated galaxies, respectively. For the *IRAS* bright galaxy sample Soifer *et al.* find log $(f_{\rm FIR}/f_b) = 0.4$. These results imply that *for a given optical luminosity, spiral galaxies in compact groups have infrared luminosities significantly higher than those of isolated galaxies, and almost as high as infrared-selected galaxies.*

As it is also of interest to compare the compact group galaxies with galaxies in clusters, we also consider the results of a study of galaxies in gas-rich and gas-poor clusters by Bicay and Giovanelli (1987). These cluster galaxies and the compact group galaxies are at comparable distances and have similar optical magnitudes. Bicay and Giovanelli found no significant differences between their gas-rich and gas-poor samples. We have combined them to form a single "cluster" sample. Figures 4 and 5 show the distribution of the ratio of far-infrared to optical luminosity and the distribution of the ratio of 100 μm to 60 μm flux (infrared color) for the detected compact group spirals and the cluster sample. There is no significant difference between the compact group and cluster samples in either the distribution of infrared to optical luminosity or infrared color.

V. DISCUSSION

The results described in this paper have shown that about one-quarter of the spiral galaxies in Hickson's compact group catalog have detectable infrared emission. The infrared-to-optical luminosity ratios are significantly higher than those found in a comparable sample of isolated galaxies and are similar to those of spiral galaxies in clusters studied by Bicay and Giovanelli (1987). An analysis of this ratio in a large sample of normal and "starburst" galaxy by Feigelson, Isobe, and Weedman (1987) has suggested that the ratio is a good indicator of infrared power and thus of star-forming activity in both types of galaxies. Our results also suggest that interactions enhance star-formation processes in spiral galaxies. The high infrared fluxes suggest that large quantities of radiating dust must be present. However, we cannot yet determine whether the radiation is diffuse, coming from the galaxy disk, or originates in the nucleus. Further evidence that interactions influence activity in galaxies in high-density environments

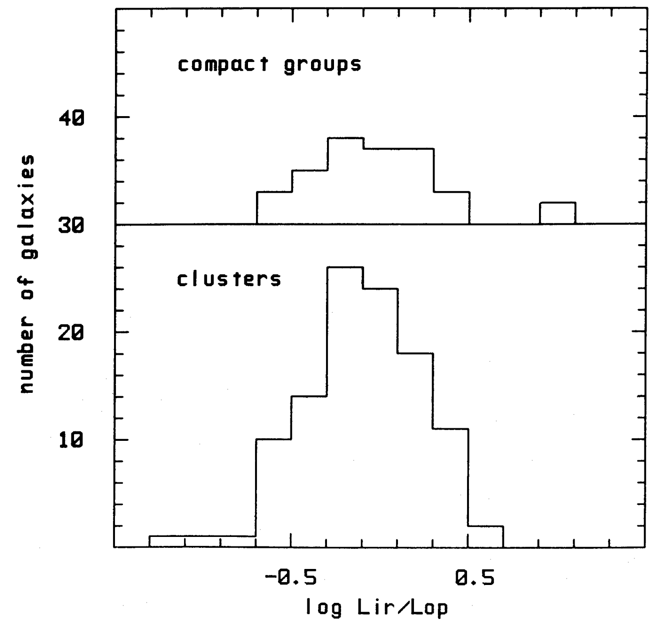

FIG. 4.—Distribution of the ratio of extrapolated far-infrared to optical luminosity for galaxies in compact groups (*upper panel*) and in clusters (*lower panel*). There is no significant difference between the two distributions.

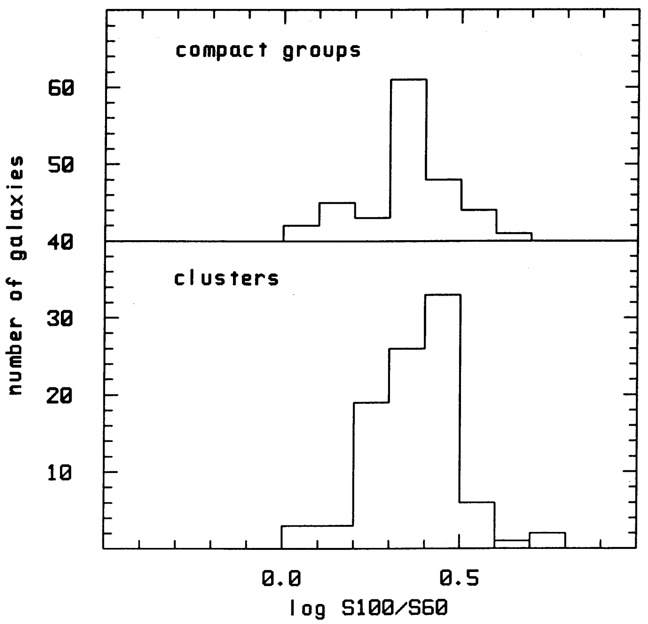

FIG. 5.—Distribution of the ratio of 100 μm to 60 μm flux for galaxies in compact groups (*upper panel*) and in clusters (*lower panel*). There is no significant difference between the two distributions.

comes from a study of radio emission in these groups (Menon and Hickson 1985).

X-ray astronomy has shown that there is a high density of gas in many clusters and that this gas provides significant energy loss by radiative cooling. Cooling flows are processes by which gas density rises in order to maintain pressure to support the overlying gas. The fraction of clusters in which cooling flows manifest themselves by X-ray emission may exceed 50% (Sarazin 1986). Since cool gas is difficult to detect, it could form a substantial component of the dark matter thought to be present from dynamical mass calculations.

In order to see whether the groups represented by this sample constitute a population of hard X-ray emitters, we searched the data from the *HEAO 1* A-2 experiment (Rothschild *et al.* 1979) for counts in the fields of the entire sample. That experiment completed two 6 month scans of the sky and a part of a third scan during the satellite mission at moderate resolution in the 2–60 keV energy band.

The detection field of view (3 × 1.5 square degrees at half-maximum power) and filter combination we chose were as in Worrall and Marshall (1984). After contamination from bright X-ray sources (Piccinotti *et al.* 1982) and confusion among group positions due to the finite beam size were taken into account, only 42 groups were left. For each scan the counting rates were found as described in Worrall, Marshall, and Boldt (1979) at all group positions, allowing for negative rates (groups can be considered pointlike sources with the above beam size).

No statistically significant hard X-ray flux was detected from the uncontaminated and unconfused directions of the groups. Consequently, only an upper limit to the mean absolute luminosity in the 2–10 keV energy band can be quoted,

$$\langle L_{2-10\,\mathrm{keV}} \rangle < 3 \times 10^{41} h^{-2}\ \mathrm{ergs}^{-1}$$

(the geometric mean redshift of the sample and the conversion factor from counting rates into physical units quoted by Piccinotti *et al.* [1982] have been used to compute this limit). The above upper limit is consistent with the individually determined luminosities of four groups in the sample obtained with the *Einstein Observatory* in the 0.5–3.0 keV energy band (Bahcall, Harris, and Rood 1984). The detection of gas and possible cooling flows could not be determined and must await more sensitive X-ray data.

We are very grateful to B. T. Soifer, the referee, for providing reprocessed *IRAS* fluxes for three galaxies, as well as useful comments. We thank A. E. Boldt for stimulating discussions. P. H. and T. K. M. are supported by grants from the Natural Science and Engineering Research Council of Canada. G. G. C. P. and M. P. thank the Laboratory for High Energy Astrophysics for hospitality and the use of data reduction facilities. Partial support from NATO (grant No. 0364/87) is gratefully acknowledged.

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