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THE EXTENDED 12 MICRON GALAXY SAMPLE

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Abstract

We have selected an all-sky ($|b| \geq 25^\circ$) $12 \mu\text{m}$ flux-limited sample of 893 galaxies from the *IRAS Faint Source Catalog, Version 2* (FSC-2). This new sample contains 2.3 times as many objects as an earlier selection (Spinoglio & Malkan 1989) based on the *IRAS Point Source Catalog, Version 2*. We have obtained accurate total fluxes in the IRAS wavebands by using the ADDSCAN procedure for all objects with FSC-2 $12 \mu\text{m}$ fluxes greater than 0.15 Jy and increasing flux densities from 12 to $60 \mu\text{m}$, and defined the sample by imposing a survey limit of 0.22 Jy on the total $12 \mu\text{m}$ flux. Its completeness is verified, by means of the classical $\text{Log } N - \text{Log } S$ and V/V_{max} tests, down to 0.30 Jy, below which we have measured the incompleteness down to the survey limit, using the $\text{Log } N - \text{Log } S$ plot, for our statistical analysis. We have obtained redshifts (mostly from catalogs) for virtually all (98.4%) the galaxies in the sample.

Using existing catalogs of active galaxies, we defined a subsample of 118 objects consisting of 53 Seyfert 1s and quasars, 63 Seyfert 2s, and 2 blazars ($\sim 13\%$ of the full sample), which is the largest unbiased sample of Seyfert galaxies ever assembled. Since the $12 \mu\text{m}$ flux has been shown to be about one-fifth of the bolometric flux for Seyfert galaxies and quasars, the subsample of Seyferts (including quasars and blazars) is complete not only to 0.30 Jy at $12 \mu\text{m}$ but also with respect to a bolometric flux limit of $\sim 2.0 \times 10^{-10} \text{erg s}^{-1} \text{cm}^{-2}$. The average value of V/V_{max} for the full sample, corrected for incompleteness at low fluxes, is 0.51 ± 0.04 , expected for a complete sample of uniformly distributed galaxies, while the value for the Seyfert galaxy subsample is 0.46 ± 0.10 , suggesting that several more galaxies are yet to be identified as Seyferts in our sample. We have derived $12 \mu\text{m}$ and far-infrared luminosity functions for the AGN, as well as for the entire sample. The AGN luminosity functions are more complete than those of the optically selected CfA Seyfert galaxies for all luminosities and AGN types.

We extracted from our sample a complete subsample of 235 galaxies flux-limited (8.3 Jy) at $60 \mu\text{m}$. The $60 \mu\text{m}$ luminosity function computed for this subsample is in satisfactory agreement with the ones derived from the bright galaxy sample (BGS; Soifer et al. 1987) and the deep high-galactic latitude sample (Lawrence et al. 1986), both selected at $60 \mu\text{m}$. Over the high luminosity range where our sample and the BGS overlap, however, our space densities are systematically lower by a factor of ~ 1.5 , whereas at low luminosities our space densities are higher by about the same amount. Comparable results are obtained when comparing the far-IR luminosity function of our entire sample with the one derived from the BGS. This is not unexpected, because of the bias towards high-luminosity spirals caused by selection at $60 \mu\text{m}$.

Subject headings: galaxies: nuclei — galaxies: Seyfert — infrared: sources — luminosity function — quasars — galaxies: photometry

1. INTRODUCTION

Complete and unbiased samples of active galactic nuclei (AGN) are essential when addressing the fundamental issues of the physical nature of galactic activity. For example, as a function of bolometric luminosity, how do the space densities of quasars, Seyfert 1 and 2 galaxies, radiogalaxies, LINERs and starburst galaxies compare to those of normal spiral and elliptical galaxies? Are all Seyfert 2s really dusty Seyfert 1s whose broad-line regions are completely obscured? Is the apparently decreasing importance of dust in more luminous active nuclei due to selection effects? How many Seyfert 2s and dusty Seyfert 1s are missing from current catalogs? Complete samples are also needed for statistical analysis leading to the major goal of minimizing the number of parameters required for a physical explanation of all AGN.

Because the nonstellar processes powering AGN have many manifestations, these objects span a diverse range of appearance, and it is nearly impossible to obtain a complete sample of them for statistical studies. Thus, nearly all previous AGN samples have suffered from some form of selection effects and/or incompleteness, diminishing their usefulness in obtaining results representative of all AGN. For example, far-infrared surveys preferentially select dusty AGN, whose bolometric luminosity is largely re-radiated by dust grains, whereas the ultraviolet-excess searches of Markarian and Green (Green, Schmidt, & Liebert 1987) are well known to be biased against reddened and dusty nuclei, in favor of blue Seyfert 1 nuclei and quasars.

We eliminate such difficulties by following the approach originated by Spinoglio & Malkan (1989, hereinafter SM) – a selection based on a flux limit at $12\ \mu\text{m}$, a waveband which minimizes wavelength-dependent selection effects. SM showed that the $12\ \mu\text{m}$ flux carries an approximately constant fraction of the bolometric flux (about one-fifth) for all types of Seyfert galaxies and quasars. Now, by selecting at $12\ \mu\text{m}$, we have obtained a sample of these objects which is complete relative to a bolometric flux of $\sim 2.0 \times 10^{-10} \text{erg s}^{-1} \text{cm}^{-2}$. See SM for a more detailed discussion of this approach.

In this paper we extend the $12\ \mu\text{m}$ galaxy sample selected by SM to a lower flux limit (0.22 Jy compared to 0.30 Jy), using the *IRAS Faint Source Catalog, Version 2* (Moshir et al. 1991, hereinafter FSC-2). To avoid the systematic underestimates of the FSC-2 fluxes of all resolved sources, we obtained accurate total flux measures for all the objects selected with the FSC-2, using the

ADDSCAN procedure, with the help of the team at the Infrared Processing and Analysis Center (IPAC). (See Appendix B for a comparison of FSC–2 and ADDSCAN fluxes) Two main objectives are achieved: first, completeness is verified down to 0.3 Jy (as opposed to 0.5 Jy in SM); second, the number of objects is more than double that in SM (893 compared to 390), allowing the production and analysis of the largest unbiased sample of Seyfert galaxies (118, including quasars and two BL Lac objects).

2. SAMPLE SELECTION

We have selected all sources in the FSC–2 that meet the following criteria: (1) 12 μm flux density in the FSC–2 ≥ 0.15 Jy; (2) either $F_{60\mu\text{m}} \geq 1/2F_{12\mu\text{m}}$ or $F_{100\mu\text{m}} \geq F_{12\mu\text{m}}$ (in order to exclude most stars and virtually no galaxies); (3) 12 μm flux density from ADDSCANS ≥ 0.22 Jy; and (4) $|b| \geq 25^\circ$ (to avoid contamination from galactic objects, especially stars). In addition, the 12 μm flux must have had a moderate or high flux quality flag, as did the flux at 60 or 100 μm , in order to assure real detections.

The details of our final selection of galaxies, and rejection of galactic sources or galaxies contaminated by stellar objects, are given in Appendix A. The total number of sources in our present sample is 893, more than double (229%) our original 12 μm sample. This includes 118 Seyfert galaxies and quasars, exactly two times the 59 reported in SM. The smaller increase in the percentage of Seyferts is likely due to the fact that the fainter, more distant, sources in the new sample have not been studied in detail and thus probably include undiscovered Seyferts.

3. COMPLETENESS

In order to derive reliable statistical results, we had as our two highest priorities obtaining a sample which was complete and yet large. We therefore selected our flux limit to be 0.22 Jy, above the completeness limit of the FSC–2, which is 0.18 Jy at 12 μm . However, it was necessary to obtain all sources with a 12 μm flux from the FSC–2 above 0.15 Jy in order to find those objects with ADDSCAN whole-galaxy fluxes above our limit. The use of the total fluxes, as compared to the FSC–2 fluxes, deteriorates the level of the completeness limit of the sample from 0.2 Jy to 0.3 Jy. This happens for several reasons. First, while the number of sources remains constant, their fluxes will systematically increase for any resolved source, so in a $\text{Log } N - \text{Log } S$ representation the points will be shifted towards higher fluxes. Second, the FSC–2 is incomplete below 0.18 Jy, so we miss some sources which would have cataloged fluxes

below that level if the FSC-2 were complete to lower fluxes. Third, there will be some sources with FSC-2 fluxes below 0.15 Jy, yet with ADDSCAN fluxes still above 0.22 Jy. At lower FSC-2 flux levels, the incompleteness grows while the number of objects with ADDSCAN fluxes above 0.22 Jy decreases. Thus we searched the FSC-2 only down to 0.15 Jy and then we measured the resulting incompleteness of our sample. A standard $\text{Log } N - \text{Log } S$ plot, shown in Figure 1, is fit well by a slope of $-3/2$ (the straight line), as expected for a spatially uniform distribution of galaxies, down to 0.30 Jy, while at lower flux levels the sample gradually becomes incomplete, reaching a level of incompleteness of $\sim 40\%$ at 0.22 Jy. This shows marked improvement over the original $12 \mu\text{m}$ sample of SM, which is complete only down to 0.50 Jy, reflecting the greater incompleteness of the IRAS Point Source Catalog, Version 2 (1988, hereinafter PSC-2), from which that sample was selected.

By fitting a function which is exponentially decreasing towards lower flux levels (the lower, curved line in Figure 1), we have estimated the incompleteness of our sample between 0.22 Jy and 0.3 Jy. We then use this estimate to correct the $12 \mu\text{m}$ luminosity functions that we derive in Section 8, in the same manner as in SM. We chose to correct for incompleteness only up to 0.30 Jy because of the good fit of the $-3/2$ slope line down to that flux, and because any incompleteness above that level is not significant, being an artifact of forcing an analytic smooth curve to the full range of data. In Figure 2.a, we show the standard volume test of Schmidt (1968), corrected for the incompleteness as estimated from Figure 1. This gives an average V/V_{max} of 0.51 ± 0.04 for the entire sample. For the computations of the volumes (V) over which each galaxy is observed and the maximum volumes (V_{max}) over which it could be observed (given the flux limit of our sample) we have used redshifts which are corrected for solar motion within the Galaxy and for a dipole Virgocentric flow, using the same correction as Geller & Huchra (1983), with an assumed infall velocity of 300 km s^{-1} .

4. FRACTIONS OF GALAXY TYPES

A preliminary classification of galaxy nuclear activity has been made using existing catalogs of active galaxies (SM; Vèron-Cetty & Vèron 1991; Hewitt & Burbidge 1991; the NASA/IPAC Extragalactic Database). About 13% of the galaxies in the sample are known to have Seyfert nuclei: 53 are Seyfert 1s and quasars, 63 are Seyfert 2s, and 2 are blazars (OJ 287 and 3C 445). Including the 29 LINERs brings the number of AGN in the sample to 16%. Thirty-eight non-Seyfert galaxies have an infrared luminosity in excess of $6 \cdot 10^{44} \text{ erg s}^{-1}$, probably due to violent star formation activity. These might be considered

active galaxies in a more general sense and we classify them as *Starburst*¹ galaxies. Including these objects would increase to 20.5% the active galaxies in our sample.

The Seyfert 1s, Seyfert 2s, Starburst galaxies and LINERs are listed in Tables 1–4, respectively, and the “normal” galaxies (nearly all spirals) are given in Table 5. These tables include, for each galaxy: the name, the equatorial coordinates (for the equinox 1950.0), the total IRAS flux densities measured by the ADDSCAN procedure, the redshift, and the reference from which the redshift has been taken.

Most (> 90%) of the flux densities quoted are those which are referred to as $F_{\nu}(z)$ in the ADDSCAN data. This represents the integral of flux between the two zero-crossings of the continuum in the in-scan direction for the median of all scans. We examined hundreds of addscans by eye to find this flux to be the most accurate for normal cases. For all other cases, specifically those objects for which the various ADDSCAN flux estimators differed significantly and/or for which the FWHM were larger than 1.5 arcmin, we examined the ADDSCAN data to determine the most accurate flux to use for each object at each waveband. This led us to sometimes use $F_{\nu}(t)$ (the flux between two points at a fixed distance from the center coordinate) or the template flux (fit to the median scan of each object) instead of $F_{\nu}(z)$. Finally, for the most extended objects in our sample we adopted the fluxes from Rice et al.’s Catalog of IRAS Observations of Large Optical Galaxies (1988; hereafter LGC). For nearly all of the objects, unless explicitly specified in the tables footnotes, the redshift given is the observed one, before any corrections.

To determine the completeness of our sample for different classes of galaxies, the standard volume test is presented separately for each class in Figure 2*b*, corrected as in Figure 2*a*. We did not consider our starburst galaxy and LINER samples in this graph because they are not complete subsamples. The “starbursts” are incomplete because they are a luminosity-limited sample by definition. Similarly, the LINERs do not form a complete subsample because their identification among our full sample has not been done systematically by examining the optical spectra, but only by a literature search, and therefore it is highly biased towards the northern hemisphere and towards the brightest and nearest (low z) objects. The values of V/V_{max} for the Seyferts in the sample are below that of the non-Seyferts, most likely because a number of faint and distant Seyfert 1s and 2s in our sample have not yet been identified

¹This classification is not identical to other popular, optically defined, definitions of starburst galaxies; we use it only for clarity when referring to this group of objects in this paper.

as such.

5. SKY AND REDSHIFT DISTRIBUTIONS

An all-sky plot of the entire sample (Figure 3) shows the galaxies are distributed roughly randomly over the $|b| \geq 25^\circ$ sky. The most noticeable departure from this is the concentration of Virgo-cluster galaxies around $\alpha_{1950.0} = 12^h 20^m$, $\delta_{1950.0} = +20^\circ$, centered on M87. Although the Seyferts alone show only a slight imbalance of more objects to the south (see Figure 3), 26 of the 29 LINERs in our sample are at positive declinations. This most likely results from the more intensive spectroscopic investigation of northern galaxies, compared to those in the south. In addition, the fact that most of the LINERs in our sample are nearby (average corrected redshift is 0.003) indicates that a number of more distant LINERs have not yet been identified as such. If so, we can expect the actual number of LINERs to be much greater, bringing our sample in closer agreement with previous studies which have suggested a higher ratio of LINERs to Seyferts (Heckman 1980; Woltjer 1990).

We corrected the observed redshifts for Galaxy rotation and motion towards the Virgo cluster using the same correction adopted in Geller & Huchra (1983). We had to ensure that the redshifts we used represent cosmological motion, and are thus proportional to distance. We therefore took the mean flow-corrected galactocentric group velocity for each of the 109 galaxies in our sample which are members of a CfA group (Geller & Huchra 1983), and for which the difference between individual and group velocity is less than 500 km s^{-1} . This approach eliminates the contributions of peculiar motion within the groups, while ensuring that only minor errors in the luminosities could result from possible incorrect group associations. Throughout this work, we assumed $H_o = 75 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

The histograms showing the distribution of distances among different classes of galaxies are presented in Fig. 4, where the normal galaxies are compared to Seyfert 1's and LINERs (top), and to Seyfert 2's and starburst galaxies (bottom). The average corrected redshift of the sample is 0.013 ($cz = 3858 \text{ km s}^{-1}$), giving an average distance of 51 Mpc. The Seyfert 1 galaxies and quasars are the more distant objects in the sample, with an average redshift of 0.035, followed by the starburst galaxies at 0.030. This is not surprising for the latter, which were defined as high luminosity galaxies. The Seyfert 2s have an average redshift of 0.021, and the LINERs 0.0029. Thus the average redshift of all *active* galaxies is 0.028 (8419 km s^{-1}), much greater than the 0.013 (3858 km s^{-1}) found for normal galaxies (that is all galaxies which are not Seyfert 1s or 2s, quasars, starburst galaxies, or LINERs) in the

sample.

6. INFRARED COLORS AND SLOPES

The color–color diagram showing the distribution of $\text{Log}(F_{60\mu\text{m}}/F_{25\mu\text{m}})$ vs. $\text{Log}(F_{25\mu\text{m}}/F_{12\mu\text{m}})$ is shown in Fig. 5a for Seyfert galaxies and in Fig. 5b for starbursts and LINERs, both compared to normal galaxies. There is a clear tendency for the Seyfert galaxies to have flatter slopes from 25 to 60 μm . Although this is the best infrared color discriminator between Seyfert and normal galaxies, it is not decisive, since about 40% of the Seyferts are found among the normal galaxies in this plot. More precisely, the color selection criterion used to select the “warm extragalactic objects” by Low et al. (1988) ($F_{25\mu\text{m}}/F_{60\mu\text{m}} > 0.25$ – see the dashed line in Fig. 5a), if applied to our sample, would have missed 20 Seyfert 1s (38%) and 29 Seyfert 2s (46%). Their criterion would also have excluded all but one of the high L_{FIR} galaxies in our sample, as shown in Fig. 5b. A discriminator based on a high 25–to–12 μm flux ratio would better select these latter objects. The vertical line in Fig. 5b (corresponding to $F_{25\mu\text{m}}/F_{12\mu\text{m}} > 4.79$), for example, separates 14 of the 38 high L_{FIR} galaxies from 97% of the normal galaxies.

The LINERs, on the other hand, have average colors very similar to those of the normal early–type galaxies in our sample, but with an even lower average value of $\text{Log}(F_{25\mu\text{m}}/F_{12\mu\text{m}})$. This indicates that much of the 12 μm emission does *not* come from star–forming regions (which produce more flux at 25 μm than at 12 μm). These colors therefore imply that our 12 μm selection is not as successful in detecting LINER active nuclei as it is for Seyfert nuclei.

To investigate the extent to which beam resolution may have affected the observed infrared colors of the sample galaxies, we have examined the difference between several spectral slopes derived from the FSC–2 fluxes and the same slopes as derived from the ADDSCAN fluxes. While we refer to Appendix B for the details of the analysis and the plots, we note here that no explicit effects of beam size on infrared colors is apparent for the (more point–like) Seyfert galaxies in our sample, and only small effects are seen among the normal galaxies.

7. COMPARISON WITH OTHER GALAXY CATALOGS

7.1. *The CfA–Seyfert and Bright Galaxy Samples*

Figure 6 is a Venn diagram showing the overlaps among our sample, the IRAS Bright Galaxy Sample (hereinafter BGS, Soifer et al. 1987, 1989), and the CfA Seyferts (*e.g.*, Edelson, Malkan, & Reike 1987). Our sample has 268 (86%) of the 313 objects in the BGS. The other 45 BGS objects are among the fainter galaxies in that sample, all having either a 12 μm flux below our completeness limit of 0.30 Jy or upper limits only in the FSC–2. To compare our sample and the BGS further, we defined subsamples from each. Our complete 60 μm –selected subsample (at 8.31 Jy; see § 8 for further details) has 235 galaxies. Of the 174 which are in the BGS’ area of sky, 172 are in the BGS. Conversely, of the 122 galaxies in a complete 12 μm –selected subsample of the BGS (at 0.79 Jy; Soifer & Neugebauer 1991), 116 are in our 12 μm Sample (the other 6 having upper limits in the FSC–2). This similarity indicates that the two methods would select virtually identical lists of galaxies down to 0.79 Jy at 12 μm or 8.31 Jy at 60 μm . At lower flux levels however, 12 μm – or 60 μm –selection will include relatively more galaxies with flat or steep IRAS spectra, respectively. See § 8.4 on how this effect, combined with the correlation of IRAS color with luminosity, will affect luminosity functions derived from the two samples.

To compare specifically the Seyfert galaxies in these samples, we note that our 12 μm Sample includes 13 of the 27 Seyfert 1s and 8 of the 21 Seyfert 2s from the CfA sample, whereas the BGS contains only 5 and 7 of these 12 μm /CfA Seyfert 1s and 2s, respectively, and no other CfA Seyferts, although all the CfA Seyferts are within the sky area surveyed by both the 12 μm and the BGS samples. The BGS also contains 50% (20/40) of the 12 μm sample Seyfert 2s which are within their surveyed sky area, but only 26% (9/34) of our Seyfert 1s in that area. (The fraction of non-Seyferts is slightly less (42%, or 239/546) than the fraction of Seyfert 2s.) Although the BGS covered less sky area ($|b| \geq 30^\circ$, plus restrictions on declination) than our sample, this cannot account for all of the missing Seyferts. More importantly, the BGS’ deficiency of Seyfert 1s *relative* to Seyfert 2s as compared to the 12 μm sample supports SM’s claim that far–infrared (*e.g.* 60 μm) surveys are biased against AGN with hotter colors, such as Seyfert 1’s.

7.2. The 6 cm Northern Sky Catalog

We have compared our entire list of galaxies with the 6 cm Northern Sky Catalog (Becker, White, & Edwards 1991, hereinafter BWE). That survey detected 30 of the 52 12 μm Seyferts (58%) in the area of sky covered but only 113 (27%) of the 419 non-Seyferts. This is not surprising, as Seyfert galaxies often have strong radio emission. Figure 7 is a plot of 6 cm luminosity (from BWE) against 60 μm luminosity for the 471 northern galaxies. Upper limits given for those objects not in BWE are the (declination-dependent) flux-limits reported in that work.

To quantify the correlation between $\log L_{6\text{cm}}$ and $\log L_{60\mu\text{m}}$ in our sample, we have used the ASURV software package (Isobe, La Valley, & Feigelson 1992). ASURV provides two statistical tests for the presence of a linear correlation between two variables when one of these variables ($\log L_{6\text{cm}}$) is heavily censored (mostly upper limits). Both the Cox Proportional Hazard and Generalized Kendall's Tau tests indicate that the correlation between $\log L_{6\text{cm}}$ and $\log L_{60\mu\text{m}}$ is significant at the 99% level. We used Schmitt's Linear Regression and the Buckley-James method to estimate the slope of this correlation. Both methods give similar results: $\log L_{6\text{cm}} \sim \text{Constant} \times \log L_{60\mu\text{m}}^{1.0}$ for the non-Seyferts and $\log L_{6\text{cm}} \sim \text{Constant} \times \log L_{60\mu\text{m}}^{1.2}$ for the Seyferts, with similar values for the constants. Since the two regression techniques agree well with each other and indicate that the relation is virtually linear, we then assumed a direct proportionality. This problem then becomes univariate, where the single variable is the ratio of radio to IR flux, which is for many galaxies only an upper limit. (Clearly there is real scatter in the relation, but this will average out, as long as the linear relation holds). In the present case we cannot assume we know the functional form of this distribution of radio/IR flux ratios. Therefore we use the Kaplan-Meier product-limit estimator (also part of the ASURV software), which is known to be a maximum-likelihood indicator, even when most of the measurements are censored (upper limits; Feigelson & Nelson 1985). The KM estimator of the luminosity ratio distribution is defined only at the values of the actual detections. The upper limits are then re-distributed uniformly among all the bins of lower detected values. Of course upper limits which are higher than the highest detection have no weight in this process. The KM estimator yields a median of $\log(L_{6\text{cm}}/L_{60\mu\text{m}}) = -4.98 \pm 0.13$ (upper dotted line) for the Seyferts and -5.61 ± 0.05 (lower dotted line) for the non-Seyferts.

The solid line shown for comparison represents a constant value of $\log(L_{6\text{cm}}/L_{60\mu\text{m}}) = -5.64$. This number is obtained by using the average value of $Q_{60} (\equiv f_{\nu=60\mu\text{m}}/f_{\nu=20\text{cm}})$ given in Bica & Helou (1990) for a sample of 25

normal spiral galaxies, and assuming a -0.7 slope power law from 6 to 20 cm. This line is identical (within error) to that calculated for our non-Seyferts.

Much of the scatter in this plot may be attributable to low-level nuclear activity. The radio-detected non-Seyferts are nearby ($\langle cz \rangle = 2520 \text{ km s}^{-1}$), as compared to the undetected non-Seyferts ($\langle cz \rangle = 3390 \text{ km s}^{-1}$). Many of these radio emitting non-Seyferts are likely to harbor some form of nuclear activity. For example, 54% of our LINERs in the area surveyed by BWE were detected by them. The higher average ratio of 6 cm to 60 μm luminosity for Seyferts is consistent with previous claims that Seyferts have excess radio power as compared to normal galaxies in the infrared-radio correlation (Condon 1992). This ratio might even be used to distinguish AGN from starbursts since the correlation has been found to be much tighter for the latter (Condon et al. 1982).

8. LUMINOSITY FUNCTIONS

8.1. Derivation

The 12 μm and the far-infrared luminosity functions (hereinafter LFs) have been calculated for the entire sample, as well as for subsamples of the different galaxy types. We have also extracted a complete 60 μm subsample, in order to correctly derive the 60 μm LF and compare it to previous works. For the Seyfert galaxies alone, we also computed the 60 μm LF from our entire sample and compared it to the one derived for the optically selected CfA Seyferts. Although neither of these latter subsamples are complete at 60 μm , they represent the best available optically and infrared selected samples of Seyfert galaxies, making a comparison meaningful.

All LFs have been derived using Schmidt's (1968) estimator

$$\Phi = \frac{4\pi}{\Omega} \sum \frac{1}{V_{max}},$$

where V_{max} was individually computed for each galaxy in the sample. The luminosities incorporate the small K-correction (Sandage 1975) calculated assuming each IRAS point can be connected by a piecewise power-law. The redshifts have been corrected for solar motion as described in Section 5.

We note here that we have corrected the two errors in SM that affected calculations of the LFs. A typographical error in the equation correcting observed redshifts for solar motion led to incorrect values of volumes and luminosities by an average of a few percent. More substantially, in SM all the LFs were underestimated by a constant factor of 2.5, which affected some of the conclusions drawn from them.

8.2. $12\ \mu\text{m}$ Luminosity Functions

The $12\ \mu\text{m}$ space densities for Seyfert 1 and 2 galaxies and for the entire sample are given in Table 6. Figs. 8*a* and *b* show the $12\ \mu\text{m}$ LF for Seyfert galaxies compared to non-Seyferts and for Seyfert 1s compared to Seyfert 2s, respectively. Again the quasars and blazars have been grouped together with Seyfert 1s. We fit our LFs to a function involving two power laws, after that used in Lawrence et al. (1986). The analytical form fitted is

$$\Phi(L) = CL^{1-\alpha} \left(1 + \frac{L}{L_*\beta}\right)^{-\beta}.$$

As expected, normal galaxies are the most numerous objects at the lower luminosities, while Seyfert galaxies begin to dominate the space density around $10^{10.8} L_\odot$, and all galaxies found above $L_{12\mu\text{m}} \sim 10^{11.2} L_\odot$ harbor active nuclei. The sharp turnover seen in the non-Seyfert LF (indicated also by the high value of β , the change in slope from low to high luminosities) resembles the “knee” observed in optical luminosity functions of normal galaxies. The best-fit parameters are:

$$\alpha = 1.3, \beta = 2.1, \log L_* = 9.8 \quad (\text{Seyferts})$$

and

$$\alpha = 1.7, \beta = 3.6, \log L_* = 9.8 \quad (\text{non-Seyferts}).$$

In Fig. 8*b* we added the constraint $\alpha \equiv 1.0$. This affects only the fits at the lowest luminosities, where small statistics make the results uncertain. Otherwise, the individual fits show the luminosity function of Sy 2s to be slightly higher than that of Seyfert 1s, except that Seyfert 1s extend to higher luminosities. The best-fit parameters are:

$$\beta = 2.1, \log L_* = 9.2 \quad (\text{Seyfert 1s})$$

and

$$\beta = 2.5, \log L_* = 9.6 \quad (\text{Seyfert 2s}).$$

In Fig. 8*c*, we also show the space densities we derived from our samples of LINERs and starburst galaxies as compared to Seyfert and normal galaxies. For the LINERs these densities must be considered as lower limits, because of the known incompleteness of the sample (see § V). Both the fraction of LINERs among the entire sample and the ratio of the LINER to the normal galaxy populations strongly decrease with luminosity. This decrease is expected if the number of LINERs in our sample not yet identified increases with redshift, and

if the intrinsic luminosity gain is less than the loss due to the distance. Because our starburst galaxy sample has been defined merely by imposing a lower far-IR luminosity limit to the non-Seyfert population, as mentioned above, the corresponding points in Fig. 8c cannot be considered to represent the starburst LF at low luminosities. The cut-off seen below $L_{12\mu m} = 10^{43.9} \text{ erg s}^{-1}$ is of course due to our selection definition. At higher luminosities, however, the sample becomes complete, and it appears that the starburst (i.e. non-Seyfert) space density, while dominating at $L_{12\mu m} = 10^{44.1} \text{ erg s}^{-1}$, falls below the Seyfert space density at $L_{12\mu m} = 10^{44.5} \text{ erg s}^{-1}$ by more than one order of magnitude.

A comparison between our 12 μm luminosity function for the whole sample and the one derived by Soifer & Neugebauer (1991) by extracting a complete 12 μm subsample of 122 galaxies from the BGS results in a very good agreement in the luminosity range $10^8 L_{\odot} < \text{Log} L < 10^{11} L_{\odot}$, where their sample has good statistics.

8.3. Far-infrared Luminosity Functions

The far-infrared luminosities have been computed by integrating the spectral energy distributions over the four *IRAS* wavebands, covering the wavelength range from 12 to 100 μm . Although it is not strictly correct to define a LF in the whole far-IR, where our sample may not be complete, this can give a first-order estimate of the bolometric LF, especially for normal galaxies. The LF for the full sample is similar to that derived by Soifer et al. (1987) for the 60 μm -selected BGS. (In the following section we compare the better defined 60 μm LFs of the two samples). The space densities for each class of Seyfert and for the entire sample are listed in Table 7. Figs. 9a and b compare the far-IR LFs of Seyfert galaxies in our sample with non-Seyferts, and with every galaxy class, respectively. As in the case of the 12 μm LF, the space densities given for LINERs are strictly lower limits, and the space density at the lower luminosity bin for “starburst” galaxies is truncated by the selection definition. The behavior at higher far-IR luminosities is similar to that of the 12 μm LF, confirming the fall-off of the starburst galaxies as compared to the Seyferts by $L_{FIR} \simeq 10^{45.3} \text{ erg s}^{-1}$. Moreover, the most luminous far-IR galaxies in our sample are still AGN, there being 4 Seyfert 1s/quasars, 6 Seyfert 2s, and 1 BL Lac more luminous than any non-active galaxy in this range. This difference would appear even greater with a truly bolometric LF, which would give more weight to the Seyferts over the starburst galaxies, since the former are brighter at virtually all non-infrared wavelengths. The difference of our conclusion from that of Soifer et al. (that infrared ultraluminous galaxies are

the “dominant” population of emitters in the universe) reflects the fact that far-IR selected surveys, including the one they did at $60\ \mu\text{m}$ miss most of the bluer (i.e. flatter IR slope) Seyfert 1 galaxies and quasars which our $12\ \mu\text{m}$ selection efficiently detects. Nevertheless, a definitive statement can not yet be made about the shape of the starburst LF at high luminosities, since there are too few galaxies to specify how it continues from the LF at lower luminosities.

8.4. $60\ \mu\text{m}$ Luminosity Functions

To compare rigorously the $60\ \mu\text{m}$ LF from our sample with those of the $60\ \mu\text{m}$ -selected BGS (Soifer et al. 1987) and of the high-galactic latitude $60\ \mu\text{m}$ sample (Lawrence et al. 1986), we have extracted from our $12\ \mu\text{m}$ sample a subsample of galaxies complete at $60\ \mu\text{m}$. To find the limiting flux density at $60\ \mu\text{m}$ for which our $12\ \mu\text{m}$ sample is complete, we plotted in Fig. 10 the differential number counts as a function of the $60\ \mu\text{m}$ flux. As can be seen, the expected slope of $-3/2$ fits the number counts down to a $60\ \mu\text{m}$ flux density of $\sim 8.31\ \text{Jy}$. This is in good agreement with what one would expect, since the reddest objects in our sample have $F_{60\mu\text{m}} \approx 30 \cdot F_{12\mu\text{m}}$, and $30 \cdot 0.3\ \text{Jy}$ (our $12\ \mu\text{m}$ completeness limit) then predicts a $60\ \mu\text{m}$ completeness limit of about $9\ \text{Jy}$. Thus we defined a complete flux-limited sample of galaxies that contains 235 objects. The $60\ \mu\text{m}$ LF of this subsample is given in Table 8. In Fig. 11 we have plotted our $60\ \mu\text{m}$ LF along with those of the BGS and of sample 3 of Lawrence et al. The latter is the weighted combination of their ‘main sample’ ($b > 60^\circ$, $0 < l < 110^\circ$, $S_{60\mu\text{m}} \geq 0.85\ \text{Jy}$) and their ‘smaller’ sample ($b > 60^\circ$, $0 < l < 110^\circ$, $RA < 13^h\ 45^m$, $0.5 \leq S_{60\mu\text{m}} < 0.85\ \text{Jy}$), converted to the units and value of H_o adopted here. We fitted each sample to the function given in Lawrence et al. The best-fit parameters are:

$$\alpha = 1.7, \beta = 1.8, \log L_\star = 10.1 \quad (60\ \mu\text{m} \text{ subsample}),$$

$$\alpha = 1.5, \beta = 1.5, \log L_\star = 10.1 \quad (\text{Lawrence et al.}),$$

and

$$\alpha = 1.1, \beta = 2.1, \log L_\star = 9.5 \quad (\text{Soifer et al.}).$$

Our $60\ \mu\text{m}$ space densities at mid and high luminosities are systematically lower, presumably because of slight incompleteness in our sample below $f_{\nu=60\mu\text{m}} \sim 9\ \text{Jy}$ (as indicated by the value of $V/V_{max} \sim 0.45$ for our $60\ \mu\text{m}$ subsample at high luminosities) and our different selection wavelength. A comparison with the LF derived by Lawrence et al. shows that, while at low luminosities ($L_{60\mu\text{m}}/L_\odot \leq 10^{10.5}$) the two LFs are consistent, at high luminosities the deep $60\ \mu\text{m}$ sample shows even higher space densities than the BGS.

At $L_{60\mu\text{m}} = 10^8 L_{\odot}$ the ratios of our fitted LF to those of Soifer et al. and Lawrence et al. are 1.59:1.23:1.0, respectively, whereas, at $L_{60\mu\text{m}} = 10^{11} L_{\odot}$ the same ratios are 1.0:1.16:1.75. These trends in the luminosity functions are not surprising since more luminous spiral galaxies emit a systematically larger fraction of their total luminosity at 25 and 60 μm (e.g., Soifer & Neugebauer 1991; Spinoglio et al. 1993). Therefore, sample selection at 60 μm is relatively better tuned than selection at 12 μm for detecting galaxies with unusually large far-infrared luminosities. To show this effect explicitly, we plot the 60–12 μm color as a function of 60 μm luminosity in Figure 12. This plot shows that, excluding Seyferts and LINERs, cooler IRAS colors are correlated with higher luminosities (a plot of the same color vs. Far-IR luminosity looks almost identical). Therefore a sample with more hot/cool objects will tend to have more low/high-luminosity galaxies, hence the difference between the two samples. We note, however, that the 3 highest luminosity bins in Figure 11, where these differences are seen, represent just over $\sim 10\%$ of the samples, and the lowest luminosity bins include an even smaller fraction.

We have also compared the 60 μm LF of the Seyfert galaxies in our entire sample to that of the optically selected CfA sample (see, for example, Edelson, Malkan, & Rieke 1987). These 48 Seyferts, spectroscopically selected from the CfA redshift survey (Huchra et al. 1992), were thought to comprise a complete and unbiased AGN sample. But the survey was based on properties of the host galaxy, and thus was not genuinely flux-limited with respect to the active nucleus. In Fig. 13*a* and *b* we compare the 60 μm LFs of the two samples for all Seyfert galaxies together and for each Seyfert type, respectively. Fig. 13*a* indicates higher space densities of Seyferts both at low ($L_{60\mu\text{m}} \leq 10^{44} \text{ erg s}^{-1}$) and high ($L_{60\mu\text{m}} \geq 10^{45} \text{ erg s}^{-1}$) luminosities in our sample. In other words, our luminosity function more closely resembles a single power-law, whereas that of the CfA Seyferts turns over more strongly in the mid-luminosity range. While the greater number of high-luminosity objects is due to the inclusion among our Seyferts of the few quasars and blazars in the 12 μm sample, the higher density at lower luminosity indicates that our selection produces a more complete sample than the one extracted from the CfA redshift survey. The same is true for both the Seyfert 1s and Seyfert 2s separately, as can be seen in Fig. 13*b*. This figure also shows that we found a result similar to the one of the CfA sample: over most of the luminosity interval, the Seyfert 2s are more numerous than Seyfert 1s by about a factor of 1.5 – 2.

9. SUMMARY AND CONCLUSIONS

The main results of this work can be summarized as follows:

1. We have defined a large sample of galaxies (893) using the $12\ \mu\text{m}$ flux as given from the *IRAS* FSC-2. This new sample contains more than twice as many objects as our earlier sample (SM), and its completeness is verified down to 0.3 Jy. Because the $12\ \mu\text{m}$ flux is representative of the bolometric flux for active galaxies (SM), we have obtained an AGN sample complete with respect to a bolometric flux limit of $\sim 2.0 \times 10^{-10} \text{erg s}^{-1} \text{cm}^{-2}$.

2. About 13% of the galaxies in the sample are known to have Seyfert or quasar nuclei. Another $\sim 3\%$ of the sample galaxies are classified as LINERs, and another $\sim 4\%$ have very high ($> 6 \cdot 10^{44} \text{erg s}^{-1}$) far-infrared luminosities, but not a Seyfert nucleus. Therefore about one fifth of the sample are galaxies that are “active” in a broad sense.

3. The high luminosity tail ($L_{FIR} > 10^{45.3} \text{erg s}^{-1}$; $L_{12\mu\text{m}} > 10^{44.5} \text{erg s}^{-1}$) of the far-IR and $12\ \mu\text{m}$ luminosity functions is dominated by Seyfert galaxies and quasars, and not by the high L_{FIR} nuclei.

4. The $60\ \mu\text{m}$ luminosity function, that we derive by extracting from our entire sample a subsample complete at $60\ \mu\text{m}$, is similar those derived from $60\ \mu\text{m}$ selected samples (Lawrence et al. 1986; Soifer et al. 1987), subject to the slight tendency for $60\ \mu\text{m}$ to select non-Seyfert galaxies of high far-infrared luminosity, relative to $12\ \mu\text{m}$ -selection.

5. A comparison of the $60\ \mu\text{m}$ luminosity function for all our Seyfert galaxies with the one derived for the CfA Seyfert galaxies shows our Seyfert sample to be more complete, by a factor of $\sim 50\%$. We find a slightly higher space density of Seyfert 2s than Seyfert 1s, in agreement with the CfA results.

We are currently combining multiwavelength observations of the $12\ \mu\text{m}$ Galaxies to construct *bolometric* luminosity functions, which will be published in a forthcoming article.

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APPENDIX A

DETAILS ON SOURCE INCLUSION AND REJECTION

We originally based our sample on the FSC-2 12 μm flux density. Applying our selection criteria to the FSC-2 produced a list of 1105 objects with a 12 μm flux density $\geq .20 \text{ Jy}$. Following SM, we then excluded all objects in the region of the Large Magellanic Cloud (109). The sources meeting our criteria within the Small Magellanic Cloud (14; Schwering & Israel, 1989) and M33 (5) regions, which are associated with dark clouds, $H\alpha$ emission nebulae, stellar cluster or HII regions have also been excluded. In addition, 160 stars found in the SAO (1966) and BSC (Hoffleit 1982) star catalogs were excluded, as well as seven planetary nebulae, six of which were clearly identified as such on the POSS plates, and one identified by Strauss (1991).

We searched major extragalactic catalogs (e.g., Vèron-Cetty & Vèron 1991; Huchra et al. 1992 (CfA Redshift Survey; ZCAT); de Vaucouleurs, de Vaucouleurs, & Corwin 1976 (RC2); Lauberts 1982 (ESO/Uppsala Survey)) to find redshifts and identifications. These supplied over 700 redshifts, and other sources (e.g., Saunders 1991; Strauss et al. 1990, 1992; Strauss 1991) provided about 60 more. For all the remaining objects without known redshifts, we made 5x magnified photographs from the POSS and ESO plates. From these finding charts, an additional 45 objects, listed in Table 9, were shown to be clearly galactic (mostly stars). This was further supported by their *IRAS* colors, which did not fall near the range established by the sample galaxies. We then obtained optical spectra from the Lick Observatory 1m and 3m telescopes for virtually all the remaining objects. These spectra provided us with several more redshifts, and enabled us to exclude 19 more objects (listed in Table 10) as stars or galactic nebulae. An additional 10 objects were excluded from our sample because, although there is a galaxy close to the *IRAS* coordinates, ADDSCANS obtained from IPAC, along with finding charts, indicated that the *IRAS* object is actually a nearby star and/or that the galaxy's contribution to the 12 μm flux is less than 0.2 Jy, the rest coming from the star. One more object (NGC 3395/6) is a double system, resolved by the *IRAS* ADDSCANS, and each galaxy contributes less than 0.2 Jy to the total 12 μm flux. These 11 objects are listed in Table 11. Finally, we had to exclude (for now) three other objects because no redshift information was available. These are given in Table 12, together with their *IRAS* FSC-2 fluxes and comments. Thus, altogether, we excluded 373 objects from our original list.

To be as complete as possible, we also applied our selection criteria to the entire *IRAS Faint Source Database* (FSDB), which contains all band-merged

sources extracted from the *IRAS Faint Source Survey* data (Moshir et al. 1991). This includes all the objects in the FSC-2, as well as those placed into the *Faint Source Reject File* (FSR). Although great attention went into compiling the FSC-2, it is known that a few true sources ended up in the FSR. We wanted to make sure that our sample did not exclude the galaxies in this group. We thus applied our selection criterion to the FSDB. This search yielded only 9 more sources, further indicating the completeness of the FSC-2. And six of these, including the Seyfert 1 galaxy NGC 4151, were excluded from the FSC-2 because they were in an area of sky not covered often enough by the *IRAS* satellite to give the minimum necessary hour-observations for inclusion (*IRAS Explanatory Supplement 1988*; Moshir et al. 1991). We included the LMC, the SMC and M 33 in our sample, using the *IRAS* fluxes given in the LGC, since these galaxies are associated with many point-like sources in the FSC-2. In addition, we added the three galaxies (NGC 2992, NGC 5595 and NGC 5597) from the SM sample for which the FSC-2 gives upper limits at both 60 and 100 μm , but good detections at 12 and 25 μm , while the PSC-2 fluxes are all good detections. The number of galaxies included from sources other than the FSC-2 is thus 15, giving a total of 747 objects in the FSC-2-based extended 12 μm sample.

Objects which are extended enough to be resolved by the *IRAS* beam will have their FSC-2 flux densities underestimated, and thus ADDSCAN data is required to obtain accurate whole-galaxy fluxes. (See Appendix B for graphs which show this explicitly for our entire sample.) We have thus obtained complete ADDSCANed flux information from IPAC for all objects with FSC-2 12 μm flux densities $\geq .15 \text{ Jy}$. We increased the limit of our sample to 0.22 Jy and added to our list 207 objects with an ADDSCAN 12 μm flux density above this limit which were not in our list of 747 galaxies selected by criteria based solely on FSC-2. Ten other such objects might have been added, but have instead been placed in Table 12 for now because we could find no redshift information for them. We also excluded 61 objects which were in the FSC-2 list of 747, but which have ADDSCAN 12 μm flux densities *below* 0.22 Jy (a few objects will actually have lower ADDSCAN than FSC-2 fluxes because of limitations in the accuracy of the FSC-2). Thus, the FINAL count of objects in this sample is (747+207-61=) 893 galaxies, plus the 13 objects in Table 12 which are likely to be galaxies, but for which we have not yet obtained a redshift.

In all of the calculations in this paper we use the ADDSCAN fluxes in each waveband for most objects. For the others, the LGC includes the largest optical galaxies that would have been resolved by the *IRAS* beam, causing their fluxes to be the most seriously underestimated. For 36 galaxies in our

sample which are also in the LGC (in addition to the LMC, SMC, and M33) we use the larger flux densities from the LGC, which more accurately represent the flux from the entire galaxy, when making calculations.

APPENDIX B

COMPARISON OF ADDSCAN AND FSC-2 FLUXES AND COLORS

1. ADDSCAN-TO-FSC-2 FLUX RATIOS VS. REDSHIFT

Since both the PSC-2 and the FSC-2 are point-source targeted surveys, they underestimate the flux densities of resolved sources (*IRAS Explanatory Supplement 1988*, Moshir et al. 1991). To study this effect quantitatively, we graphed the ratio of ADDSCAN-to-FSC-2 flux densities as a function of redshift in each of the four *IRAS* wavebands. Figures B1a–B1d show the results for the normal galaxies in our sample and Figures B2a–B2d for the Seyfert Galaxies.

We binned the objects according to redshift (with bin sizes of 500 km s^{-1} for the normal galaxies and 1000 km s^{-1} for the Seyferts), and then plotted the median and first and third quartile points. The points in higher-redshift bins are decreasingly reliable statistically, each bin above $\sim 7500 \text{ km s}^{-1}$ representing only a few objects. At $12 \mu\text{m}$, it can be seen that the ADDSCAN flux densities are greater by a factor of about 1.6 for most objects, with this ratio decreasing with redshift to a minimum value of about 1.2 for Seyferts and 1.3 for normal Galaxies. At $25 \mu\text{m}$, this same effect exists, but to a lesser degree, the ratio becoming as low as 1.1 at higher redshifts. At 60 and $100 \mu\text{m}$ the ratio is only ~ 1.2 for the most resolved sources and decreases quickly to 1.05–1.1 for normal Galaxies and to 1–1.05 for Seyferts. In each waveband, the effects are less for Seyferts than for normal galaxies because they are more point-like. These effects would be even less for very point-like sources such as higher-redshift active galaxies.

One might expect these flux ratios on average to approach unity at sufficiently high redshift, but there are a few reasons why this may not quite happen in practice. First, since ours is a relatively low-redshift sample, even some of the more distant sources could still be resolved by the *IRAS* beam, thus having their flux densities under-estimated in the FSC-2. Secondly, since our top priority is to obtain estimates of the *total* galactic flux, we usually use the flux density referred to as $F_{\text{nu}}(z)$ in the ADDSCANS. This is the integral

of flux between the two zero-crossings of the continuum in the in-scan direction for the median of all scans. At the lowest signal/noise ratios, this value will be slightly biased towards higher fluxes since, as the integral is calculated outward from the peak position, negative noise in the source wings tends to be neglected if it causes the signal to fall below the continuum (thus determining the zero-crossing), whereas all positive noise fluctuations before the first zero-crossing are included. In a plot of (ADDSCAN/FSC-2) 12 μm flux ratio vs. SNR, this ratio tends to increase as SNR decreases below ~ 10 . As a test, we fitted the average of this trend as a function of SNR from this plot, and then decreased all of our ADDSCAN 12 μm fluxes by the amount needed to produce average agreement with the FSC-2. We found that only very slight changes were made in the 12 μm LF.

In conclusion, at lower redshifts, our ADDSCAN fluxes are slightly larger than those in the FSC-2 due to the resolution of extended emission by the FSC-2 spatial template, especially at 12 and 25 μm . At higher redshifts, the over-estimation of $F_{\nu}(z)$ also contributes, but the resolution effect is still probably a dominant contributor, since at 60 and 100 μm where the resolution effect is least significant, the ADDSCAN and FSC-2 fluxes become virtually identical. Comparing the small flux over-estimate made by $F_{\nu}(z)$ for low-SNR sources, to the large under-estimation of fluxes in the FSC-2 and PSC-2, we conclude that ADDSCAN/SCANPI data, while imperfect, are the best method available to obtain accurate *total galaxy* flux densities.

2. ADDSCAN-FSC-2 COLOR DIFFERENCES VS. REDSHIFT

We have also plotted the difference in infrared colors obtained from the ADDSCAN and FSC-2 flux densities. If beam resolution strongly affected the observed infrared colors of the sample galaxies, we would see the effects in these graphs. As is evident, a best-fit line to the points shows no effect at any color for the Seyfert galaxies and small effects for the normal galaxies. The slopes for the normal galaxies show the FSC-2 colors to be redder at lower redshifts, where beam size is more important, as is expected from the large beams at longer wavelengths. The only exception is the 12-25 μm color, which compares two wavebands with the same detector size (the 25 μm detectors, on the average, are larger by $\sim 3\%$, *IRAS Explanatory Supplement 1988*). The slope in this graphs goes slightly the other way (redder color at higher redshifts), probably because the higher-luminosity objects have relatively stronger 25 μm emission. We note that, since the intrinsic scatter in the

colors is large compared to the possible effects of beam size, this test is not very sensitive, and thus should only be taken as a consistency check.

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FIGURE LEGENDS

Figure 1 – The differential $12\mu\text{m}$ number counts versus log flux (from ADDSCANS), for all objects in our sample. The solid line is the best fit line (to all points with a $12\mu\text{m}$ flux density $\geq .3 Jy$) with a slope of $-3/2$, as expected slope for a complete sample with a uniform spatial distribution. The lower line is an exponentially decreasing (towards lower flux) function, fit to all data points.

Figure 2 – *a*: The average values of V/V_{max} for sample galaxies as a function of their $12\mu\text{m}$ luminosity. The error bars are the Poisson–statistical fluctuations (point without error bars represent 3 or fewer objects.). The dashed line shows the Euclidean value of 0.5 *b*: The average values of V/V_{max} for the different subsamples of galaxies as a function of their $12\mu\text{m}$ luminosity. The error bars are the Poisson–statistical fluctuations. The dashed lines represent values of 0.5 for each subsample.

Figure 3 – Sky distribution, in galactic coordinates. Top: all galaxies in the $12\mu\text{m}$ sample; bottom: Seyfert galaxies in the $12\mu\text{m}$ sample.

Figure 4 – Distribution of distances for the various classes of galaxies: top: normal galaxies compared to Seyfert 1 galaxies and LINERs; bottom: normal galaxies compared to Seyfert 2 galaxies and starburst (high L_{FIR}) galaxies.

Figure 5 – The $[60 - 25] / [25 - 12]$ two–color diagram for all the sample galaxies. Both axes are logarithmic. *a*: colors of normal galaxies, Seyfert 1s, and Seyfert 2s. *b*: colors of normal galaxies, LINERs and starburst galaxies. The horizontal dashed line indicates the maximum $[60 - 25]$ color allowed in the selection of the warm extragalactic objects by Low et al. (1988).

Figure 6 – The Venn diagram showing the overlaps among our sample, the BGS and the CfA Seyfert galaxies.

Figure 7 – Plot of 6 cm vs. $60\mu\text{m}$ luminosity for all 471 $12\mu\text{m}$ objects in the area of sky covered by the 4.85 GHz Survey (Becker et al. 1991). Large symbols represent 6 cm detections and small symbols represent upper limits.

Figure 8 – The $12\mu\text{m}$ luminosity functions. The differential space densities (per magnitude) of the galaxies in our $12\mu\text{m}$ sample as function of the $12\mu\text{m}$ luminosity are plotted in logarithmic form. The error bars show the Poisson–statistical counting uncertainties. *a*: Seyfert galaxies are compared to non–Seyfert galaxies; *b*: Seyfert 1 galaxies are compared to Seyfert 2 galaxies. Curves represent fits to a double power–law, as explained in the text; *c*: Each galaxy type shown individually, including the lower limits of the differential space densities of LINERs and the points referring to the luminosity–limited sample of starburst galaxies (see the discussion in the

text). Points have been shifted horizontally for clarity.

Figure 9 – The far-infrared luminosity functions. The differential space densities (per magnitude) of the galaxies in our $12\ \mu\text{m}$ sample as function of the far-IR luminosity integrated over the four *IRAS* bands are plotted in logarithmic form. The error bars show the Poisson-statistical counting uncertainties. *a*: Seyfert galaxies are compared to non-Seyfert galaxies; *b*: Normal galaxies are compared to Seyfert 1, Seyfert 2, LINERs and starburst galaxies. As discussed in the text, the space densities for LINERs are lower limits, while those of starburst galaxies have to be considered with caution, because of the luminosity-limited selection of this subsample. The points in *b* are shifted horizontally for clarity.

Figure 10 – The differential $60\ \mu\text{m}$ number counts versus log flux for our entire sample. The solid line of slope $-3/2$ shows completeness down to a $60\ \mu\text{m}$ flux of $8.3\ \text{Jy}$.

Figure 11 – The $60\ \mu\text{m}$ space densities of the subsample of 235 galaxies complete at $60\ \mu\text{m}$ that we extracted from our $12\ \mu\text{m}$ sample are compared with the ones derived for the BGS (Soifer et al. 1987), and for the deep high galactic latitude $60\ \mu\text{m}$ sample of Lawrence et al. (1986). Curves represent fits to a double power-law, as explained in the text.

Figure 12 – The $60\text{--}12\ \mu\text{m}$ color as a function of $60\ \mu\text{m}$ Luminosity. All objects are plotted. The solid line represents a least-square-fit to the data, excluding the Seyferts and LINERs.

Figure 13 – A comparison of our Seyfert galaxy luminosity functions with those of the CfA sample (Edelson, Malkan, and Rieke 1987). *a*: The $60\ \mu\text{m}$ space densities of all Seyfert galaxies in our sample are compared to the ones derived for all CfA Seyfert galaxies; *b*: Same as *a*, but for each type of Seyfert individually.

Figure B1 – The ratio of ADDSCAN-to-FSC-2 flux densities are plotted as a function of redshift for all normal galaxies in our sample. Solid circles represent the median value of the flux density ratio in each $500\ \text{km s}^{-1}$ bin of redshift. Open squares and triangles represent the first and third quartile points in each bin, respectively. Bins with only 1 or two points have only as many objects. The few objects with $V > 12,000\ \text{km s}^{-1}$. are not included. *a*, *b*, *c*, and *d*: 12 , 25 , 60 , and $100\ \mu\text{m}$ flux density, respectively.

Figure B2 – The same plots as Figure B1, for all of the Seyfert galaxies in our sample.

Figure B3 – The difference between infrared spectral slopes, as obtained from ADDSCAN and FSC-2 flux densities, are shown as a function of redshift. The solid line is a least-squares fit to the Seyferts (large circles) and the dashed line is a least-squares fit to the non-Seyferts (small x's).

a, *b*, *c*, and *d*: 25–12 μm , 60–25 μm , 100–60 μm , and 60–12 μm slopes, respectively.