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ULTRAVIOLET AND FAR-INFRARED–SELECTED STAR-FORMING GALAXIES AT $z = 0$: DIFFERENCES AND OVERLAPS

C. Kevin Xu,[1] Veronique Buat,[2] Jorge Iglesias-Páramo,[3] Tsutomu T. Takeuchi,[4] Tom A. Barlow,[1] Luciana Bianchi,[5] Jose Donas,[6] Karl Forster,[1] Peter G. Friedman,[1] Timothy M. Heckman,[7] Patrick N. Jelinsky,[8] Young-Wook Lee,[9] Barry F. Madore,[10,11] Roger F. Malina,[6] D. Christopher Martin,[1] Bruno Milliard,[6] Patrick Morrissey,[1] R. Michael Rich,[12] Susan G. Neff,[13] David Schiminovich,[1] Oswald H. W. Siegmund,[8] Todd Small,[1] Alex S. Szalay,[7] Barry Y. Welsh,[8] Ted K. Wyder,[1] and Sukyoung Yi[9]

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ABSTRACT

We study two samples of local galaxies, one UV (*GALEX*) selected and the other FIR (*IRAS*) selected, to address the question of whether UV and FIR surveys see two sides ("bright" and "dark") of the star formation of the same population of galaxies or two different populations of star-forming galaxies. No significant difference between the $L_{\rm tot}$ ($=L_{60} + L_{\rm FUV}$) luminosity functions of the UV and FIR samples is found. In addition, after the correction for the "Malmquist bias" (bias for flux-limited samples), the FIR-to-UV ratio versus $L_{\rm tot}$ relations of the two samples are consistent with each other. In the range of $9 \lesssim \log (L_{\rm tot}/L_\odot) \lesssim 12$, both can be approximated by a simple linear relation of $\log (L_{60}/L_{\rm FUV}) = \log (L_{\rm tot}/L_\odot) - 9.66$. These are consistent with the hypothesis that the two samples represent the same population of star-forming galaxies, and their well-documented differences in $L_{\rm tot}$ and in FIR-to-UV ratio are due only to the selection effect. A comparison between the UV luminosity functions shows marginal evidence for a population of faint UV galaxies missing in the FIR-selected sample. The contribution from these "FIR-quiet" galaxies to the overall UV population is insignificant, given that the *K*-band luminosity functions (i.e., the stellar mass functions) of the two samples do not show any significant difference.

Subject headings: dust: extinction — galaxies: active — galaxies: luminosity function — galaxies: mass function — galaxies: starburst — infrared: galaxies — stars: formation — ultraviolet: galaxies

1. INTRODUCTION

The evolution of star-forming galaxies tells much about the history of the universe. The star formation activity in these galaxies can be best studied by observing the emission from young massive stars in the rest-frame ultraviolet (UV) and far-infrared (FIR). The UV observations record the direct light from the hot young stars, and the FIR observations collect starlight absorbed and then reemitted by the ubiquitous dust. A complete picture of star formation in the universe can only be obtained when the observations in these two wave bands are properly synthesized. Indeed, our knowledge on the star formation history of the universe has been mostly derived from deep surveys in the rest-frame UV and FIR. Many studies have been devoted to methods of deriving the star formation rates (SFRs) of individual galaxies using the UV or FIR luminosities (Calzetti 1997; Meurer et al. 1999; Buat & Xu 1996; Iglesias-Páramo et al. 2006), and the strengths and shortcomings of these methods have been discussed thoroughly in the literature (Kennicutt 1998; Adelberger & Steidel 2000; Bell 2002, 2003; Buat et al. 2005; Kong et al. 2004; Iglesias-Páramo et al. 2006). However, an arguably more important issue is the selection effect of the surveys that can be summed up by the following question: Do UV and FIR surveys see two sides ("bright" and "dark") of the star formation of the same population of galaxies, or do they see two different populations of star-forming galaxies? This is important because if the correct answer is the latter, then even if one can accurately estimate the SFR for galaxies in surveys in one band, the star formation in galaxies detected in the other band is still missing. Actually, this question is at the heart of an ongoing debate on whether the SFR of the $z \sim 3$ universe can be derived from observations of Lyman break galaxies (LBGs), which are UV-selected star-forming galaxies at $z \sim 3$ (Adelberger & Steidel 2000), given that SCUBA (Submillimeter Common-User Bolometric Array) surveys in the submillimeter (rest-frame FIR for $z \gtrsim 2$) have detected many violent star-forming galaxies at about the same redshift that are not seen by LBG surveys (Smail et al. 2001, 2004).

There have been limited overlaps between rest-frame UV surveys and rest-frame IR surveys. In the SCUBA survey of LBGs (Chapman et al. 2000), only one LBG was detected. As summarized in Adelberger & Steidel (2000), only a couple of SCUBA sources are bright enough in the optical to be detected in LBG

[1] California Institute of Technology, MC 405-47, 1200 East California Boulevard, Pasadena, CA 91125.
[2] Observatoire Astronomique Marseille Provence, Laboratoire d'Astrophysique de Marseille, 13012 Marseille, France.
[3] Instituto de Astrofisica de Andlucia (CSIC), Camino Bajo de Huetor 50, 18008 Granada, Spain.
[4] Astronomical Institute, Tohoku University, Aoba, Aramaki, Aoba-ku, Sendai 980-8578, Japan.
[5] Center for Astrophysical Sciences, Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218.
[6] Laboratoire d'Astrophysique de Marseille, BP 8, Traverse du Siphon, 13376 Marseille Cedex 12, France.
[7] Department of Physics and Astronomy, Johns Hopkins University, Homewood Campus, Baltimore, MD 21218.
[8] Space Sciences Laboratory, University of California at Berkeley, 601 Campbell Hall, Berkeley, CA 94720.
[9] Center for Space Astrophysics, Yonsei University, Seoul 120-749, South Korea.
[10] Observatories of the Carnegie Institution of Washington, 813 Santa Barbara Street, Pasadena, CA 91101.
[11] NASA/IPAC Extragalactic Database, California Institute of Technology, MC 100-22, 770 South Wilson Avenue, Pasadena, CA 91125.
[12] Department of Physics and Astronomy, University of California, Los Angeles, CA 90095.
[13] Laboratory for Astronomy and Solar Physics, NASA Goddard Space Flight Center, Greenbelt, MD 20771.

surveys. The situation is better for $z \sim 1$ star-forming galaxies, which now can be routinely identified by large-scale spectroscopic surveys and multiband optical surveys. They have also been detected in abundance in the mid-infrared (MIR) by *Infrared Space Observatory* (*ISO*) deep surveys (Elbaz et al. 2002; Hammer et al. 2005) and *Spitzer* surveys (Le Floc'h et al. 2005) and in the UV by the *Galaxy Evolution Explorer* (*GALEX*; Arnouts et al. 2005; Burgarella et al. 2006). However, the extrapolation from the mid-IR to the total dust emission is very uncertain and may be subject to significant evolution itself. The same criticism can also be applied to the comparisons between rest-frame UV and MIR sources at $z \sim 2$, the latter having been detected recently by *Spitzer* at 24 μm (Chary et al. 2004; D. Shupe et al. 2006, in preparation). Because of the relatively high confusion limits for surveys in the *Spitzer* MIPS 70 and 160 μm bands, thorough comparisons of rest-frame UV and FIR sources of $z \gtrsim 1$, down to luminosity levels fainter than the "knee" of the luminosity functions of both bands, may have to wait until the launch of the *Herschel Space Observatory* (Pilbratt 2005).

In this paper, we investigate the difference and overlaps of the UV- and FIR-selected samples in the local universe in an attempt to shed light on the selection effects of high-z samples similarly selected. The UV data are taken from observations by *GALEX*, and the FIR data are taken from the *Infrared Astronomical Satellite* (*IRAS*) database. Several papers have been published using these data. Martin et al. (2005, hereafter M05) derived the local ($z = 0$) bivariate luminosity function for the far-UV (FUV; 1530 Å) and FIR (60 μm) bands, which shows that the FUV luminosity saturates at about $2 \times 10^{10}\ L_\odot$ while the FIR luminosity can be as high as $\sim 10^{13}\ L_\odot$. This is consistent with a very strong dependence of the FIR/FUV ratio on the total luminosity ($L_{\rm tot} = L_{\rm FIR} + L_{\rm FUV}$). The luminosity function of $L_{\rm tot}$ has a lognormal form. Buat et al. (2005) compared the extinction properties of local UV- and FIR-selected galaxies and found that the mean NUV (2267 Å) extinction of UV-selected galaxies is significantly lower than that of FIR-selected galaxies ($\sim$1 mag vs. $\sim$2.5 mag). Iglesias-Páramo et al. (2006) carried out an extensive study, using combined *GALEX* and *IRAS* data, on the UV and FIR emission as star formation indicators and found a rather modest star formation activity for local star-forming galaxies. Pre-*GALEX* studies on comparisons between UV- and FIR-selected samples can be found in Buat & Burgarella (1998), Buat et al. (1999), and Iglesias-Páramo et al. (2004). In this work, we study some statistics that are free of the selection effect in order to check quantitatively how much the UV- and FIR-selected samples differ/overlap with each other. The paper is arranged as follows: After this introduction, the data sets analyzed in this paper are presented in § 2. Major results are listed in § 3. Section 4 is devoted to the discussion. Throughout this paper, we assume $\Omega_\Lambda = 0.7$, $\Omega_m = 0.3$, and $H_0 = 70$ km s^{-1} Mpc^{-1}.

2. DATA

The data sets are basically the same as those in Iglesias-Páramo et al. (2006) and Buat et al. (2005). The original UV-selected sample (Iglesias-Páramo et al. 2006) includes 95 galaxies brighter than NUV = 16 mag selected from the *GALEX* G1 stage All-sky Imaging Survey (AIS), covering 654 deg^2. From these we exclude one galaxy, 2MASX1 J20341333−0405, which does not have a measured redshift. The FIR-selected sample is also taken from Iglesias-Páramo et al. (2006). From the original sample, including 163 galaxies with $f_{60} \geq 0.6$ Jy in 509 deg^2 of the sky covered by both *GALEX* AIS and the *IRAS* Point Source Catalog Redshift Survey (Saunders et al. 2000), two are excluded: NGC 7725 (no redshift) and IRAS F00443+1038 (not a galaxy). Consequently, the UV- and FIR-selected samples studied in this paper have 94 and 161 galaxies, respectively. The K_s (2.16 μm) band magnitudes $K_{\rm tot}$ are taken from the Extended Source Catalog (XSC) of the Two Micron All Sky Survey (2MASS; Jarrett et al. 2000). Since this is very close to the classical K (2.2 μm) magnitude, we call it K magnitude hereafter for the sake of simplicity. For both the UV-selected sample (94 galaxies) and the FIR-selected sample (161 galaxies), each has 12 galaxies undetected by 2MASS. According to the sensitivity limit of 2MASS XSC (Jarrett et al. 2000), upper limits of $K = 13.5$ mag are assigned to the nondetections.

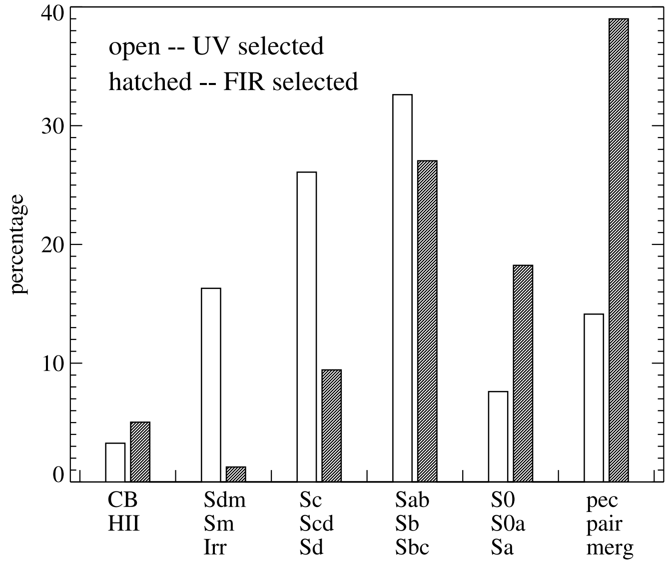

FIG. 1.—Morphological type distributions of the UV- and FIR-selected samples.

Morphological classifications were searched in the NASA/IPAC Extragalactic Database (NED). For those galaxies without morphological classification in the literature, images taken from the Sloan Digital Sky Survey (SDSS), Digitized Sky Survey, and 2MASS (in order of priority) were inspected and eyeball classification was carried out. Galaxies included in the Atlas of Peculiar Galaxies (Arp 1966), Southern Peculiar Galaxies and Associations (Arp & Madore 1987), and Catalog of Isolated Pairs of Galaxies (Karachentsev 1972) are classified as peculiar, interacting, or mergers. For a few galaxies that are faint ($b > 15$ mag) and small ($\lesssim 10''$) the classification can be very uncertain. Most such galaxies are in the FIR-selected sample, and very often there is a clear sign of interaction (close companion of similar brightness and/or diffuse tidal features). In Figure 1 the distributions of morphological types (not including QSOs and elliptical galaxies) of the two samples are compared. The overall overlap between the two distributions is about 60%. There is a significant excess of peculiar, interacting, and merging galaxies in the FIR-selected sample (39%) compared to those in the UV-selected sample (14%). For normal galaxies both UV- and FIR-selected samples peak in the bin of Sab/Sb/Sbc. Detailed analysis shows that the median type for normal UV galaxies is Sc and that of normal FIR galaxies is Sb. The FIR-selected sample is tilted toward the earlier spiral galaxies, whereas the UV sample has more late-type (later than Sc) galaxies.

3. RESULTS

3.1. *Comparisons of Luminosity Functions of UV and FIR Galaxies*

Much of the difference between the UV- and FIR-selected samples can be traced back to a single selection effect: UV observations

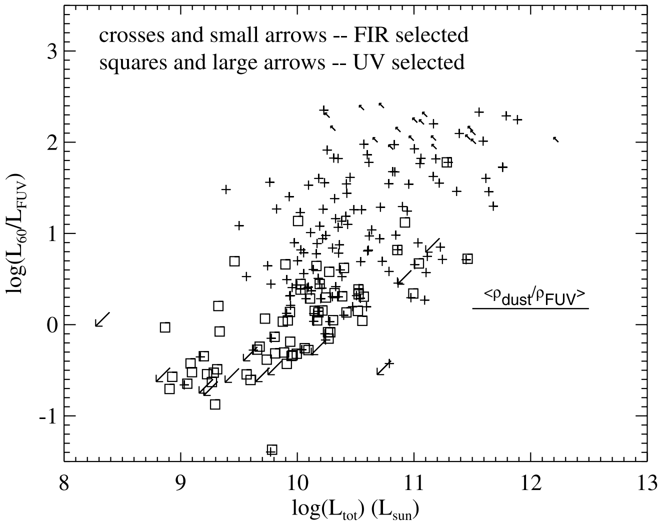

FIG. 2.—The $L_{60}/L_{\rm FUV}$ ratio vs. $L_{\rm tot}$ ($L_{60}+L_{\rm FUV}$) plot for UV- and FIR-selected galaxies. The cosmic mean of the FIR/UV ratio, $\langle\rho_{\rm dust}/\rho_{\rm FUV}\rangle$, is taken from Takeuchi et al. (2005), assuming $L_{60}=0.4L_{\rm dust}$.

preferentially detect galaxies with low $L_{\rm FIR}/L_{\rm UV}$ ratios, and in contrast, FIR observations select galaxies with high $L_{\rm FIR}/L_{\rm UV}$ ratios. Since the FIR/UV ratio is a good indicator of dust attenuation (Xu & Buat 1995; Buat & Xu 1996; Meurer et al. 1999; Gordon et al. 2000), it follows that UV samples select galaxies with significantly lower dust attenuation than galaxies in the FIR-selected sample: Buat et al. (2005) found a median FUV attenuation of $A({\rm FUV})=0.8\pm0.3$ mag for the UV-selected sample, compared to a $A({\rm FUV})=2.1^{+1.1}_{-0.9}$ mag for the FIR-selected sample.

It has been well established that there is a strong correlation between luminosity and dust attenuation in the sense that more luminous galaxies have higher dust attenuation (Wang & Heckman 1996; Buat & Burgarella 1998; Adelberger & Steidel 2000; M05). Figure 2 shows that galaxies in both the FIR and UV samples follow the strong $L_{60}/L_{\rm UV}$ versus $L_{\rm tot}$ correlation. On the other hand, UV galaxies in general have significantly lower $L_{\rm tot}$ and lower $L_{60}/L_{\rm UV}$ ratios for a given $L_{\rm tot}$ compared to FIR galaxies (Buat & Burgarella 1998; Adelberger & Steidel 2000; Iglesias-Páramo et al. 2006). Can these trends be attributed solely to the selection effects, or do they reflect some intrinsic differences between the two populations?

In order to answer this question, we have to compare the statistics of $L_{\rm tot}$ and of $L_{60}/L_{\rm UV}$ that are free from the selection effect. The selection effect is introduced by the so-called Malmquist bias on both flux-limited samples: For a given $L_{\rm tot}$, galaxies with higher FIR-to-UV ratios have brighter L_{60} and therefore can be seen at larger distances (i.e., having a larger maximum finding volume $V_{\rm max}$) in a f_{60}-limited sample. Similarly, for a given $L_{\rm tot}$, galaxies with lower FIR-to-UV ratios have higher $L_{\rm UV}$ and therefore larger $V_{\rm max}$ in a UV flux–limited sample. In what follows we compare the $L_{\rm tot}$ luminosity functions (LFs) of the two samples to examine whether they have the same intrinsic $L_{\rm tot}$ distributions. Because LFs are luminosity distributions of galaxies in a unit volume, they are not subject to the bias discussed above.

Here we exclude the sources whose *IRAS* fluxes are affected by the cirrus. In addition, UV galaxies not covered by the *IRAS* survey are dropped. This reduces the FIR sample to 151 galaxies and the UV sample to 81 galaxies. The *IRAS* detections of five UV galaxies are confused with other UV sources; therefore, the corresponding *IRAS* fluxes are treated as upper limits. Altogether, 14 UV galaxies have only upper limits for the *IRAS* flux. For galaxies in the FIR-selected sample, 14 have only upper limits for the FUV flux.

Define $\phi_{\rm tot}^{\rm FUV}(L_k)$ as the $L_{\rm tot}$ LF of UV-selected galaxies at $\log L_{\rm tot}=L_k$, $\phi_{\rm FUV}(L_i)$ as the FUV (1530 Å) LF at $\log L_{\rm FUV}=L_i$, and $P_{k,i}$ as the conditional probability of finding UV galaxies of $\log L_{\rm FUV}=L_i$ in the bin of $L_k-0.5\delta_k<\log L_{\rm tot}\le L_k+0.5\delta_k$. Then

$$\phi_{\rm tot}^{\rm FUV}(L_k)=\sum_i\frac{P_{k,i}\phi_{\rm FUV}(L_i)\delta_i}{\delta_k}. \quad (1)$$

Similarly, the $L_{\rm tot}$ luminosity function of the FIR-selected sample can be derived using the formula

$$\phi_{\rm tot}^{60}(L_{k'})=\sum_j\frac{P_{k',j}\phi_{60}(L_j)\delta_j}{\delta_{k'}}, \quad (2)$$

where $P_{k',j}$ the conditional probability of finding FIR galaxies of $\log L_{60}=L_j$ in the bin of $L_{k'}-0.5\delta_{k'}<\log L_{\rm tot}\le L_{k'}+0.5\delta_{k'}$. Data in our two samples are used in the calculations of the conditional probability functions $P_{k,i}$ and $P_{k',j}$. In order to take into account the information content in the upper limits, the Kaplan-Meier (KM) estimator (Kaplan & Meier 1958; Feigelson & Nelson 1985; Schmitt 1985) has been applied in these calculations. We have chosen $\delta_i=1$ mag for the $L_{\rm FUV}$ bin width, $\delta_j=0.5$ dex for the L_{60} bin width, and $\delta_k=0.5$ dex for the $L_{\rm tot}$ bin width. Other choices of the bin widths result in LFs with either larger scatters (bin widths too narrow) or coarse resolutions (bin widths too broad). The FUV LF and L_{60} LF are taken from Wyder et al. (2005) and Takeuchi et al. (2003), respectively.

The results are listed in Table 1 and plotted in Figure 3. In the $L_{\rm tot}$ range where they overlap, the LFs of the two populations

TABLE 1

THE $L_{\rm tot}$ ($L_{60}+L_{\rm FUV}$) LUMINOSITY FUNCTIONS OF UV- AND FIR-SELECTED GALAXIES

$\log L_{\rm tot}$ ($L_\odot$) (1)	$\phi_{\rm tot}^{\rm FUV}$ (Mpc^{-3} dex^{-1}) (2)	Error (Mpc^{-3} dex^{-1}) (3)	$\phi_{\rm tot}^{60}$ (Mpc^{-3} dex^{-1}) (4)	Error (Mpc^{-3} dex^{-1}) (5)
9.0	1.076E−2	2.039E−3	7.948E−3	4.739E−3
9.5	6.522E−3	2.024E−3	1.298E−2	3.907E−3
10.0	2.564E−3	6.875E−4	3.804E−3	8.727E−4
10.5	4.548E−4	2.200E−4	5.978E−4	1.124E−4
11.0	1.033E−4	7.394E−5	7.077E−5	2.915E−5
11.5	4.310E−6	4.223E−6	4.574E−6	4.528E−6
12.0	. . .	. . .	2.430E−7	2.430E−7

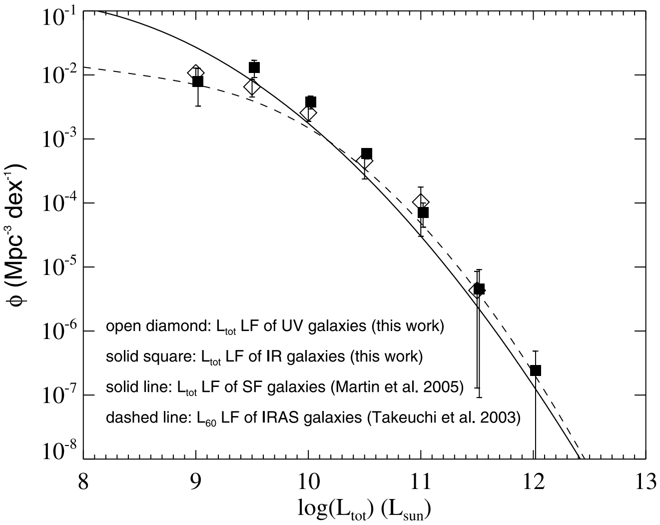

FIG. 3.—The $L_{\rm tot}$ ($L_{60} + L_{\rm FUV}$) LFs of UV galaxies (*open diamonds*) and FIR galaxies (*filled squares*).

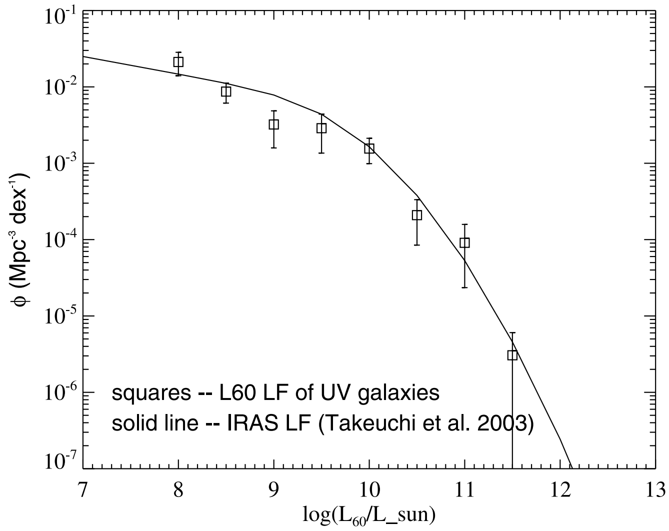

FIG. 4.—The $L_{\rm FIR}$ (60 μm) LF of UV-selected galaxies compared to the *IRAS* 60 μm luminosity function (Takeuchi et al. 2003).

are consistent with each other. The solid line is the best fit of the $L_{\rm tot}$ LF of M05, derived from a combined sample of UV- and FIR-selected galaxies. It is a lognormal function with the center at $\log(L_{\rm tot}/L_\odot) = 7.43$ and $\sigma = 0.87$. In bins of $\log(L_{\rm tot}/L_\odot) \gtrsim 10$, our LFs are marginally higher than that of M05. In order to check whether this indicates overestimation in our results, we also compared with the L_{60} LF of Takeuchi et al. (2003). There is a good agreement between our results and that of Takeuchi et al. (2003) for bins of $\log(L_{\rm tot}/L_\odot) \gtrsim 11$ (where L_{60} always dominates $L_{\rm tot}$); both are slightly higher than that of M05. At $\log(L_{\rm tot}/L_\odot) = 9$, our results for both samples are lower than that of M05, possibly due to uncertainties caused by the small size of our samples compared to that of M05.

The above result is consistent with the UV and the FIR samples being drawn from the same population of star-forming galaxies. However, the $L_{\rm tot}$ LF comparison could be insensitive to some differences. For example, in bins where $L_{\rm tot}$ is dominated by L_{60}, the differences between the $L_{\rm FUV}$ distributions of two samples can be hidden by the similarity between L_{60} distributions, and vice versa. Therefore, in what follows we calculate the L_{60} LF of UV galaxies and compare it with the L_{60} LF of *IRAS* galaxies (Takeuchi et al. 2003) and calculate the $L_{\rm FUV}$ (1530 Å) LF of FIR galaxies and compare it with that of *GALEX* galaxies (Wyder et al. 2005).

The formalism for the calculations of the L_{60} LF of UV galaxies, $\phi_{60}^{\rm FUV}(L_{60})$, and of the $L_{\rm FUV}$ LF of FIR galaxies, $\phi_{\rm FUV}^{60}(L_{\rm FUV})$, is the same as that used in the calculations of the $L_{\rm tot}$ LFs. One needs only to replace $L_{\rm tot}$ with L_{60} in equation (1) and with $L_{\rm FUV}$ in equation (2).

The results are listed in Tables 2 and 3. In Figure 4, $\phi_{60}^{\rm FUV}(L_j)$ is compared with the 60 μm luminosity function of *IRAS* sources (Takeuchi et al. 2003). It appears that UV galaxies can account for the FIR luminosity function up to $L_{60} \sim 10^{11.5}\ L_\odot$. Only ultraluminous infrared galaxies (ULIRGs) of $L_{60} \gtrsim 10^{12}\ L_\odot$ are missing in the UV sample. This is because ULIRGs are very rare in the local universe, and they are much fainter in UV. Therefore, they are probed by UV surveys in a very much smaller volume than that probed by the FIR surveys. It should be pointed out that the UV LF of Wyder et al. (2005) excludes the contribution from broad-line active galactic nuclei (AGNs) identified using SDSS spectra. These are UV/optical-selected QSOs and Seyfert 1 galaxies. According to Sanders et al. (1989) and Spinoglio & Malkan (1989), these sources never contribute more than 10% of the IR LF in the whole range of FIR luminosity. The comparison between the FUV luminosity function of the FIR-selected sample and the *GALEX* FUV luminosity function (Wyder et al. 2005) is in Figure 5. It shows that UV galaxies brighter than L_*(FUV) ($\sim 10^{9.5}\ L_\odot$) are fully represented in the FIR-selected sample. In fact, there is a significant excess in the brightest bin ($M_{\rm FUV} = -21$) of the UV LF of FIR sources compared to the UV LF of Wyder et al. (2005), likely being caused by the exclusion of the broad-line AGNs in the latter. There is marginal evidence for fainter UV galaxies of $L_{\rm FUV} < 10^{9.5}\ L_\odot$ being underrepresented in the FIR-selected sample, suggesting that a population

TABLE 2

THE FIR (60 μm) LUMINOSITY FUNCTION OF UV-SELECTED GALAXIES

$\log L_{60}$ ($L_\odot$) (1)	$\phi_{60}^{\rm FUV}$ (Mpc^{-3} dex^{-1}) (2)	Error (Mpc^{-3} dex^{-1}) (3)
8.0	2.117E−2	7.181E−3
8.5	8.679E−3	2.548E−3
9.0	3.219E−3	1.634E−3
9.5	2.875E−3	1.517E−3
10.0	1.555E−3	5.680E−4
10.5	2.090E−4	1.243E−4
11.0	9.078E−5	6.729E−5
11.5	3.057E−6	2.996E−6

TABLE 3

THE FUV (1530 Å) LUMINOSITY FUNCTION OF FIR-SELECTED GALAXIES

$M_{\rm FUV}$ (mag) (1)	$\phi_{\rm FUV}^{60}$ (Mpc^{-3} mag^{-1}) (2)	Error (Mpc^{-3} mag^{-1}) (3)
−16	1.936E−3	1.332E−3
−17	2.226E−3	1.486E−3
−18	1.552E−3	7.211E−4
−19	3.407E−4	1.316E−4
−20	7.286E−6	4.748E−6
−21	2.934E−6	2.281E−6

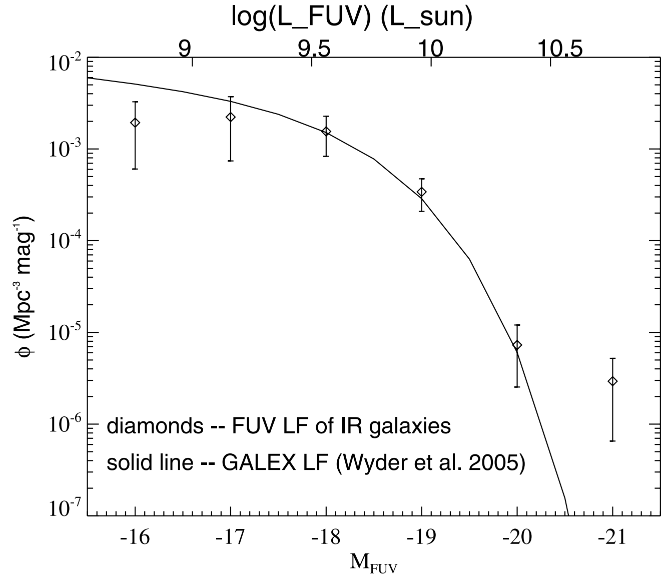

FIG. 5.—FUV (1530 Å) luminosity function of FIR-selected galaxies compared to the *GALEX* FUV luminosity function (Wyder et al. 2005).

of "FIR-quiet" UV galaxies might be missing in the FIR-selected sample.

3.2. *FIR-to-UV versus* L_{tot} *Relations of UV and FIR Galaxies*

Let $R = \log(L_{60}/L_{FUV}) = \log L_{60} - \log L_{FUV}$. For UV galaxies with a given $L_{tot} = L_k$, a "Malmquist bias–free" (i.e., selection effect–free) indicator of mean FIR-to-UV ratio can be defined as follows:

$$R_{UV}(L_k) = \frac{\sum_{j,i}(L_j - L_i)P_{j,i}\phi_{FUV}(L_i)\delta_i}{\sum_{j,i}P_{j,i}\phi_{FUV}(L_i)\delta_i}, \quad (3)$$

where $P_{j,i}$ is the conditional probability of finding UV galaxies of $\log L_{FUV} = L_i$ in the FIR luminosity bin $L_j - 0.5\delta_j < \log L_{60} \le L_j + 0.5\delta_j$, and the summation goes through both indices i and j including all bins satisfying the condition $L_k - 0.5\delta_k < \log(10^{L_i} + 10^{L_j}) \le L_k + 0.5\delta_k$. A similar FIR-to-UV ratio indicator can be defined for FIR galaxies:

$$R_{FIR}(L_k) = \frac{\sum_{i,j}(L_j - L_i)P_{i,j}\phi_{60}(L_j)\delta_j}{\sum_{i,j}P_{i,j}\phi_{60}(L_j)\delta_j}, \quad (4)$$

where $P_{i,j}$ is the conditional probability of finding FIR galaxies of $\log L_{60} = L_j$ in the FUV luminosity bin $L_i - 0.5\delta_i < \log L_{FUV} \le L_i + 0.5\delta_i$. The variance of $R_{UV}(L_k)$ and that of $R_{FIR}(L_k)$ are

$$\sigma^2_{UV}(L_k) = \frac{\sum_{j,i}[(L_j - L_i) - R_{UV}(L_k)]^2 P_{j,i}\phi_{FUV}(L_i)\delta_i}{\sum_{j,i}P_{j,i}\phi_{FUV}(L_i)\delta_i}, \quad (5)$$

$$\sigma^2_{FIR}(L_k) = \frac{\sum_{j,i}[(L_j - L_i) - R_{FIR}(L_k)]^2 P_{i,j}\phi_{60}(L_j)\delta_j}{\sum_{j,i}P_{i,j}\phi_{60}(L_j)\delta_j}, \quad (6)$$

respectively.

Results for R_{UV}, R_{FIR}, σ_{UV}, and σ_{FIR} are listed in Table 4. As shown in Figure 6, there is no significant difference between the R_{UV} versus L_{tot} relation of UV galaxies and the R_{FIR} versus L_{tot} relation of FIR galaxies, again in consistency with the hypothesis that the two samples represent the same population, and their difference in Figure 2 is due to the selection effect. Both R versus L_{tot} relations can be approximated by a simple linear relation: $R = \log L_{tot} - 9.66$, as shown by the solid line in Figure 6. In the L_{tot} range covered by our samples, this relation is slightly lower than the nonlinear relation between R and $\log L_{tot}$ (Fig. 6, *dashed curve*) derived by M05 from the bivariate function of their combined sample. It should be pointed out that the simple linear relation should not be extrapolated to galaxies of $L_{tot} \lesssim 10^9\ L_\odot$, where a flatter relation is more likely (M05).

TABLE 4

THE FIR-TO-UV RATIO [$R = \log(L_{60}/L_{FUV})$] VERSUS L_{tot} ($L_{60} + L_{FUV}$) RELATIONS FOR UV- AND FIR-SELECTED GALAXIES

$\log(L_{tot}/L_\odot)$ (1)	R_{UV} (2)	σ_{UV} (3)	R_{FIR} (4)	σ_{FIR} (5)
9.0	−0.495	0.374	−0.451	0.282
9.5	0.133	0.600	−0.320	0.722
10.0	0.324	0.600	0.317	0.598
10.5	0.351	0.427	0.697	0.833
11.0	1.305	0.299	1.370	0.907
11.5	1.948	0.201	1.932	0.516
12.0	...	...	2.279	0.281

3.3. *K-Band Luminosity Functions and Stellar Mass Distributions*

The NIR *K*-band luminosity, very insensitive to both the dust extinction and the star formation history variation (Bell & De Jong 2001; Bell et al. 2003), is the best stellar mass indicator. The stellar mass distribution is one of the most important characteristics defining galaxy populations; therefore, we should compare the *K*-band LF of UV galaxies with that of FIR galaxies. Because of the presence of upper limits in the *K*-band fluxes in both the UV and FIR samples, we exploit the same formalism as presented in equations (1) and (2) and use the KM estimator in calculating the conditional probability functions $P(M - 0.5\delta < M_K \le M + 0.5\delta | L_{FUV})$ and $P(M - 0.5\delta < M_K \le M + 0.5\delta | L_{60})$.

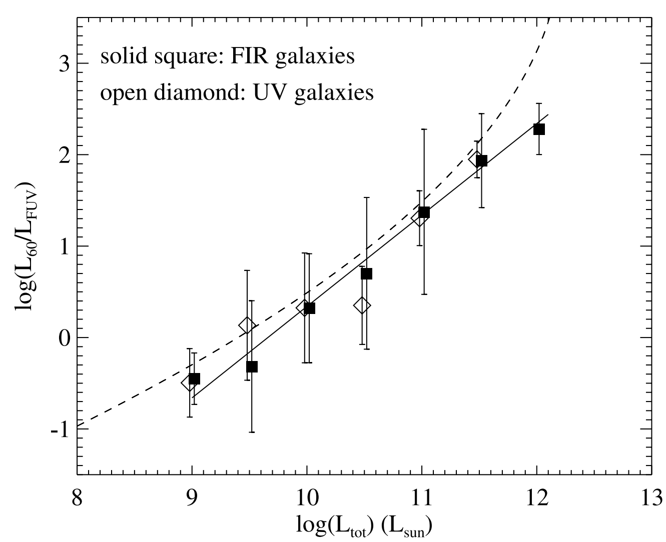

FIG. 6.—FIR-to-UV ratio [$R = \log(L_{60}/L_{FUV})$] vs. L_{tot} ($L_{60} + L_{FUV}$) relations for UV- and FIR-selected galaxies. *Solid line:* $R = \log L_{tot} - 9.66$. *Dashed curve:* R vs. $\log L_{tot}$ relation derived by Martin et al. (2005) for a combined sample.

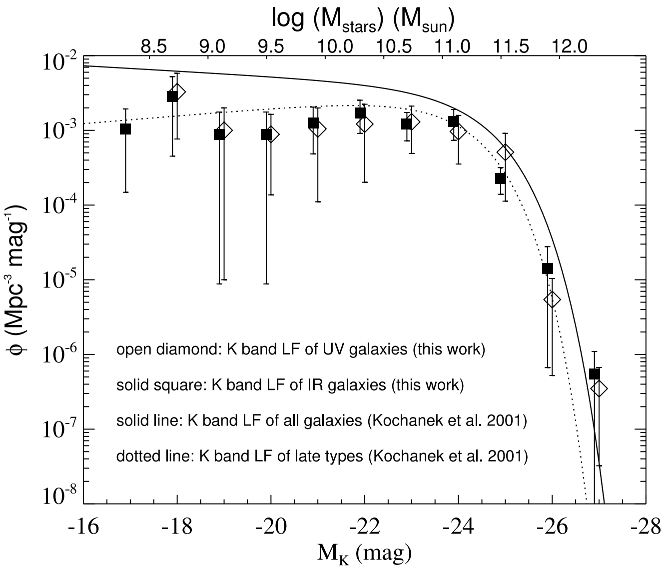

Fig. 7.—*K*-band luminosity functions (stellar mass distributions) of UV- and FIR-selected samples.

In Figure 7, the resulting *K* LFs of the two samples are compared with each other. No significant difference is found between them. It is interesting to note that both *K* LFs are consistent with the *K* LF of late-type galaxies derived by Kochanek et al. (2001), specified by a Schechter function with $\phi_0 = 0.0101$, $\alpha = -0.87$, and $M_* = -22.98 + 5\log(h_0) - \delta$, where $h_0 = 0.7$ and $\delta = 0.2$ (the difference between the isophotal magnitude and the "total" magnitude; Cole et al. 2001). The conversion factor $M_{\rm stars}/L_K = 1.32\ M_\odot/L_\odot$, which is derived for a stellar population with constant SFR and a Salpeter initial mass function (Cole et al. 2001), is assumed when converting the *K*-band luminosity to stellar mass.

4. DISCUSSION

Our results indicate that the bulk of the $z = 0$ galaxies selected in the UV and FIR samples are from the same population of active star-forming galaxies. In particular, galaxies in the two samples have indistinguishable $L_{\rm tot}$ LFs. In addition, their FIR-to-UV ratio versus $L_{\rm tot}$ relations, after correction for the Malmquist bias, are consistent with each other. Therefore, the well-documented results that galaxies in the UV flux–limited samples tend to have lower $L_{\rm tot}$ and lower FIR-to-UV ratios for a given $L_{\rm tot}$ than those galaxies in the FIR flux–limited samples are purely due to the selection effect.

The only sign of a possible difference between the UV and FIR populations is a marginal deficiency of galaxies of low UV luminosity in the FIR-selected sample, indicating the existence of an FIR-quiet UV population. Indeed, it has been known that there is a population of low-metallicity, low dust content "blue compact dwarf" galaxies. The prototype is I Zw 18, a galaxy with one of the lowest metallicities, 1/50 solar (Searle & Sargent 1972). I Zw 18 has never been detected in FIR. The FUV magnitude of I Zw 18 derived from its *GALEX* image is 15.75 mag (G. De Paz 2005, private communication). Its *IRAS* upper limit of $f_{60\,\mu{\rm m}} < 0.2$ Jy corresponds to an upper limit of $L_{60}/L_{\rm FUV} < 0.27$. Only a few percent of the galaxies in our UV sample have such a low $L_{60}/L_{\rm FUV}$ ratio, indicating a low contribution from these FIR-quiet galaxies to the overall UV population. This is in agreement with the result in Figure 7, which shows no significant difference in the *K* LFs (i.e., stellar mass functions) of the UV and FIR galaxies. Furthermore, because they have rather low UV and FIR luminosities, these galaxies contribute negligibly to the total SFR of the local universe. It will be interesting to know whether in the earlier universe more star-forming galaxies are becoming FIR quiet, given the lower metallicity in high-*z* galaxies and marginal evidence for a net increase of the faint end of the UV LF (Arnouts et al. 2005). The new results of Burgarella et al. (2006) on LBGs at $z \sim 1$ suggest the existence of a population of low-attenuation, bright UV galaxies at that redshift.

There are no ULIRGs in our UV sample. It is generally true that ULIRGs are absent in UV samples of sizes less than a few thousand. In the local universe, LIRGS/ULIRGs contribute less than a few percent to the total star formation in all galaxies (Soifer & Neugebauer 1991). Therefore, their absence in UV-selected samples does not introduce significant bias in the estimate of the total star formation rate. However, in the earlier universe of $z \gtrsim 1$, this bias may be more significant. According to Le Floc'h et al. (2005), about more than 10% of star formation at $z \sim 1$ is due to ULIRGs.

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