The Star Formation Reference Survey. I. Survey Description and Basic Data

M. L. N. Ashby, S. Mahajan, H. A. Smith, S. P. Willner, G. G. Fazio, S. Raychaudhury, A. Zezas, P. Barmby, P. Bonfini, C. Cao, E. González-Alfonso, D. Ishihara, H. Kaneda, V. Lyttle, S. Madden, C. Papovich, E. Sturm, J. Surace, H. Wu, and Y.-N. Zhu

ABSTRACT. Star formation is arguably the most important physical process in the cosmos. It is a fundamental driver of galaxy evolution and the ultimate source of most of the energy emitted by galaxies in the local universe. A correct interpretation of star formation rate (SFR) measures is therefore essential to our understanding of galaxy formation and evolution. Unfortunately, however, no single SFR estimator is universally available or even applicable in all circumstances: the numerous galaxies found in deep surveys are often too faint (or too distant) to yield significant detections with most standard SFR measures, and until now there have been no global multiband observations of nearby galaxies that span all the conditions under which star formation is taking place. To address this need in a systematic way, we have undertaken a multiband survey of all types of star-forming galaxies in the local universe. This project, the Star Formation Reference Survey (SFRS), is based on a statistically valid sample of 369 nearby galaxies that span all existing combinations of dust temperature, SFR, and specific SFR. Furthermore, because the SFRS is blind with respect to AGN fraction and environment, it serves as a means to assess the influence of these factors on SFR. Our panchromatic global flux measurements (including GALEX FUV + NUV, SDSS ugriz, 2MASS JHKs, Spitzer 3–8 μm, and others) furnish uniform SFR measures and the context in which their reliability can be assessed. This article describes the SFRS survey strategy, defines the sample, and presents the multiband photometry collected to date.

Online material: machine-readable tables

1. INTRODUCTION

Star formation has been the most important single physical process since recombination. Not only have stars created most of the luminous energy in the universe, they have produced the heavy elements needed for planets and life. Star formation has naturally been the subject of vast numbers of studies, leading, for example, to our current understanding of the star formation history of the universe (e.g., Lilly et al. 1996; Hopkins & Beacom 2006; Madau et al. 1998) and the discovery of the Schmidt law (Schmidt 1959; updated by Kennicutt et al. 1998) relating the SFR in galaxies to the gas surface density.

A general inadequacy of existing work is the lack of a self-consistent treatment of SFR across the full electromagnetic spectrum: ultraviolet (UV) continuum only samples the SFR in the absence of dust; Hα and [O II] measure ionizing photons coming from only the high-mass (≥5 M⊙) population. Emission in the polycyclic aromatic hydrocarbon (PAH) bands is taken as a SFR measure (e.g., Madden et al. 2006; Wu et al. 2005) but may be unreliable for low-luminosity (or low-metallicity) galaxies (Hogg et al. 2005) or in the presence of a hard radiation field. Far-infrared dust reradiation samples a broad range of star formation (~10 M⊙ for reasonable initial mass functions) but only becomes a precise SFR measure in the optically thick limit.
Star formation activity is by no means evenly distributed throughout galaxies. Instead, stars form within the densest regions of giant molecular clouds; this phenomenon manifests in the IRAS bands as far-infrared radiation when the (hot) young stellar objects deeply embedded in their natal clouds illuminate the surrounding interstellar material (e.g., Parker 1991), which then reradiates that energy at long wavelengths. In a detailed case study of Milky Way giant molecular cloud complexes (e.g., the California Nebula) Lada et al. (2010) demonstrated a remarkably tight correlation between SFR and the total mass of dense gas, lending further support to this view. There is considerable evidence in the literature that our understanding of star formation depends on making consistent use of all available wavebands. For example, Kartaltepe et al. (2010) showed that without photometry at wavelengths longer than 100 μm, total far-IR luminosities (and thus SFRs) are typically underestimated by 0.2 dex; in some cases the discrepancy can be much larger. This can be interpreted as an inability to adequately measure emission from a cold dust component (if present) when such far-IR data are lacking. These issues are now becoming better understood as a result of AKARI and Herschel programs that reach deeper into the far-IR than could IRAS, ISO, or Spitzer. The situation remains complex, however. In Herschel-selected galaxies, dust attenuation appears to strongly impact the UV detection fraction and the relationship between UV and IR SFR indicators (Buat et al. 2010). There are strong hints of systematic discrepancies between AKARI and IRAS photometry at ~100 μm (Jeong et al. 2007; Figs. 1 and 7 of Takeuchi et al. 2010). These unresolved issues can, in principle, be addressed with thoughtful controls. But there are also systematic effects intrinsic to the galaxies themselves. For example, there is evidence that the specific SFR (sSFR, the SFR per unit stellar mass) depends on stellar mass (e.g., Sobral et al. 2010; Elbaz et al. 2011). For many years there have been suggestions that dust temperature was dependent on luminosity (e.g., Sanders et al. 2003). And there is as yet no systematic treatment of the contribution of the older, quiescent stellar components to the SFR tracers most commonly used.

To better understand the complexities of star formation, a comprehensive treatment examining the influence of all the major parameters—stellar mass, dust mass and temperature, and metallicity—on SFR indicators is needed. The importance and timeliness of this subject is attested by numerous recent efforts to grapple with the nuances of SFR estimation. Notable examples include the Spitzer Infrared Nearby Galaxies Sample (SINGS; Kennicutt et al. 2003; Calzetti et al. 2010), the Local Volume Legacy Survey (VLVS; Dale et al. 2009), the Herschel Reference Survey (HRS; Boselli et al. 2010), the Great Observatories All-sky LIRG Survey (GOALS; Armus et al. 2009), and the Multi-wavelength Extreme Starburst Sample (MESS; Laag et al. 2010), among others. Each of these undertakings has been designed to attack specific aspects of the star formation phenomenon, but each also has limitations that prevent it from providing a comprehensive picture of star formation in galaxies.

This article presents the Star Formation Reference Survey (SFRS): a sample of nearby galaxies having a unique capacity to describe star formation under all conditions in which it occurs in the local universe. Section 2 describes the selection criteria used to define the SFRS. Section 3 presents the SFRS data sets obtained to date. Section 4 shows how the SFRS complements the aforementioned projects, presents an estimate of active galactic nucleus (AGN) prevalence and the ramifications for far-infrared SFR measures, and briefly describes SFRS-related observing campaigns now in progress.

### 2. SAMPLE SELECTION

The complexities of the real universe mean that an understanding of global galaxy properties will inherently be statistical in nature. Progress, even in the local universe, requires uniform measurements of the properties of a well-chosen, sufficiently large number of galaxies that they sample star formation across the full range of galaxy properties. In other words, having the proper study sample is critical to the success of this undertaking.

The SFRS selection criteria were defined objectively to guarantee that the sample spans the full range of properties exhibited by star-forming galaxies in the local universe. We began with the IRAS 60 μm luminosity as an unbiased (but perhaps not always correct) star formation tracer by virtue of the breadth and uniformity of IRAS coverage and because of the proximity of the 60 μm band to the SED peak associated with star formation. Although the selection was based squarely on the 60 μm flux, this should not be taken as an assertion that all issues of interpretation have been resolved. Some fraction of the 60 μm luminosity, at least in some galaxies, must arise from dust illuminated by the older stellar population. Addressing this matter is one of the aims of the SFRS project and a primary motivation for the assembly of the data sets described in § 3.

The parent sample for the present study is the PSCz catalog (Saunders et al. 2000): a full-sky database of 15,000 nearby star-forming galaxies brighter than 0.6 Jy at 60 μm. Most PSCz objects are closer than z = 0.2. The PSCz is not biased toward relatively rare ultraluminous objects (unlike the 1 Jy sample of Kim et al. 2002) and is more representative than more restricted samples (e.g., the IRAS Bright Galaxy Sample; F(60) > 5.24 Jy; Sanders et al. 2003). PSCz galaxy luminosities range from \( L(60 \, \mu m) = 10^7 \) to \( 10^{12} \, L_\odot \).

Star-forming galaxies have a wide range of properties, but aside from absolute luminosity, the specific SFR and the color temperature of far-infrared dust emission are arguably the most important. These parameters reflect the relative importance of present and past star formation and the densities of the regions where stars are forming. High color temperature is usually taken to indicate that dust grains are close to the newly formed stars;
i.e., it is a measure of active star formation. A low color temperature (high $F_{100}/F_{60}$ ratio), on the other hand, can be interpreted as reflective of a situation in which the ambient UV field from older stars in the galaxy disk is illuminating dust in the interstellar medium (ISM). Figure 1 illustrates one way in which dust temperature and luminosity relate. Nearly all “cool” galaxies (i.e., those with a far-IR flux density ratio $F_{100}/F_{60} \geq 2$) reside in the low-luminosity regime. The situation is different for “warmer” ($F_{100}/F_{60} < 2$) galaxies, however—this population is roughly evenly divided between high- and low-luminosity sources. To capture this behavior in a study sample, it is not adequate to make a simple luminosity cut: one must account for the dust temperature or be at risk of underrepresenting the mode (warm or cool) at which star formation occurs for some luminosities.

Figure 1 also reveals a dichotomy in the relationship of sSFR and luminosity. While essentially all the low-sSFR galaxies are low-luminosity objects, those with high sSFRs are a mix, with both low- and high-luminosity galaxies present. A selection on luminosity alone is therefore extremely unlikely to include sources with the full range of sSFRs that exist, and a high-luminosity selection will miss the low-sSFR sources entirely.

A full sampling of star-forming galaxy properties requires that the SFRS be defined in a three-dimensional space spanning the full ranges occupied by PSCz galaxies in 60 μm luminosity, flux ratio $F_{60}/K_s$, and far-IR flux density ratio $F_{100}/F_{60}$. In this scheme the Two Micron All Sky Survey (2MASS) $K_s$ serves as a proxy for stellar mass, the far-to near-infrared flux ratio measures specific SFR, and the far-IR flux density ratio acts as a measure of dust temperature. This three-dimensional parameter space was binned by decade in 60 μm luminosity and by quartiles in both the $K_s - 60 \mu m$ color and the $F_{100}/F_{60}$ flux density ratio (Fig. 2). The bins are defined in Table 1. This ensured that the sample contains all existing combinations of high- and low-sSFR with far-IR color and luminosity. The changeover from cool dust and low sSFR to warm dust and high sSFR occurs around $L(60) = 10^{9.5}$ to $10^{10.5} L_\odot$, which is the most heavily populated decade in luminosity. We therefore split this range into two half-decades in $L(60)$ to sample this

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**Fig. 1.**—Histograms of sSFR and dust temperature proxies within the parent PSCz galaxy sample. Thick lines show galaxy numbers for the full sample. The PSCz has been divided into two subsamples at $v_L(60 \mu m) = 10^{9.5} L_\odot$. Thin solid lines indicate the distributions for the high-luminosity subsample, and dashed lines indicate the distributions for the low-luminosity subsample. Top: Abscissa is the ratio of $K_s$ to 60 μm flux densities expressed as the difference in AB magnitudes. Bottom: Abscissa is the ratio of 100 to 60 μm flux densities ($F_{60}$).

**Fig. 2.**—Distributions of the SFRS galaxies in each of the three parameter spaces used to select the sample. Thick histograms indicate the SFRS galaxies and are referenced to the left-hand axes, and thin histograms represent the larger PSCz sample from which the SFRS sample is drawn and are referenced to the right-hand axes. The distributions are very similar in all three panels. The vertical dotted lines in each panel indicate the boundaries defining the bins (Table 1).
important regime more finely. The result is $4 \times 4$ bins in each of two colors and eight bins in luminosity: 128 bins altogether.

After the bin boundaries were determined from the complete PSCz, a representative subsample was selected as follows. First, only galaxies with measured positive redshifts were included. Second, galaxies outside the Sloan Digital Sky Survey (SDSS) and NRAO VLA Sky Survey (NVSS) surveys of the northern Galactic cap were excluded. This constraint ensures that visible and radio detections, and hence radio-derived SFRs, would be available for all galaxies, and it simultaneously minimizes foreground confusion because the Galactic plane is greater than $20^\circ$ distant from all sources. Out of the 15,000 PSCz galaxies, 2564 meet these restrictions. Third, the few nearest galaxies were eliminated in order to avoid time-consuming Spitzer mapping of objects with large angular diameters and the attendant uncertainties in calculating global measurements. The exact distance limit was made luminosity-dependent: at $L_{100} < 10^{7.5} L_\odot$ and $L_{100} > 10^{10} L_\odot$, all galaxies were eligible because they were either sufficiently small or distant that they could be imaged efficiently with Spitzer. At intermediate luminosities, galaxies with recession velocities $cz < 0.05 \times L_{100}^{1/2}$ km s$^{-1}$ were excluded, where $L_{100}$ is expressed in units of $L_\odot$. This criterion excluded 194 galaxies. Because all these restrictions are based strictly on galaxy positions in three-dimensional space, they in no way bias the sample, and they ensure that low-luminosity sources are retained.

The final SFRS consists of a representative number of galaxies from each bin. The number chosen from each bin containing $N$ galaxies was $\sqrt{N}$, rounded up to a maximum of 10 galaxies. The specific galaxies chosen were the brightest within each bin. This selection sets the sample size at 369 galaxies and guarantees that the sample will be representative of the much larger PSCz and, by inference, representative of star-forming galaxies in general. The distributions of the sample galaxies in the two-dimensional projections of the three-dimensional selection space are illustrated in Figures 3 and 4. The SFRS distributions are very similar in all three selection parameters (Fig. 2) to those for the full PSCz. The resulting sample is thus statistically well defined and covers the entire range of star formation properties seen locally: five decades in luminosity (and thus SFR); a factor of nearly 200 in specific SFR; and all masses, morphologies, and sizes.

### Table 1

**Bin Boundaries Applied to Parent PSCz Sample**

| Parameter                        | Q1/Q2 | Q2/Q3 | Q3/Q4 |
|----------------------------------|-------|-------|-------|
| sSFR proxy ($K_s - F_{60}$)      | 3.78  | 4.56  | 5.34  |
| $T_{DUST}$ proxy ($F_{100}/F_{60}$) | 1.71  | 2.14  | 2.69  |

**Note.**—The quartile boundaries applied to the sSFR and $T_{DUST}$ proxies used to define the SFRS sample. The third selection dimension, $60 \mu$m luminosity, was binned in decades starting at $\log(L_{60}) = 10^{5.5} L_\odot$ with an additional half-decade bin boundary at $10^{10} L_\odot$, near the peak of the distribution (Fig. 2).

![Figure 3](image3.png)

**Fig. 3.**—Three-dimensional SFRS galaxy distribution projected into the two-dimensional space defined by 60 $\mu$m luminosity and far-IR flux density ratio. The symbol size is inversely proportional to weight: large symbols indicate relatively rare objects that occupy sparsely populated bins; they significantly enlarge the parameter space explored by our sample and may be underrepresented by programs not implementing selections similar to the SFRS.

The relative prevalence of a galaxy of any type within the sample is reflected in its weight: each SFRS galaxy in a given selection bin is assigned a weight determined by the ratio of the total number of PSCz galaxies in that bin to the number of sample galaxies drawn from that bin into the SFRS sample. Relatively rare galaxy types have low weights, while those from heavily populated bins have large weights. The names, positions, individual weights, and IRAS 60 and 100 $\mu$m fluxes used to define the sample are given in Table 2. These weights project the SFRS sample back to the parent PSCz population. Additional weighting based on the volume in which a galaxy would enter the PSCz would be needed to define a true volume-limited sample.

![Figure 4](image4.png)

**Fig. 4.**—Three-dimensional SFRS galaxy distribution projected into the two-dimensional space defined by 60 $\mu$m luminosity and near-to far-IR color (specific SFR proxy). Symbols are as in Fig. 3.
Because of the rigid selection criteria, the well-known quasar 3C 273 and the blazar OJ 287 are members of the SFRS. Each is the only galaxy in its bin (weight \( w \equiv 1 \)). While we retain these objects to preserve the demographics of our selection, they can be ignored for studies relating purely to star formation.

### 3. BASIC DATA

In addition to the 2MASS and IRAS data used to define the selection criteria, many other resources are available. These are summarized in Table 3 and described in detail beginning with § 3.2.

#### 3.1. Distances

A significant fraction of the SFRS galaxies are very nearby and can have peculiar velocities comparable with their Hubble flow velocities. Tully et al. (2008) have recently accumulated redshift-independent distance measurements for nearby galaxies by using alternate methods, including the Tully-Fisher relation (Tully & Fisher 1977), Cepheids (Freedman et al. 2001), the luminosity of stars at the tip of the red giant branch (Karachentsev et al. 2004, 2006), and surface-brightness fluctuations (Tonry et al. 2001). These measurements yield \( q_0 \) distances for nearby \((v < 3000 \text{ km s}^{-1})\) galaxies with distance modulus uncertainties \( < 0.1 \text{ mag} \). Tully et al. (2008) estimated the distances of additional galaxies based on their association with groups/clusters. In total, their catalog \(^{13}\) includes 3529 distance measurements (Tully 2010, private communication) for galaxies with \( v < 10,000 \text{ km s}^{-1} \), of which 127 are in the SFRS.

For the 242 galaxies lacking quality distances, the heliocentric velocities in the PSCz catalog were converted to a corrected recession velocity, taking into account the velocity field of Virgo, the Great attractor, and the Shapley supercluster, following Mould et al. (2000). All cataloged PSCz heliocentric velocities agree with those provided by the NASA Extragalactic Database (NED) \(^{14}\), within the uncertainties.

The resulting corrected velocities were used to estimate distances for all SFRS galaxies, assuming \( H_0 = 73 \text{ km s}^{-1} \text{ Mpc}^{-1} \). The distances are given in Table 2, and the overall distance distribution is plotted in Figure 5. The SFRS galaxies tend to be bright by virtue of their proximity (60% are nearer than 100 Mpc, and 90% are closer than 180 Mpc) and are therefore easily accessible from a wide range of telescopes.

#### 3.2. Infrared Array Camera Photometry

The Infrared Array Camera (IRAC; Fazio et al. 2004) observations of most SFRS sources (i.e., all those lacking suitable archival data) were carried out during Cycle 5 (PID 50128) using standard observing parameters. Each of the 273 galaxies targeted by PID 50128 was observed with at least 6 \( \times \) 12 s full-array exposures using a cycling dither with a medium dither scale. All sources were observed in both IRAC fields of view, yielding a total exposure time of at least 72 s in each of the four IRAC bands at 3.6, 4.5, 5.8, and 8.0 \( \mu\text{m} \). This relatively low

\(^{13}\) The Extragalactic Distance Database, http://edd.ifa.hawaii.edu/.

\(^{14}\) See http://ned.ipac.caltech.edu/.
exposure time consistently yielded S/N > 1000 for these very bright galaxies. All sources not included in PID 50128 had already been observed by other programs, and the corresponding data were downloaded from the archive.

The archival and PID 50128 data were reduced together in as homogeneous a manner as possible. The basic IRAC data reduction was carried out by team members at the University of Western Ontario and at the Center for Astrophysics. In both instances it was based on the corrected basic calibrated data (cBCD). The cBCD frames were object-masked and median-stacked on a per-AOR (Astronomical Observing Request) basis; the resulting stacked images were visually inspected and subtracted from individual cBCDs within each AOR. This was done to eliminate long-term residual images arising from prior observations of bright sources by the 3.6, 5.8, and 8.0 μm arrays. The 4.5 μm detector array did not suffer from residual images during Spitzer’s cryogenic mission. Subtracting the median stacks also minimized gradients in the celestial backgrounds around each source. After these preliminaries, the data for each galaxy were mosaicked into four spatially registered mosaics using IRACproc (Schuster et al. 2006). IRACproc augments the capabilities of the standard IRAC reduction software (MOPEX). The software was configured to automatically flag and reject cosmic ray hits based on pipeline-generated masks together with a sigma-clipping algorithm for spatially coincident pixels. IRACproc calculates the spatial derivative of each image and adjusts the clipping algorithm accordingly. Thus, pixels where the derivative is low (in the field) are clipped more aggressively than are pixels where the spatial derivative is high (point sources). This avoids downward biasing of point-source fluxes in the output mosaics. The mosaics were resampled to 0.84″ per pixel, so each pixel in the final mosaic subtends half the solid angle of the native IRAC pixels.

Photometry was carried out with SExtractor (version 2.5.0; Bertin & Arnouts 1996). Because our interest lies in global photometry and, in particular, in ensuring accurate global SEDs, we first registered all IRAC and GALEX mosaics (for which GALEX data were available; § 3.7) to a common spatial scale using SWarp (version 2.17.1) and then applied SExtractor in two-image mode to photometer the galaxies. In two-image mode, SExtractor performs detection and characterization of the surface-brightness distribution in one image and applies that surface-brightness distribution to a second image. This was necessary because the infrared and ultraviolet mosaics in many instances have significant morphological differences; two-image mode prevents this fact from biasing the global color measurements. We used the IRAC 3.6 μm mosaic—the best tracer of the stellar light distribution—as the detection image and photometered the GALEX and IRAC mosaics using the surface-brightness distribution at 3.6 μm to define the apertures. In a few cases where UV-bright features dominate, it was necessary to use the GALEX NUV image as the detection image in order to ensure that the SExtractor captures all the light in all six GALEX and IRAC bands. The IRAC photometry appears in Table 4.

### 3.3. Radio Continuum Flux Densities

Most of the radio observations come from the NVSS (Condon et al. 1998): a snapshot survey of 82% of the celestial sphere at 1.4 GHz. The survey’s key features are that it used VLA D-array, and the images were cleaned and restored with a 45″ beam (Condon et al. 1998). Typical rms brightness fluctuations in the survey are 0.45 mJy beam$^{-1}$, and the survey catalog reaches the 50% completeness level at $S = 2.5$ mJy. In practice, the SFRS sources were retrieved from the online

| Bandpass       | Observatory     | Sample coverage |
|----------------|-----------------|-----------------|
| 1.4 GHz        | VLA/NVSS        | 100%            |
| 12.25, 60, 100 μm| IRAS            | 100%            |
| 65, 90, 140, 160 μm| AKARI FIR All- | 95%             |
| 24 μm          | Spitzer/MIPS    | 70%             |
| 3.6, 4.5, 5.8, 8.0 μm| Spitzer/IRAC  | 100%            |
| JHK            | 2MASS           | 100%            |
| ugriz          | SDSS            | 100%            |
| Optical spectra| SDSS (fiber)    | 57%             |
| Hα             | NAOC            | 30% (campaign ongoing) |
| 0.13–0.28 μm   | GALEX           | 90% to date     |

Fig. 5.—Distance/redshift distribution of the SFRS, in 20 Mpc bins. Because of the 60 μm IRAS selection, most of the sample galaxies are nearby ($z < 0.05$), but the distribution has a tail of higher-luminosity galaxies toward higher redshifts. The plot has been scaled to emphasize the nearby galaxies; the four most distant objects are not shown (3C 273, IRAS 11267 + 1558, IRAS 13218 + 0552, and OJ 287 at 660, 740, 850, and 1260 Mpc, respectively; Table 2).

Table 3

| Bandpass       | Observatory     | Sample coverage |
|----------------|-----------------|-----------------|
| 1.4 GHz        | VLA/NVSS        | 100%            |
| 12.25, 60, 100 μm| IRAS            | 100%            |
| 65, 90, 140, 160 μm| AKARI FIR All- | 95%             |
| 24 μm          | Spitzer/MIPS    | 70%             |
| 3.6, 4.5, 5.8, 8.0 μm| Spitzer/IRAC  | 100%            |
| JHK            | 2MASS           | 100%            |
| ugriz          | SDSS            | 100%            |
| Optical spectra| SDSS (fiber)    | 57%             |
| Hα             | NAOC            | 30% (campaign ongoing) |
| 0.13–0.28 μm   | GALEX           | 90% to date     |
When small-diameter objects could be identified, their positions were held fixed, and objects were forced to be point sources whenever possible. Extended objects had position angles held fixed when those could be determined from visible or IR data.

catalog\textsuperscript{15} with a 30″ search radius. Such queries returned results for 342 of the SFRS galaxies, all with unique matches. Figure 6 of Condon et al. (1998) shows a 1% chance of finding a spurious match within this distance of an arbitrary position. Ten additional matches, two of them double, were found in a search radius of 60″, and two additional matches were found with a 90″ search. The probability of spurious matches at these distances is 5–10%, but such large position errors are highly unlikely for correct matches unless the source itself is very extended.

Condon et al. (2002) gave flux densities based on NVSS data for 192 of the SFRS galaxies. In all but 14 cases, the flux densities are essentially identical to the ones from the automated lookup. For the 14 discrepant cases and also for all cases where the NVSS position differed from the adopted galaxy position by more than 10″, we examined the NVSS images\textsuperscript{16} together with the IRAS and IRAC infrared images. Most of the discrepancies were caused by blends of two radio sources; one of them was the SFRS galaxy and the second was a nearby galaxy or QSO. This cause (blended sources) was found to explain discrepancies both in total measured flux and for discrepancies in the reported coordinates. In about half of the cases, the blended source was identifiable on the IRAC image or in NED. Most of the time, the \textit{IRAS} (i.e., SFRS) source was attributable to a single galaxy, but in some cases two galaxies are likely to contribute. The radio blends were deconvolved using IMFIT in the Common Astronomy Software Applications (CASA) package,\textsuperscript{17} in each case with the minimal set of free parameters that led to a satisfactory fit.\textsuperscript{18} Another cause of discrepancy was extended radio sources. The NVSS catalog fit Gaussians to all sources, but in some cases this is not an accurate description of the galaxy. In these cases, the radio flux was measured in a circular, rectangular, or polygonal beam, as appropriate for the particular galaxy. In general, our results agree with those of Condon et al. (2002) but differ slightly because we took into account information from the \textit{IRAS} images in determining how to fit the radio sources.

A final 16 SFRS sources either were not detected in the NVSS or had very low signal-to-noise ratio (S/N). These were observed with the VLA in D configuration in 2008 July (program AA 319).\textsuperscript{19} The observations used the same observing frequencies and bandwidth as those of the NVSS but were ≥7 minutes long, as opposed to 30 s for the NVSS in the relevant declination bands. Data reduction was with CASA and followed the NVSS procedure in using superuniform weighting with $\text{n pix} = 5$. The reductions differed in using 7.5″ pixels and a restoring beam set by the actual baselines and weightings of each observation; typical beams were 30″ × 40″. The two frequencies observed were imaged and cleaned separately and the resulting images were averaged; the separate images were also inspected and source flux densities were measured on each of them, as well as on the combined image. This was especially important for three galaxies with bright radio sources (M87 and 3C 273) in the outer part of the VLA primary beam. Flux densities were measured via Gaussian fitting (CASA IMFIT), by adding up pixels in rectangular areas, or where needed by deconvolution as discussed previously. In many cases, the limiting noise source is sidelobes from strong, imperfectly cleaned sources in the field. The tabulated uncertainties are our best estimate taking these into account, especially by comparison of the images at the two frequencies and of different methods of measuring flux density.

All the radio flux densities are given in Table 5. Uncertainties are higher for sources marked as “extended” because the peak surface brightness is the best-measured parameter, and uncertainty in the source size contributes to the uncertainty in flux density. Unrecognized blends may give spuriously high flux densities, but this is likely to be the case for only a very few objects.

\subsection*{3.4. Multiband Imaging Photometer for \textit{Spitzer} 24 \textmu m Photometry}

Many SFRS galaxies are not well detected by \textit{IRAS} at 12 and 25 \textmu m, leaving an obvious gap in the suite of useful SFR estimators (e.g., Calzetti et al. 2010). To fill this gap we photometered all available archival \textit{Spitzer}/MIPS (Multiband Imaging Photometer for \textit{Spitzer}) observations (Rieke et al. 2004) and

\begin{table}[h]
\centering
\caption{\textit{Spitzer}/IRAC Photometry for SFRS Galaxies}
\begin{tabular}{lcccc}
\hline
SFRS & Name & 3.6 \textmu m & 4.5 \textmu m & 5.8 \textmu m & 8.0 \textmu m \\
\hline
1 & IC 486 & 12.58 & 12.71 & 12.37 & 11.81 \\
2 & IC 2217 & 13.06 & 13.44 & 11.95 & 10.78 \\
3 & NGC 2500 & 11.78 & 12.25 & 11.48 & 10.95 \\
4 & NGC 2512 & 12.25 & 12.64 & 11.67 & 10.63 \\
5 & MCG 6-18-009 & 13.14 & 13.50 & 12.80 & 11.51 \\
6 & MK 1212 & 13.65 & 13.90 & 12.85 & 11.37 \\
7 & \textit{IRAS} 08072+1847 & 13.81 & 13.35 & 12.11 & 10.94 \\
8 & NGC 2532 & ... & ... & ... & 9.97 \\
9 & UGC 4261 & 14.07 & 14.48 & 13.31 & 12.17 \\
10 & NGC 2535 & 12.52 & 12.94 & 11.94 & 10.96 \\
\hline
\end{tabular}
\end{table}

\textsuperscript{15} See http://www.cv.nrao.edu/nvss/NVSSlist.shtml, lookup done in 2010 in catalog dated 2004.

\textsuperscript{16} See http://www.cv.nrao.edu/nvss/postage.shtml.

\textsuperscript{17} See http://casa.nrao.edu/index.shtml.

\textsuperscript{18} When small-diameter objects could be identified, their positions were held fixed, and objects were forced to be point sources whenever possible. Extended objects had position angles held fixed when those could be determined from visible or IR data.

\textsuperscript{19}The AA 319 observations also included two galaxies that were in an early version of the SFRS sample but were later deleted.
TABLE 5
1.4 GHz Flux Measurements for SFRS Galaxies

| SFRS Name | Position (J2000) | Offset (″) | F(1.4 GHz) (mJy) | References |
|-----------|-----------------|-----------|------------------|------------|
| IC 486    | 08:00:29.98 +26:36:50.2 | 1.5       | 10.2 ± 0.5       | 1          |
| IC 2217   | 08:00:49.89 +27:30:01.9 | 2.2       | 18.8 ± 0.7       | 1          |
| NGC 2500  | 08:01:52.41 +50:44:25.6 | 14.0      | 14.7 ± 3.2       | 1          |
| NGC 2512  | 08:03:07.86 +23:22:31.6 | 1.1       | 18.6 ± 0.7       | 1          |
| MCG 6-18-009 | 08:03:28.82 +33:27:44.4 | 1.5       | 17.9 ± 0.7       | 1          |
| MK 1212   | 08:07:50.61 +27:07:33.8 | 1.2       | 12.4 ± 0.6       | 1          |
| J1926+1847| 08:10:15.43 +33:57:25.9 | 3.9       | 46.5 ± 2.1       | 1          |
| NGC 2532  | 08:10:15.43 +33:57:25.9 | 3.9       | 46.5 ± 2.1       | 1          |
| UGC 4261  | 08:10:56.46 +36:49:47.3 | 6.7       | 8.2 ± 0.5        | 1          |
| NGC 2535  | 08:11:13.63 +25:12:27.1 | 13.9      | 18.2 ± 1.9       | 1          |

Note—Further details for individual sources are marked with an asterisk (*): (3) High integral, 110" × 105" at a 30° P.A.; (10) 55° × 45° at a 29° P.A., excludes 4.4 mJy point source at 08:11 : 16.1 + 25:10 : 55. Table 5 is published in its entirety in the electronic edition of the PASP. A portion is shown here for guidance regarding its form and content.

* Coordinates correspond to the centroids measured in the NVSS or AA319 images.
* Offset measured relative to the IRAC position.
* E = extended source.

REFERENCES.—(1) NVSS query; (2) NVSS image.

were awarded time to observe the remainder of the sample via our own observing program (PID 50132, PI Fazio).

Our MIPS 24 μm campaign was active from the start of 2008 November until the exhaustion of Spitzer’s cryogen in 2009 May. A total of 178 SFRS galaxies were observed, all of them in Phot mode. Most used a small field size, 10 s exposures per position, and two cycles. For six relatively large galaxies, a large field size was used to ensure that a sufficiently large source-free background was present in the final mosaics to permit an accurate background subtraction. In one instance (NGC 3338), a raster map had to be used to cover the full spatial extent of the source plus the nearby field.

All PID 50132 data were reduced using standard techniques. We used object-masked median stacks of all exposures of each target to eliminate array artifacts from the enhanced basic calibrated data (eBCD) before mosaicking. All mosaics were pixelated to 2.5″.

The archival observations were a heterogeneous data set employing a variety of exposure times and observing strategies. Our analysis of these 101 observations therefore began with the post-BCD data products, which retain some array-based artifacts but were nonetheless suitable for deriving global photometry. Two galaxies (NGC 4314 and 4418) exhibited saturation at their cores in the archival data, but apart from this we retrieved mosaics covering the full extent of a total of 101 of our sample galaxies. Together with the 178 objects from PID 50132, a total of roughly three-fourths of the SFRS galaxies yielded useful mosaics.

We photometered all sources identically using SExtractor, accounting for differences in pixelation by an appropriate choice of convolution kernel. Typically, the sources were detected with S/N of hundreds or even thousands in mosaics that were very far from being confused with unrelated background or foreground sources. Using the effective radii measured by SExtractor (KRON_RADIUS), we applied appropriate aperture corrections to the total fluxes following Table 4.13 of the MIPS Instrument Handbook. No special effort was made to identify and exclude foreground stars, but because of the typically very high galactic latitude of the sources, this should not significantly bias the photometry.

The MIPS photometry was verified in two ways. First, all the SExtractor-generated background and object check images were inspected to make sure that the backgrounds were smooth on scales larger than the galaxies themselves and that SExtractor had identified all the pixels associated with a particular galaxy. Second, the results were compared with those reported for the 15 SFRS galaxies in common with the SINGS and LVLS samples (Table 6; Dale et al. 2007, 2009). All agree within 1σ, except for NGC 5474 and NGC 4395. The measurement for NGC 5474 (0.14 Jy) is 1.7σ lower than the SINGS measurement (0.18 Jy). Among 15 independent measurements, a single discrepancy at the 1–2σ level is acceptable agreement. NGC 4395 is arguably a different case, because the photometry is discrepant at the 3σ level. This galaxy is unusually extended with a particularly uneven surface-brightness profile. The failure of the curve of growth to converge on a single level strongly suggested that the MIPS photometry for NGC 4395 was biased low. For this single object the Dale et al. (2009) measurement was therefore adopted in preference to our own measurement.
3.5. Far-Infrared Photometry from Planck

Planck (Ade et al. 2011a) is a space-based mission now carrying out an all-sky survey in six bands from 25–1000 GHz with a spatial resolution that progresses from ~30′ to 5′, depending on the band. Although its main mission is to measure spatial anisotropies in the cosmic microwave background, in the course of its repeated surveys of the sky it has detected thousands of foreground sources. More than 1700 detections resulting from the first pass through the sky are tabulated in the Planck Early Release Compact Source Catalog (Ade et al. 2011b). Because the SFRS galaxies are bright, a significant number are detected by Planck: 176, 78, and 28 are detected by Planck’s High-Frequency Instrument (Lamarre et al. 2010) at 350, 550, and 850 μm, respectively. This far-infrared photometry provides new and valuable constraints on the cold dust content of the detected SFRS galaxies, e.g., Ade et al. (2011c) found evidence for cold (T < 20 K) dust in their analysis of combined IRAS and Planck SEDs. The relevant photometry is presented in Table 7. The SFRS detection fraction will undoubtedly increase as Planck accumulates more complete passes over the sky and reaches correspondingly fainter flux limits.

3.6. Visible and Near-Infrared Observations

The visible photometry was taken from the Data Release 7 of the SDSS (Abazajian et al. 2009). The SDSS consists of an imaging survey of π steradians, mainly in the northern sky, in five passbands: u, g, r, i, and z. The imaging was done in drift-scan mode, and the data were processed using the photometric pipeline PHOTO (Lupton et al. 2001), specially written for SDSS. All SFRS galaxies have photometry available in the five SDSS bands, although in six cases the cataloged values greatly underestimate the true values, because they pertain only to the galaxy nuclei instead of the entire galaxy. We used the

TABLE 6

| GALAXIES IN COMMON WITH OTHER SURVEYS |
|--------------------------------------|
| Spitzer Infrared Nearby Galaxy Survey (SINGS) |
| NGC 3049  NGC 3265  NGC 5474 |
| NGC 3190  NGC 3773 |
| Local Volume Legacy Survey (LVLS) |
| NGC 2500  NGC 4020  NGC 5474 |
| NGC 2557  NGC 4244  NGC 5585 |
| NGC 2552  NGC 4395 |
| NGC 3274  NGC 5204 |
| Herschel Reference Survey (HR) |
| NGC 3245  NGC 4237  NGC 4548 |
| NGC 3338  NGC 4294  NGC 4592 |
| NGC 3370  NGC 4396  NGC 4607 |
| NGC 3430  NGC 4412  NGC 4630 |
| NGC 3659  NGC 4420  NGC 4689 |
| NGC 3666  NGC 4424  NGC 4688 |
| NGC 3686  NGC 4435  NGC 4701 |
| NGC 3729  NGC 4438  NGC 4747 |
| NGC 4116  NGC 4470  UGC 8041 |
| NGC 4178  NGC 4491  NGC 5014 |
| NGC 4207  NGC 4519  NGC 5303 |

Table 6 is published in its entirety in the electronic edition of the PASP. A portion is shown here for guidance regarding its form and content.

TABLE 7

| FAR-INFRARED PHOTOMETRY FOR SFRS GALAXIES |
|-------------------------------------------|
| SFRS | Name | L[TIR] (L⊙) | MIPS F(24) | IRAS F(60) | IRAS F(100) | Planck F(350) | Planck F(550) | Planck F(850) |
|------|------|-------------|------------|------------|------------|-------------|-------------|-------------|
| 1    | IC 486 | 10.90       | 0.44       | 0.99       | >1.51      | ...         | ...         | ...         |
| 2    | IC 2217 | 10.74       | >0.32      | 2.46       | 4.81       | ...         | ...         | ...         |
| 3    | NGC 2500 | 9.34        | 0.22       | 2.81       | 5.75       | 3.02±0.14   | ...         | ...         |
| 4    | NGC 2512 | 10.88       | 0.66       | 3.80       | 7.31       | ...         | ...         | ...         |
| 5    | MCG 6-18-009 | 11.25      | >0.27      | 1.65       | 3.09       | ...         | ...         | ...         |
| 6    | MK 1212 | 11.35       | >0.33      | 1.87       | 3.36       | ...         | ...         | ...         |
| 7    | IRAS 08072+1847 | 10.72       | 0.74       | 2.79       | 3.08       | ...         | ...         | ...         |
| 8    | NGC 2532 | 11.09       | 0.63       | 3.61       | 10.34      | 4.02±0.21   | 1.43±0.08   | ...         |
| 9    | UGC 4261 | 10.65       | >0.35      | 1.22       | 1.56       | ...         | ...         | ...         |
| 10   | NGC 2535 | 10.62       | 0.28       | 2.13       | 5.97       | ...         | ...         | ...         |

a The MIPS 24 μm photometry has been aperture-corrected using the correction factors listed in Table 8. The uncertainties in total 24 μm flux densities are dominated by the uncertainty in the absolute calibration, which is estimated as 4–8% according to the MIPS Instrument Handbook, version 2. Where upper limits are given, the photometry is from IRAS with quality flag = 1. Table 7 is published in its entirety in the electronic edition of the PASP. A portion is shown here for guidance regarding its form and content.

b IRAS flux density (MIPS not available). Typical uncertainties are 10–20%.
TABLE 8
SPITZER/MIPS APERTURE CORRECTION FACTORS FOR SFRS GALAXIES

| SFRS Name | Factor |
|-----------|--------|
| NGC 2623  | 1.01   |
| NGC 2719  | 1.01   |
| IRAS 08572+3915 | 1.04 |
| NGC 2854  | 1.05   |
| MCG 8-18-013 | 1.05 |
| NGC 3049  | 1.01   |
| UGC 5644  | 1.07   |
| NGC 3265  | 1.03   |
| UGC 5720  | 1.03   |
| NGC 3413  | 1.07   |
| CGCG 95-055 | 1.08 |
| IRAS 10565+2448 | 1.05 |
| MCG 7-23-019 | 1.07 |
| IRAS 11069+2711 | 1.02 |
| IC 676    | 1.06   |
| IRAS 11102+3026 | 1.08 |
| IC 2637   | 1.08   |
| 7ZW 384   | 1.06   |

NOTE.—MIPS 24 μm aperture correction factors based on Version 2 of the MIPS Instrument Handbook, page 94. These factors have been applied to the photometry presented in Table 7. When not given, the correction factor was taken to be unity. Table 8 is published in its entirety in the electronic edition of the PASP. A portion is shown here for guidance regarding its form and content.

Petrosian magnitudes as the best measure of the total flux in the five SDSS bands (Blanton et al. 2001). The Petrosian magnitudes were calculated using the aperture set by the “Petrosian radius” in the r band, thus providing consistent measurements. SDSS Petrosian magnitudes should recover all the flux for an exponential galaxy profile independent of the axis ratio (Blanton et al. 2001) and about 80% of the flux for a de Vaucouleurs profile.

SDSS also acquired nuclear spectra for 210 SFRS galaxies. The spectra were obtained using two fiber-fed double spectrographs covering a wavelength range of 3800–9200 Å. The resolution Δλ/Δλ varies between 1850 and 2200. The SDSS fibers have a diameter of 3″.

Near-infrared photometry was taken from the 2MASS extended source catalog. Although isophotal magnitudes had been used for the initial SFRS sample selection, total magnitudes were extracted from the 2MASS database for greater consistency with the global photometry measured in the other bands. The 2MASS extrapolated total magnitudes are typically ~0.3 mag brighter than isophotal magnitudes. Typical measurement uncertainties are given as 0.03, 0.04, and 0.05 mag at J, H, and Ks, respectively. Section 4.3.2 discusses the systematic biases in the 2MASS photometry.

The SDSS and 2MASS photometry is presented in Table 9.

3.7. GALEX Photometry in the Near- and Far-Ultraviolet Bands

GALEX (Martin et al. 2005) is an astronomical satellite with sensitive wide-field ultraviolet imaging capability in two bands, the FUV (1350–1750 Å) and NUV (1750–2800 Å). The GALEX archive (release GR6) contains scientifically usable imaging (covering the full extent of our sources and therefore capable of yielding global flux measurements) in at least one of the GALEX bands for 332/369 SFRS galaxies, or 90% of the sample. The fraction observed by GALEX in the NUV will increase as the survey portion of the mission continues, although FUV imaging is no longer possible.

Almost three-quarters of these imaging data in both wavebands were taken as part of GALEX’s primary surveys—the all-sky survey (AIS) with an effective exposure time of ~0.1 ks and the relatively deep nearby galaxy survey (NGS) with an effective exposure time of ~1.5 ks. With a resolution of 4″–6″, GALEX images have lower spatial resolution than Spitzer/IRAC. However, since almost one-third of the SFRS galaxies lie less than 40 Mpc away, together with a 1.25″ GALEX field of view, the moderate GALEX spatial resolution nonetheless allows for robust measures of spatially integrated fluxes and color that are comparable with data at other wavelengths. The GALEX observations and an analysis of the UV properties of the SFRS galaxies are described by S. Mahajan et al. (2012, in preparation; hereafter Paper II).

3.8. Hα Imaging from the National Astronomical Observatory of China

In the spring of both 2008 and 2009, Hα imaging was acquired for SFRS sample galaxies from the NAOC 2.16 m telescope in Xinlong, Hebei Province, China. The Beijing Faint Object Spectrograph and Camera (BFOSC) was used to obtain on-source integrations lasting between 1800 and 3600 s for each galaxy observed. The choice of exposure time was made based on prevailing conditions; longer exposures were used during bright-sky time or for relatively faint targets. The 10″ × 10.5″ BFOSC field of view illuminates a single CCD with 2048×2080 pixels. Each pixel subtends roughly 0.3″, well below the typical seeing during our campaign (20″–2.5″). This spatial resolution is reasonably well matched to the FWHM intrinsic to IRAC (1.66″–1.98″). The BFOSC is equipped with a suite of 11 narrow Hα filters centered at wavelengths ranging from 6563 Å to 7060 Å at 50 Å intervals. The filter bandpasses are 70 Å wide. In the two observing campaigns carried out to date, a total of 105 SFRS galaxies were observed through one of these narrow-band Hα filters, with the specific filter being chosen to cover the Hα + [N ii] complex at the target’s redshift. Observations were also made of each galaxy through the standard Johnson R-band.

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20 See http://galexgi.gsfc.nasa.gov/docs/galex/Documents/ERO_data_description_2.htm.
filter, but with shorter exposure times (400–600 s) in order to measure the continuum flux.

The BFOSC data were reduced in the usual way. The lowest 32 rows of pixels were used for overscan correction. Standard IRAF tasks were used to subtract bias frames, construct and apply flat fields, to co-add frames while simultaneously correcting for cosmic rays and known bad pixels using outlier rejection, and to photometer each of the 105 observed sources in both H$\alpha$ and $R$. This work was carried out at the Chinese Academy of Sciences in Beijing. The quality of the final H$\alpha$ mosaics is indicated by Figure 6, which shows the outcome for UGC 8058, which is a typical case.

Figure 7 shows the relationship between the SFRs derived independently in H$\alpha$ and the far-infrared for the 40 SFRS galaxies fully processed so far. The SFR estimates were made following the methods applied by Kewley et al. (2002) to 81 “pure” starburst galaxies in the Nearby Field Galaxy Survey (hereafter NFGS). Specifically, we estimated the H$\alpha$-based SFR as SFR(H$\alpha$) = 7.9 × 10^{-42}L(H$\alpha$) and the far-infrared SFR as SFR(FIR) = 4.5 × 10^{-42}L(TIR) (Kennicutt 1998), where we have estimated the total far-infrared luminosity $L(TIR)$ as described in § 4.2.

Kewley et al. (2002) demonstrated that for 81 NFGS galaxies selected at visible wavelengths to cover a range of luminosities, SFR(H$\alpha$) is discrepant with SFR(IR) in the sense that SFR(H$\alpha$) tends to be significantly lower than SFR(IR). The discrepancy was measured to be a factor of nearly 3 (2.7 ± 0.3) and was shown to increase with increasing SFR. Both of those findings also apply to the SFRS galaxies shown in Figure 7, but more so: as shown subsequently, the infrared-selected SFRS galaxies require a significantly larger mean reddening correction than did the NFGS galaxies to bring the H$\alpha$ and far-infrared SFR indicators into agreement.

Most of the galaxies shown in Figure 7 have GALEX photometry available. For all such objects an extinction correction $A_{H\alpha}$ appropriate for H$\alpha$ was estimated based on the NUV photometry in Paper II, which implemented the empirical IRX-based prescription following equation (1) of Buat et al. (2005). That estimate for $A_{NUV}$ was then converted into an H$\alpha$ extinction estimate $A_{H\alpha}$ assuming a Calzetti (2001) dust law: $A_{H\alpha} = 0.79(A_{V} + A_{MW}) = 0.79(0.77 \times A_{NUV} + A_{MW})$, where $A_{MW}$ is the foreground extinction due to the Milky Way. Following this prescription the mean $A_{H\alpha}$ was found to be 1.7 mag, corresponding to attenuation by a factor of 4.7. This likely reflects the fact that our sample is (primarily) infrared-selected, unlike the NFGS. A similar effect is seen for ultraviolet selection (Buat et al. 2005). Intriguingly, four galaxies (out of 34 with extinction estimates) lie more than an order of magnitude from the line of equality, even when extinction-corrected. This suggests that for a minority of infrared-selected galaxies, either the intrinsic H$\alpha$ emission does not accurately reflect the “true” SFR, or the standard extinction corrections may not work well for such objects, as has been found for galaxies with large SFR(IR)/SFR(UV) ratios (Wuyts et al. 2011). The reason will remain unclear, pending acquisition and analysis of H$\alpha$ emission-line intensities for the full SFRS. This will be possible as soon as the NAOC H$\alpha$ imaging campaign is completed. In the summer of 2010 the BFOSC was upgraded with a new CCD having lower read noise. A subset of our team (led by H. Wu) has been awarded time in the 2011 observing season to complete the imaging campaign for the roughly two-thirds of the SFRS for which H$\alpha$ imaging has not yet been obtained.

We have also begun a long-slit spectroscopic campaign (§ 4.3.1) to obtain dust reddening estimates for all SFRS galaxies via the Balmer decrement and to thereby address the possibility that $A_{NUV}$ may not be the most reliable extinction indicator at visible wavelengths (Bell 2003). A detailed analysis of the global H$\alpha$ emission-line flux measurements for the full sample will be presented in a forthcoming article (Y.-N. Zhu et al. 2011, in preparation).

4. DISCUSSION

4.1. SFRS Compared to Other Nearby Galaxy Samples

A number of recent survey programs have documented important aspects of star formation phenomenology. In addition to the studies mentioned previously (SINGS, LVLS, and MESS), there are the NFGS (Kewley et al. 2002) and the Herschel Reference Survey (Boselli et al. 2010). The SFRS differs from these other efforts in significant ways.

SINGS is fundamentally different from SFRS because SINGS is comprised of a relatively small number (75) of very nearby extended objects. SINGS therefore allows spatially resolved measurements in numerous wavebands (Dale et al. 2007), but the SINGS galaxies sample primarily the low-luminosity end of the far-infrared luminosity function. This means that SINGS is not representative of star formation in general. Only five SINGS galaxies are present in the SFRS (Table 6).
The distinction between the LVLS and SFRS is less obvious because of the two-tiered optical/volume-limited nature of the selection used for the LVLS. The fundamental difference is that the LVLS is mostly comprised of low-luminosity dwarf galaxies, well below the break in the far-infrared luminosity function at $L_{\text{FIR}} = 10^{10.25} L_\odot$. Even so, the overlap between the LVLS and the SFRS samples is surprisingly small—only 11 objects (Table 6).

The MESS sample relies on a SDSS H$\alpha$ emission-line-strength selection criterion to define a sample of 138 IR-luminous galaxies that are very rapidly forming stars. MESS galaxy SFRs range from 11 to 61 $M_\odot$ yr$^{-1}$. Because it uses a single selection criterion, MESS does not control for ISM temperature or stellar mass and so cannot be representative of even high-intensity star formation in general. Furthermore, H$\alpha$ fluxes

![Graph showing comparison of far-infrared and H$\alpha$ SFRs for an unrepresentative subset of the SFRS, following Fig. 1 of Kewley et al. (2002). Circles denote galaxies when SFR (H$\alpha$) is not correct for extinction due to dust. Solid triangles show the revised (larger) SFR(H$\alpha$) estimates that result when the extinction estimates from Paper II are applied. The solid line indicates where the points would fall if the Kennicutt (1998) relations were in agreement. The dashed line indicates the Kewley et al. (2002) fit to the corresponding data for the NFGS, not extinction-corrected.]
TABLE 9

| SFRS | u | g | r | i | z | J | 2MASS | H | Ks |
|------|---|---|---|---|---|---|-------|---|-----|
| 1    | 15.838±0.015 | 14.095±0.002 | 13.370±0.004 | 13.099±0.002 | 12.807±0.005 | 12.38±0.02 | 12.18±0.02 | 12.34±0.03 |
| 2    | 15.387±0.025 | 14.100±0.010 | 13.683±0.018 | 13.407±0.023 | 13.289±0.023 | 12.70±0.02 | 12.54±0.03 | 12.74±0.04 |
| 3    | 15.796±0.049 | 13.236±0.006 | 12.769±0.006 | 12.985±0.017 | 13.718±0.032 | 11.66±0.02 | 11.52±0.03 | 11.12±0.07 |
| 4    | 15.413±0.018 | 13.567±0.004 | 12.873±0.003 | 12.531±0.003 | 12.321±0.005 | 11.73±0.02 | 11.47±0.03 | 11.66±0.03 |
| 5    | 15.966±0.019 | 14.575±0.003 | 13.885±0.004 | 13.486±0.003 | 13.239±0.005 | 12.67±0.03 | 12.49±0.03 | 12.60±0.04 |
| 6    | 16.531±0.015 | 15.256±0.027 | 14.641±0.033 | 14.277±0.025 | 14.062±0.025 | 13.46±0.03 | 13.35±0.03 | 13.43±0.04 |
| 7    | 18.184±0.043 | 16.437±0.005 | 15.549±0.003 | 15.117±0.004 | 14.790±0.008 | 14.14±0.04 | 14.04±0.06 | 14.03±0.06 |
| 8    | 15.073±0.025 | 13.432±0.007 | 12.865±0.004 | 12.500±0.005 | 12.571±0.009 | 11.54±0.02 | 11.36±0.03 | 11.45±0.04 |
| 9    | 16.282±0.034 | 15.343±0.022 | 15.027±0.025 | 14.781±0.022 | 14.631±0.022 | 13.76±0.04 | 13.65±0.06 | 13.87±0.07 |
| 10   | 15.622±0.045 | 13.769±0.019 | 13.273±0.017 | 13.002±0.018 | 13.477±0.053 | 11.86±0.03 | 11.70±0.03 | 11.96±0.04 |

**Note:** SDSS DR7 Petrosian magnitudes and 2MASS total magnitudes for the SFRS galaxies. Where the SDSS photometry is unreliable due to shedding, no values are given. Uncertainties are taken from the 2MASS extended source catalog and reflect measurement errors only. Issues pertaining to systematic errors in the 2MASS data are discussed in § 4.3.2. Uncertainties are taken from the 2MASS extended source catalog and reflect measurement errors only. Issues pertaining to systematic errors in the 2MASS data are discussed in § 4.3.2. All magnitudes are expressed on the AB system. Table 9 is published in its entirety in the electronic edition of the PASP. A portion is shown here for guidance regarding its form and content.

The Herschel Reference Survey (Boselli et al. 2010) contains nearly as many galaxies as the SFRS (323 vs. 369) but does not capture the full range of star-forming behavior, because it is explicitly oriented toward high-density environments. Consequently, it contains a much larger fraction of elliptical galaxies (LIRGs, galaxies with $L > 10^{11} L_\odot$). The AGN fraction is significantly higher for high-luminosity galaxies. Indeed, it is a feature of the GOALS sample that it contains the full range of optical spectral types, including many dominant AGNs, as well as major-merger systems. While SFRS galaxies are by no means entirely free of AGN contributions (§ 4.2), they are a relatively minor contributor, and the fact that the SFRS spans the full range of both far-infrared color and luminosity simultaneously makes the SFRS less biased in characterizing star formation than GOALS.

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The most sensitive method for identifying AGNs is probably the BPT diagram (Baldwin, Phillips, & Terlevich 1981; Kewley et al. 2001), an emission-line intensity ratio diagnostic that identifies AGNs via species that trace high-excitation conditions. Because it relies on visible lines, the BPT method will not find highly obscured AGNs, but it can identify so-called transition sources in which the contributions of star-forming activity and a central AGN are comparable. Figure 8 shows this method applied to a subsample of SFRS galaxies, i.e., all 165 objects for which the set of four necessary emission-line intensities have been measured by SDSS. Of these 165 sources, 30 are identified as AGNs according to the Kewley et al. (2001) line-ratio criterion. Another 45 objects were observed spectroscopically by SDSS but do not exhibit the emission lines linked with AGNs.
These 45 galaxies are unlikely to host strong AGNs. Thus, the AGN fraction identified by the BPT diagram is roughly $1/7$.

Figure 9 shows the IRAC color-color plot first used by Stern et al. (2005) to empirically discriminate galaxies with infrared SEDs dominated by active nuclei from those dominated by star formation. It identifies 19 of the 369 SFRS galaxies ($\sim 5\%$) as AGNs according to the empirical Stern et al. criteria. For these sources, emission from an active nucleus is a significant, or even dominant, contributor to the mid-IR SED. Moreover, some of the 18 galaxies outside the Stern et al. “wedge” but having redder $[3.6]–[4.5]$ colors than the main group probably also contain AGNs. The most extreme such outliers are UGC 9560 ($=\text{HIZw}70$) and UGC 5613, which have very different luminosities but are both strongly star-forming (Oconnell et al. 1978; Poggianti & Wu 2000). An outlier with much smaller $[5.8]–[8.0]$ color is IC 486 ($=\text{UGC}4155$), which is a Seyfert 1 galaxy (Bonatto & Pastoriza 1997). The outliers are thus a mixed group.

A third method to identify AGNs is based on the 25 $\mu$m (or 24 $\mu$m) flux density (Sanders et al. 1988): specifically, $F_{25}/F_{60} > 0.2$. Despite their large 60 $\mu$m fluxes, many SFRS galaxies are not reliably detected by IRAS in the 25 $\mu$m band. We therefore used MIPS 24 $\mu$m flux measurements, where available, to form the flux density ratio $F_{24}/F_{60}$, because MIPS 24 $\mu$m fluxes track IRAS 25 $\mu$m fluxes very closely, on average (Dale et al. 2009). The distribution of the 313 SFRS galaxies with such data is shown in Figure 10. The distribution is qualitatively similar to that of the Revised Bright Galaxy Survey (Sanders et al. 2003). Only a small minority of the sources (22/313, or about 7$\%$) lie at $F_{24}/F_{60} > 0.2$, which Sanders et al. (1988) identify as potentially arising from a significant contribution coming from an active nucleus. Most of the galaxies identified as AGNs in this way are also identified by one of the other two methods (Table 10).

No matter how they are identified, the AGNs in the SFRS do not have a noticeably different $F_{60}/F_{100}$ ratio from that of the non-AGNs. Figure 11 is a far-infrared color-color diagram.
showing the 313 SFRS galaxies with either IRAS 25 μm or MIPS 24 μm flux measurements, including the 22 objects identified as AGNs by the Sanders et al. (1988) criterion. This suggests that for most galaxies in the sample, AGNs contribute relatively little of the far-infrared light. Conversely, the far-infrared emission is an uncontaminated tracer of star formation. This result is consistent with Mullaney et al. (2011), who found that the SEDs of AGNs drop rapidly at wavelengths longer than 40 μm. It is also consistent with the outcome of Netzer et al. (2007), who found that the far-infrared properties of QSOs is almost entirely due to star formation. This view is confirmed by an examination of the FIR-radio correlation (e.g., Condon et al. 1992; Helou et al. 1985) and the fact that the nonthermal radio emission and the thermal far-infrared emission correlate tightly over at least 4 orders of magnitude in far-infrared luminosity. Figure 12 shows the FIR-radio correlation constructed using total infrared flux estimates

\[ F(\text{TIR}) = 2.403v_f(25 \, \mu m) - 0.2454v_f(60 \, \mu m) + 1.347v_f(100 \, \mu m) \]

in the usual way (Dale & Helou 2002), except that we employ MIPS 24 μm fluxes where available instead of the less precise IRAS 25 μm fluxes. The solid line in the lower panel of Figure 12 is an unweighted least-squares fit to all SFRS galaxies (except 3C 273 and OJ 287, which have extremely high radio continuum luminosities arising from dominant central AGNs). If all galaxies flagged as hosting an AGN by at least one of the preceding three criteria are excluded from the fit, the slope changes very little (to 1.09 from 1.086) and the scatter about the fit does likewise (decreasing to 0.29 dex from 0.31 dex). Thus, if the two dominant AGNs are excluded from the fit, the FIR-radio correlation is not significantly affected by the presence of AGNs in 52/367 (roughly one of every seven galaxies). This underlines the utility of the thermal far-IR as an optimal probe of SFR.

The FIR-radio correlation obtained for the SFRS sample is higher than unity, but nonetheless shallower than that reported by Devereux & Eales (1989)—roughly 1.1 instead of 1.28. This could be due to selection effects: Devereux & Eales (1989) employed an optical selection that sampled luminosities only up to \( \sim 10^{11} L_\odot \). Yun et al. (2001) found a slope much closer to unity for their sample of bright infrared-selected galaxies—a result that was later confirmed by Bell (2003).

In summary, the three different AGN detection criteria identify three different AGN subsamples comprising from 5 to 10% of the SFRS study sample. There is only modest overlap among the three criteria (Table 10), which, in hindsight, validates the use of multiple tracers of AGN activity. AGNs are more prevalent at higher luminosities, despite the fact that they contribute little to the total far-infrared luminosities of star-forming galaxies. AGNs were detected in \(~15\%\) of the sample (52/369 galaxies) when all three detection methods were combined. Taken as a whole, these results suggest that the far-infrared selection described in § 2 has successfully yielded a sample with bolometric luminosities dominated by star formation, and there is no compelling evidence that the AGNs significantly contaminate the far-infrared SEDS.
4.3. Pending Observing Campaigns

There are several ongoing observing campaigns for which significant data have been acquired but are not yet complete. They are described in this section.

4.3.1. Long-Slit Optical Spectroscopy with FAST

Visible spectra from SDSS are available only for a fraction of the SFRS galaxies (Abazajian et al. 2009). Moreover, the SDSS spectra were obtained through fibers centered on the nuclei and so do not uniformly measure or constrain the excitation conditions within the galaxy disks. We are therefore reobserving SDSS galaxies with a long-slit spectrograph in order to (1) build a consistent set of disk and nuclear spectra with better sky subtraction, (2) take advantage of the spatial dimension to implement accurate starlight subtraction, and (3) measure rotation curves.

The observations are currently being carried out at the Fred Lawrence Whipple Observatory 1.5 m telescope at Mount Hopkins with FAST (Fabricant et al. 1998). FAST is being used with a 2″ wide slit positioned along the major axis of the galaxies. For galaxies that extend beyond the slit ends, we obtain either a second spectrum along the minor axis of the galaxy or a second spectrum at a sky position away from the galaxy. The spectra are obtained with a 600 lines mm⁻¹ grating in two tilt positions in order to cover the blue (3700–5700 Å) and the red (5500–7500 Å) parts of the spectrum with resolutions of 2.2 Å and 2.7 Å, respectively. Throughout the modest redshift range occupied by our sample, this setup covers the standard diagnostic emission lines in the optical band: [O II] λ3727; Hβ; [O III] λλ4959, 5007; [O I] λ6300; [N II] λλ6548, 6583; Hα; and [S II] λλ6716, 6731. The exposure time for each nucleus has been chosen in order to achieve a S/N of at least 40 at the Hα line, based on the available photometry from SDSS.

4.3.2. Peters Automated IR Imaging Telescope Near-IR Imaging

As described in § 2, 2MASS K₂₀ magnitudes were used as a stellar mass proxy to define the SFRS sample because of the well-characterized and uniform data quality and the full-sky
coverage. However, a campaign has been initiated to replace the 2MASS photometry with significantly deeper near-IR observations in the same three bands, because the 2MASS observations are somewhat shallow. They are not optimal for detecting the faint outskirts of even nearby galaxies, where relatively high sky backgrounds obscure the outermost, low surface brightness features. This leads to a systematic downward bias in the 2MASS photometry that is not fully characterized at present. Kirby et al. (2008) found the discrepancy to be highly variable, ranging up to 2.5 mag in extreme cases. Karachentsev et al. (2002) found that the global 2MASS extended source catalog photometry implied unphysical colors in some cases.

Deeper near-infrared observations will offer several advantages. They will greatly reduce both the measurement uncertainties and the bias in the existing photometry. They will better characterize the true extents and morphologies of the SFRS galaxies. They will also be a much better match to the existing Spitzer/IRAC data, which benefit from the very low backgrounds available from space. This will facilitate accurate K-corrections and stellar mass estimates for subsequent articles, as well as reliable bulge/disk decompositions (because a greater extent and dynamic range in disk surface brightness is sampled).

Motivated by these considerations, the SFRS team sought and was awarded time for near-infrared imaging in 2009, 2010, and 2011 with Peters Automated IR Imaging Telescope (PAIRITEL; Bloom et al. 2006), the same telescope originally used for 2MASS. Useful $JHK_s$ imaging (i.e., flattened, background-subtracted, and astrometrically correct mosaics encompassing all the emission from the targets) has been acquired for 259 SFRS galaxies to date. Exposure times were typically 20 min on source, but in some cases the exposures were shorter because of circumstances related to weather or instrumentation. The PAIRITEL observations typically reach 2 mag deeper than 2MASS. Based on a preliminary analysis of the $K_s$ imaging data reduced to date, it appears that the total magnitudes listed in Table 9 underestimate the galaxies’ true output by about 0.3 mag (P. Bonfini 2011, private communication). The goal is to complete the deep $JHK_s$ coverage in the 2012a observing semester, after which the imaging and photometry will be presented together with a structural decomposition of the SFRS galaxies (P. Bonfini et al. 2012, in preparation).

### 4.3.3. Far-Infrared Detections by AKARI

AKARI is a cryogenic space-based infrared telescope facility launched in 2006. Because it uses infrared detectors with smaller pixels than used by IRAS (0.5′–0.9′; Jeong et al. 2007), AKARI offers spatial resolution superior to that of IRAS despite having a primary mirror that is only slightly larger. For example, the Far-Infrared Surveyor (FIS) point-spread functions have FWHM ranging from 40″ to 60″, depending on the band (Kawada et al. 2007). AKARI therefore offers a way to improve upon IRAS photometry and to likewise improve the fidelity of the far-IR SFRs inferred for our sample in cases of high foreground gradients arising from Galactic cirrus and/or confused IRAS sources, because AKARI has the potential to resolve out such contributions to the IRAS flux measurements.

Two all-sky surveys were carried out by the AKARI mission, covering greater than 94% of the sky more than twice (Murakami et al. 2007). The central wavelengths of the six survey bands are 9 and 18 μm with the Infrared Camera (IRC; Ishihara et al. 2010) and 65, 90, 140, and 160 μm with the FIS (Kawada et al. 2007). All SFRS galaxies were detected in both the FIS and IRC all-sky surveys, which reached detection limits of 0.21 Jy at the 80% completeness level at 18 μm and a 5σ detection limit of 0.55 Jy at 90 μm. The 90 μm band is the most sensitive of the four FIS bands and covers a bandpass very similar to the IRAS 100 μm band. A subsequent article (H. Kaneda et al. 2011, in preparation) is planned to refine the far-IR SFR estimates with the full suite of AKARI photometry.

### 5. CONCLUSION

The Star Formation Reference Survey, by virtue of its reliance on a restricted but representative far-IR selection, ensures the capability to study obscured star formation in all of its varied manifestations in the local universe. Its panchromatic resources, spanning UV to radio wavelengths and featuring 100% complete photometry in the visible to mid-infrared regimes ($ugrizJHK_s$ and four IRAC bands) provides an opportunity to quantitatively assess the degree to which far-IR emission reflects total (not just obscured) SFR. This comprehensive collection of the most widely used SFR indicators will furnish an invaluable resource for the interpretation of more distant galaxies, i.e., galaxies for which some or even nearly all such SFR metrics are inaccessible because of their relative faintness, so that a context exists in which to better understand the limited data available. Because the SFRS is fully representative of star-forming galaxies in the local universe, it is an optimal benchmark for understanding star formation in the distant cosmos.

The interplay of various star formation and AGN indicators will be explored in future articles. Paper II will examine the relationship of UV SFR indicators to those obtained in the other bands. P. Bonfini et al. (2011, in preparation) will describe the methods whereby relatively faint AGNs in the sample are identified using structural decomposition. Y.-N. Zhu et al. (2011, in preparation) will examine a suite of narrowband Hα imaging and compare the global Hα-derived SFRs with those in the other bands compiled for the SFRS. All the related photometry will be made public to facilitate investigations by others in the community.

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REFERENCES

Abazajian, K. N., et al. 2009, ApJS, 182, 543
Ade, P. A. R., Aghanim, N., Arnaud, M., et al. 2011a, preprint (arXiv:1101.2022)
———. 2011b, preprint (arXiv:1101.2041)
———. 2011c, preprint (arXiv:1101.2045)
Armus, L., et al. 2009, PASP, 121, 559
Baldwin, J. A., Phillips, M. M., & Terlevich, R. 1981, PASP, 93, 5
Bell, E. F. 2003, ApJ, 586, 794
Bertin, E., & Arnouts, S. 1996, A&AS, 117, 393
Blanton, M. R., et al. 2001, AJ, 121, 2358
Bloom, J. S., Starr, D. L., Blake, C. H., Skrutskie, M. F., & Falco, E. E. 2006, Astronomical Data Analysis Software and Systems XV, 351, 751
Bonatto, C. J., & Pastoriza, M. G. 1997, ApJ, 486, 132
Boselli, A., et al. 2010, PASP, 122, 261
Buat, V., et al. 2005, ApJ, 619, L51
———. 2010, MNRAS, 409, L1
Calzetti, D. 2001, PASP, 113, 1449
Calzetti, D., et al. 2010, ApJ, 714, 1256
Condon, J. J. 1992, ARA&A, 30, 575
Condon, J. J., Cotton, W. D., Greisen, E. W., Yin, Q. F., Perley, R. A., Taylor, G. B., & Broderick, J. J. 1998, AJ, 115, 1693
———. 2002. VizieR Online Data Catalog, 3865, 0
Dale, D. A., & Helou, G. 2002, ApJ, 576, 159
Dale, D. A., et al. 2005, ApJ, 633, 857
———. 2007, ApJ, 655, 863
———. 2009, ApJ, 703, 517
Devereux, N. A., & Eales, S. A. 1989, ApJ, 340, 708
Elbaz, D., et al. 2011, preprint (arXiv:1105.2537)
Fabricant, D., Cheimets, P., Caldwell, N., & Geary, J. 1998, PASP, 110, 79
Fazio, G. G., et al. 2004, ApJS, 154, 10
Freedman, W. L., et al. 2001, ApJ, 553, 47
Helou, G., Soifer, B. T., & Rowan-Robinson, M. 1985, ApJ, 298, L7
Hogg, D. W., Tremonti, C. A., Blanton, M. R., Finkbeiner, D. P., Padmanabhan, N., Quintero, A. D., Schlegel, D. J., & Wherry, N. 2005, ApJ, 624, 162
Hopkins, A. M., & Beacom, J. F. 2006, ApJ, 651, 142
Impey, C. D., & Neugebauer, G. 1988, AJ, 95, 307
Ishihara, D., et al. 2010, A&A, 514, A 1
Jeong, W.-S., et al. 2007, PASJ, 59, 429
Jester, S., et al. 2005, AJ, 130, 873
Karachentsev, I. D., Karachentseva, V. E., Huchtmeier, W. K., & Makarov, D. I. 2004, AJ, 127, 2031
Karachentsev, I. D., Kudrya, Y. N., Karachentseva, V. E., & Mitronova, S. N. 2006, Astrophysics, 49, 450
Karachentsev, I. D., Mitronova, S. N., Karachentseva, V. E., Kudrya, Y. N., & Jarrett, T. H. 2002, A&A, 396, 431
Kartaltepe, J. S., et al. 2010, ApJ, 709, 572
Kauffmann, G., et al. 2003, MNRAS, 346, 1055
Kawada, M., et al. 2007, PASJ, 59, S 389
Kennicutt, R. C., Jr. 1998, ARA&A, 36, 189
———. 2003, PASP, 115, 928
Kewley, L. J., Dopita, M. A., Sutherland, R. S., Heisler, C. A., & Trevena, J. 2001, ApJ, 556, 121
Kewley, L. J., Geller, M. J., Jansen, R. A., & Dopita, M. A. 2002, AJ, 124, 3135
Kewley, L. J., Groves, B., Kauffmann, G., & Heckman, T. 2006, MNRAS, 372, 961
Kim, D.-C., Veilleux, S., & Sanders, D. B. 2002, ApJS, 143, 277
Kirby, E. M., Jerjen, H., Ryder, S. D., & Driver, S. P. 2008, AJ, 136, 1866
Laag, E., Croft, S., Canalizo, G., & Lacy, M. 2010, preprint (arXiv:1010.1704)
Lada, C. J., Lombardi, M., & Alves, J. F. 2010, preprint (arXiv:1009.2985)
Lamarre, J.-M., et al. 2010, A&A, 520, A 9
Lilly, S. J., Le Fevre, O., Hammer, F., & Crampton, D. 1996, ApJ, 460, L1
Lupton, R., Gunn, J. E., Ivezić, Z., Knapp, G. R., & Kent, S. 2001, Astronomical Data Analysis Software and Systems X, 238, 269
Madden, S. C., Galliano, F., Jones, A. P., & Sauvage, M. 2006, A&A, 446, 877
Madau, P., Pozzetti, L., & Dickinson, M. 1998, ApJ, 498, 106
Martin, D. C., et al. 2005, ApJ, 619, L1
Mould, J. R., et al. 2000, ApJ, 529, 786
Mullaney, J. R., Alexander, D. M., Goulding, A. D., & Hickox, R. C. 2011, MNRAS, 414, 1082
Murakami, H., et al. 2007, PASJ, 59, S 369
Netzer, H., et al. 2007, ApJ, 666, 806
Oconnell, R. W., & Busch, M. E. 2010, ApJ, 711, 1108
Osterbrock, D. E., & Poglitsch, A. 1985, ApJ, 294, 76
Poggesi, I., & Rieke, M. J. 2007, ApJ, 655, 572
Poglitsch, A., & Rieke, M. J. 2007, ApJ, 655, 572
Rice, W., et al. 1988, ApJS, 68, 91
Rieke, G. H., & Lebofsky, M. J. 1986, ApJ, 308, 54
Sanders, D. B., Mazzarella, J. M., Kim, D.-C., Surace, J. A., & Soifer, B. T. 2003, AJ, 126, 1607
Sanders, D. B., Soifer, B. T., Elias, J. H., Neugebauer, G., & Matthews, K. 1988, ApJ, 328, L35
Saunders, W., et al. 2000, MNRAS, 317, 55
Schmidt, M. 1959, ApJ, 129, 243
Schuster, M. T., Marengo, M., & Patten, B. M. 2006, Proc. SPIE, 6270, 65
Sobral, D., et al., 2011, MNRAS, 411, 675
Stern, D., et al. 2005, ApJ, 631, 163
Takeuchi, T. T., Buat, V., Heinis, S., Giovannoli, E., Yuan, F.-T., Iglesias-Páramo, J., Murata, K. L., & Burgarella, D. 2010, A&A, 514, A 4

Tonry, J. L., Dressler, A., Blakeslee, J. P., Ajhar, E. A., Fletcher, A. B., Luppino, G. A., Metzger, M. R., & Moore, C. B. 2001, ApJ, 546, 681
Tully, R. B., & Fisher, J. R. 1977, A&A, 54, 661
Tully, R. B., Shaya, E. J., Karachentsev, I. D., Courtois, H. M., Kocevski, D. D., Rizzi, L., & Peel, A. 2008, ApJ, 676, 184
Wu, H., Cao, C., Hao, C.-N., Liu, F.-S., Wang, J.-L., Xia, X.-Y., Deng, Z.-G., & Young, C. K.-S. 2005, ApJ, 632, L79
Wuyts, S., et al. 2011, preprint (arXiv:1106.5502)
Yun, M. S., Reddy, N. A., & Condon, J. J. 2001, ApJ, 554, 803