SPITZER PHOTOMETRY OF ~1 MILLION STARS IN M31 AND 15 OTHER GALAXIES*

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Received 2016 September 6; revised 2016 November 8; accepted 2016 November 16; published 2017 January 9

ABSTRACT

We present Spitzer IRAC 3.6–8 μm and Multiband Imaging Photometer 24 μm point-source catalogs for M31 and 15 other mostly large, star-forming galaxies at distances ~3.5–14 Mpc, including M51, M83, M101, and NGC 6946. These catalogs contain ~1 million sources including ~859,000 in M31 and ~116,000 in the other galaxies. They were created following the procedures described in Khan et al. through a combination of point-spread function (PSF) fitting and aperture photometry. These data products constitute a resource to improve our understanding of the IR-bright (3.6–24 μm) point-source populations in crowded extragalactic stellar fields and to plan observations with the James Webb Space Telescope.

Key words: catalogs – surveys – techniques: photometric

Supporting material: machine-readable tables

1 INTRODUCTION

The Infrared Array Camera (IRAC; Fazio et al. 2004) and the Multiband Imaging Photometer (MIPS; Rieke et al. 2004) instruments aboard the Spitzer Space Telescope (Spitzer; Werner et al. 2004) have collected a vast archive of mid-infrared (mid-IR) imaging data. This resource makes it feasible to identify and characterize mid-IR luminous stars in the crowded and dusty disks of large star-forming galaxies despite difficulties due to IR emission from interstellar dust, blending, and background contamination. In Khan et al. (2010) we published the first-ever mid-IR point-source catalogs for galaxies significantly beyond the Local Group (≥1.9 Mpc). In Khan et al. (2015c) we used archival IRAC and MIPS images of seven galaxies at ~1–4 Mpc to catalog ~300,000 stars, which were used to identify an emerging class of high-mass (>25 M⊙) post-main-sequence stars (Khan et al. 2015b). Here we present photometric inventories of the mid-IR point sources in the IRAC 3.6, 4.5, 5.8, and 8 μm as well as MIPS 24 μm images of the Andromeda galaxy (M31) and 15 other nearby (≤14 Mpc) galaxies beyond the Local Group. Our key motivation here is to facilitate targeted follow-up of individual objects and observation planning of IR-bright extragalactic stellar populations in the upcoming era of the James Webb Space Telescope (JWST; Gardner et al. 2006) and the Wide-Field InfraRed Survey Telescope (WFIRST; Spergel et al. 2015).

As the nearest major spiral galaxy to the Milky Way, the Andromeda galaxy (M31) has been extensively observed over the years from both ground- and space-based observatories (e.g., Baade 1944; de Vaucouleurs 1958; Massey et al. 2006; Johnson et al. 2012). The Panchromatic Hubble Andromeda Treasury (Dalcanton et al. 2012) mapped roughly a third of M31’s star-forming disk, using six filters covering the ultraviolet through the near-infrared (near-IR) to produce the most detailed picture of resolved extragalactic stellar populations in a galaxy. However, public availability of mid-IR stellar catalogs of this galaxy is very limited. Mould et al. (2008) performed mid-IR photometry of point sources on Spitzer IRAC and MIPS images of M31. However, although their paper shows mid-IR color–magnitude diagrams (CMDs) containing seemingly many hundred thousand sources, they published only a small fraction (~500–900 sources at various bands) of the catalog, consisting of the brightest sources in the field. In this paper, we present an extensive mid-IR point-source catalog of M31 consisting of ~859,000 sources, covering the entirety of M31’s disk including the accompanying M32 and M110 galaxies.

When selecting the 15 other galaxies, we concentrated on those with higher recent star formation rate (SFR), as these would have large numbers of short-lived, massive, evolved mid-IR-bright stars, and we cataloged ~116,000 stars in these galaxies. These catalogs include the highly star-forming galaxies M83, NGC 6946, M101, and M51 (M51a and M51b), which enabled the first-ever identification of extragalactic candidate analogs of the Galactic stellar behemoth η Carinae (Khan et al. 2015a). We selected these 15 galaxies to span a range of distances and SFRs (~3.5–14 Mpc and ≤0.1–~1 M⊙/year; see Table 1), and currently there are no public mid-IR stellar catalogs for 13 of these galaxies. Williams et al. (2015) published a mid-IR-bright source catalog of M83 including Spitzer 3.6 and 4.5 μm band measurements for <4000 objects, while the M83 catalog presented here contains Spitzer 3.6, 4.5, 5.8, 8, and 24 μm band measurements for ~23,000 sources. Likewise, Khan et al. (2010) reported two Spitzer band measurements of <6000 objects in NGC 6946 whereas the catalog for this galaxy presented here contains five Spitzer band measurements for ~16,000 sources.

For M31, we used the IRAC 3.6, 4.5, 5.8, and 8 μm mosaics produced by Mould et al. (2008) and the MIPS 24 μm mosaic produced by Gordon et al. (2006). For the other galaxies, we used the IRAC and MIPS mosaics produced by the Spitzer Infrared Nearby Galaxies Survey (SINGS; Kennicutt et al. 2003) and the Local Volume Legacy Survey (LVL; Dale et al. 2009). We utilize the full mosaics available for each galaxy. The M31 mosaics (covering ~4.2 square degrees) are constructed from many individual

* Based on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA.

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exposures whereas each of the more distant galaxy images from the LVL and SINGS archives are usually combinations of two slightly offset images. We do not take advantage of the uncertainty maps and assume mean noise properties, since in our experience the dominant source of flux uncertainty in this context is related to crowding, which varies significantly across the face of the target galaxies. In what follows, we summarize our methodology (Section 2; see Khan et al. 2015c for details), and discuss the properties of the catalogs and color–magnitude distributions (Section 3).

2. PHOTOMETRY

We obtained the photometric measurements at various wavelengths and combined them to construct the point-source catalogs following the procedures established in Khan et al. (2015c). We implement a strict detection criteria by requiring $>3\sigma$ detection of all cataloged sources at 3.6 and 4.5 $\mu$m. We then complement those measurements at the 5.8 $\mu$m, 8.0 $\mu$m, and 24 $\mu$m bands through a combination of point-spread-function-fitting (PSF-fitting) photometry and aperture photometry. For all objects that do not have a $>3\sigma$ detection at these three longer wavelengths, we estimate their $3\sigma$ flux upper limits in those bands.

First we select all sources detected through PSF-fitting photometry at $>3\sigma$ in both the 3.6 and 4.5 $\mu$m images within a 1 pixel matching radius as point sources. Next, we search for $>3\sigma$ detections of these point sources in the 5.8 and 8.0 $\mu$m images within the same matching radius. If no counterpart is found, we attempt to measure the flux at the location of the 3.6/4.5 $\mu$m point source through PSF fitting, and failing that, through aperture photometry. For the MIPS 24 $\mu$m images, we only use aperture photometry due to the much lower resolution and larger PSF size compared to the IRAC images. Finally, for all objects that do not have a $>3\sigma$ detection at 5.8, 8.0, and 24 $\mu$m, we estimate the $3\sigma$ flux upper limits. The fluxes and upper limits are transformed to Vega-calibrated magnitudes using the flux zero-points and aperture corrections provided in the Spitzer Data Analysis Cookbook.

We used the DAOPHOT/ALLSTAR PSF-fitting and photometry package (Stetson 1992) to construct the PSFs, to identify the $>3\sigma$ sources, and to measure their flux at all four IRAC bands. We used the IRAF ApHOT/PHOT tool to perform aperture photometry for all IRAC bands and the MIPS 24 $\mu$m band. For the four IRAC bands, we use an extraction aperture of 2$''$, a local background annulus of 2$''$4–7$''$, and aperture corrections of 1.213, 1.234, 1.379, and 1.584, respectively. For the MIPS 24 $\mu$m band, we use an extraction aperture of 3$''$5, a local background annulus of 6$''$–8$''$, and an aperture correction of 2.78. We estimate the local background using a 2$''$ outlier rejection procedure in order to exclude sources located in the local sky annulus and correct for the excluded pixels assuming a Gaussian background distribution. We determine the $3\sigma$ flux upper limit for each aperture location using the local background estimate.

We present the results of our mid-IR photometric survey following the same format as the catalogs published in Khan et al. (2015c). Tables 2–17 list the coordinates (J2000.0; R.A.) and fluxes for the PSFs.

### Table 1

| Galaxy | Galactic coor. | Reference | Data Source | SFR* | Number of Sources |
|--------|----------------|-----------|-------------|------|------------------|
| M31    | 121.174        | −21.573   | 0.78        | Stanek & Garnavich (1998) | Noteb | 0.7c           | 859,165 |
| NGC 3077 | 141.899       | 41.659    | 3.7         | Jacobs et al. (2009) | LVLd   | 0.076         | 3794   |
| NGC 1313 | 283.359       | −44.643   | 4.4         | Jacobs et al. (2009) | LVLd   | 0.316         | 6972   |
| NGC 5236 | 314.584       | 31.973    | 4.61        | Saha et al. (2006) | LVLd   | 1.411         | 23,331 |
| NGC 4736 | 123.363       | 76.007    | 4.66        | Jacobs et al. (2009) | SINGS6 | 0.224         | 10,264 |
| NGC 4736 | 123.363       | 76.007    | 4.66        | Jacobs et al. (2009) | SINGS6 | 0.355         | 5137   |
| NGC 1313 | 283.359       | −44.643   | 4.4         | Jacobs et al. (2009) | LVLd   | 0.524         | 4568   |
| NGC 5236 | 314.584       | 31.973    | 4.61        | Saha et al. (2006) | SINGS6 | 2.289         | 15,813 |
| NGC 5474 | 64.301        | 22.933    | 6           | Rouanaki & Rowan-Robinson (1994) | SINGS6 | 0.115         | 991    |
| NGC 5457 | 102.037       | 59.771    | 6.43        | Shappe & Staneck (2011) | LVLd   | 1.697         | 16,291 |
| NGC 45  | 55.903        | −80.672   | 6.6         | Jacobs et al. (2009) | LVLd   | 0.245         | 4321   |
| NGC 5194 | 104.851       | 68.561    | 8           | Ferrarese et al. (2000) | SINGS6 | 1.512         | 8601   |
| NGC 2903 | 208.711       | 44.540    | 8.55        | Tully et al. (2009) | LVLd   | 0.932         | 5579   |
| NGC 925 | 144.885       | −25.174   | 9.3         | Silbermann et al. (1996) | SINGS6 | 0.562         | 4217   |
| NGC 3627 | 241.961       | 64.418    | 10.5        | Freedman et al. (2001) | LVLd   | 1.022         | 3102   |
| NGC 3184 | 178.336       | 55.638    | 14.4        | Ferrarese et al. (2000) | SINGS6 | ...           | 3548   |

Notes.

1. $H\alpha$ luminosity from Kennicutt et al. (2008) are converted to star formation rate (SFR) following Equation (2) of Kennicutt (1998).
2. $\mu$m images within the same matching radius. If no counterpart is found, we attempt to measure the flux at the location of the 3.6/4.5 $\mu$m point source through PSF fitting, and failing that, through aperture photometry. For the MIPS 24 $\mu$m images, we only use aperture photometry due to the much lower resolution and larger PSF size compared to the IRAC images. Finally, for all objects that do not have a $>3\sigma$ detection at 5.8, 8.0, and 24 $\mu$m, we estimate the $3\sigma$ flux upper limits. The fluxes and upper limits are transformed to Vega-calibrated magnitudes using the flux zero-points and aperture corrections provided in the Spitzer Data Analysis Cookbook.

6. Spitzer Infrared Nearby Galaxies Survey (SINGS; Kennicutt et al. 2003).
and decl.) of the point sources followed by their Vega-calibrated apparent magnitudes ($m_\lambda$), the associated 1σ uncertainties ($\sigma_\lambda$), and (for the 3.6–8.0 μm bands) the differences between the PSF and aperture photometry magnitudes ($\delta_\lambda$). For the 5.8, 8.0, and 24 μm bands, $\sigma_\lambda = 99.99$ implies that the associated photometric measurement is a 3σ flux upper limit, and $m_\lambda = 99.99$ (as well as $\delta_\lambda = 99.99$) indicates that no reliable photometric measurement could be obtained for that location. For the IRAC bands, $\delta_\lambda = 99.99$ implies that one or both of the associated photometric measurements did not yield a >3σ flux measurement.

Large mismatches between the two (PSF-fitting and aperture) measurements, especially when $|\delta_\lambda| \gg \sigma_\lambda$, are a good indicator of when crowding is significantly affecting the photometry and can be useful as an alternative estimate of photometric uncertainty. Although PSF-fitting photometry may be generally preferable for crowded field photometry where possible, the $\delta_\lambda$ values would let one revert to using the aperture photometry measurements instead. Large $\delta_\lambda$ values associated with seemingly bright sources are also indicative of contamination due to saturated foreground objects being resolved into multiple bright sources by the PSF-fitting point-source detection procedure (foreground giants would have $m \lesssim 7$; e.g., McQuinn et al. 2007). This is a major source of false positives, especially for M31, as its large field of view contains numerous foreground objects. Indeed, our attempt to identify evolved dust-obscured very high-mass stars ($M_{\text{ZAMS}} \gtrsim 25 M_\odot$) in M31 following the selection criteria described in Khan et al. (2013) picked up many such spurious sources due to their apparently peculiar spectral energy distributions (SEDs).

### 3. DISCUSSION

Figure 1 shows the $m_{4.5}$ versus $m_{3.6} - m_{4.5}$ CMD for M31, and Figure 2 shows the same for the galaxies M83, NGC 6946, M101, and M51, which have the highest SFR among all the galaxies surveyed. The 1σ color and magnitude uncertainties indicate that the horizontal extent of the CMDs are largely a result of color uncertainties. The blueward extent of the M31 CMD is consistent with, e.g., the comparable CMDs of M33 shown on Figure 14 of McQuinn et al. (2007) and Figure 4 of Khan et al. (2015c), and it contains a larger fraction of blue sources than the 15 galaxies beyond the local group cataloged here. As these galaxies are between factors of ∼4.5 (NGC 3077 at 3.7 Mpc) and ∼18 (NGC 3184 at 14.4 Mpc) farther away than M31 (at 0.78 Mpc), in M31 we identify intrinsically fainter and lower mass stars with relatively bluer colors. These include O- and C-rich Asymptotic Giant Branch (AGB) stars (e.g., Bolatto et al. 2007) and possibly some Red Giant Branch stars ($m_{4.5} \lesssim 18$ in M31; e.g., Blum et al. 2006; Boyer et al. 2015) as well as the more evolved and more luminous (massive) stars with warm circumstellar dust which have redder mid-IR colors (M31 is known to have some young massive stars, e.g., Lewis et al. 2015; Massey et al. 2016).

All normal stars have the same mid-IR color in the first two IRAC bands because of the Rayleigh–Jeans tails of their spectra, and we see this as a sequence of foreground dwarfs with $m_{3.6} - m_{4.5} \approx 0$ on the M31 CMD, as well as a “plume” of bright and red extreme Asymptotic Giant Branch (ex-AGB) stars (Thompson et al. 2009; Khan et al. 2010; Boyer et al. 2015) at $m_{4.5} \approx 13–16$. This feature is not as prominent on the M31 CMD when compared to the tight stream of ex-AGB stars visible on the CMD of M33, which has a significantly higher ($\gtrsim 10^\times$) specific SFR (e.g., see Lewis et al. 2015 for a detailed discussion of M31’s recent star formation history) and thus a larger number of younger massive stars per unit stellar mass, although it is still a prominent feature when compared to CMDs of even lower mass/SFR galaxies such as NGC 6822 (see Figure 4 of Khan et al. 2015c for M33 and NGC 6822 mid-IR CMDs).

### Table 2

| R.A. (degree) | Decl. (degree) | $m_{3.6}$ (mag) | $\sigma_{3.6}$ | $\delta_{3.6}$ | $m_{4.5}$ (mag) | $\sigma_{4.5}$ | $\delta_{4.5}$ | $m_{5.8}$ (mag) | $\sigma_{5.8}$ | $\delta_{5.8}$ | $m_{8.0}$ (mag) | $\sigma_{8.0}$ | $\delta_{8.0}$ | $m_{24}$ (mag) | $\sigma_{24}$ |
|--------------|---------------|-----------------|---------------|---------------|-----------------|---------------|---------------|-----------------|---------------|---------------|-----------------|---------------|---------------|-----------------|---------------|
| ...          | ...           | ...             | ...           | ...           | ...             | ...           | ...           | ...             | ...           | ...           | ...             | ...           | ...           | ...             | ...           |
| 11.48283     | 42.63817      | 10.01           | 0.03          | 0.10          | 9.68            | 0.04          | -0.01         | 9.57            | 0.03          | -0.12         | 9.54            | 0.03          | 0.03         | 9.72            | 0.04          |
| 11.54072     | 41.57872      | 10.46           | 0.13          | 0.83          | 9.69            | 0.08          | -0.02         | 6.79            | 0.01          | 9.99         | 9.53            | 0.16          | 2.45         | 6.18            | 0.01          |
| 10.56790     | 41.51002      | 10.12           | 0.10          | 1.01          | 9.70            | 0.06          | 0.86          | 8.30            | 0.01          | 9.99         | 8.32            | 0.03          | 0.09         | 8.08            | 0.01          |
| 10.26228     | 41.57781      | 10.00           | 0.04          | 0.06          | 9.71            | 0.04          | -0.01         | 9.65            | 0.03          | -0.05        | 9.89            | 0.06          | 0.21         | 9.71            | 0.04          |
| 10.01774     | 42.00484      | 10.02           | 0.01          | 0.11          | 9.71            | 0.02          | 0.01          | 9.66            | 0.03          | -0.18        | 9.70            | 0.03          | 0.03         | 9.61            | 0.02          |

(This table is available in its entirety in machine-readable form.)
However, quasars also have this color (e.g., Stern et al. 2005), as do star-forming galaxies with strong PAH emission at 8.0 μm (e.g., the SED models in Assef et al. 2010), and the ex-AGB stars are far less noticeable amid background contaminants on the more distant galaxy CMDs. Although these galaxies have smaller effective survey areas and do not have more background contamination per unit area than M31, their greater distance modulus (μ) means that stars in those galaxies have larger apparent magnitudes. As a result, the evolved stellar populations in those galaxies are effectively buried among background sources on the CMDs. For example, the tip of the AGB branch that is at m_4.5 = 13 on the M31 CMD (μ ≈ 24.5; Figure 2) would be at m_4.5 = 17 on the M83 CMD (μ ≈ 28.3; Figure 2). Given the rarity of ex-AGB stars (e.g., Thompson et al. 2009; Khan et al. 2010; Boyer et al. 2015), it is very likely that most of the very red (m_3.6 - m_4.5 ≥ 1) sources we identify are background contaminants. However, verifying the nature of individual sources would require mid-IR variability study and/or construction of extended multiwavelength SEDs on a case-by-case basis (e.g., Khan et al. 2013). Indeed, only a few rare cataloged mid-IR sources in these distant galaxies would be relevant in the context of studying properties of individual stars—but that is what makes them very interesting to analyze (e.g., Khan et al. 2015a).

Figure 3 shows the apparent-magnitude histograms of all sources in the catalog of M31 (clear region) as well as in the other galaxies (shaded region). For a qualitative comparison, we also show the magnitude histogram for all sources in a 6 deg² region of the NOAO Bootes Field produced from Spitzer Deep Wide Field Survey (SDWFS; Ashby et al. 2009) data (dotted line). The SDWFS catalog can be largely considered “empty,” as most sources are background galaxies and quasars, with only a small fraction being foreground stars (e.g., see Kozłowski et al. 2016). Figure 3 shows that our catalogs are ≥1 mag deeper than the SDWFS catalog. It is worth noting that our catalogs simply inventory all the sources present on the image mosaics and we do not attempt to distinguish between sources physically associated with the galaxies and unrelated foreground and background contaminants. We cannot claim completeness at any magnitude limit; rather, we can only infer that the observed luminosity function turns over at a certain magnitude while the intrinsic one continues rising as the catalogs become increasingly incomplete for fainter sources. Overall, Figure 3 qualitatively

Figure 2. Same as Figure 1 for the galaxies M51, M83, M101, and NGC 6946.

Figure 3. Apparent-magnitude histograms for all cataloged sources in M31 and in the 15 other galaxies (shaded regions), with the latter scaled up for clarity by a factor of 3. The dotted lines show the apparent-magnitude histograms of the SDWFS catalog sources, scaled up for clarity by a factor of 30 for m_3.6 and m_4.5, and by a factor of 50 for m_5.8 and m_8.0.

Figure 4. Mid-IR color histograms for all cataloged sources in M31 and in the 15 other galaxies (shaded regions) with 1σ uncertainty in color ≤0.2, with the latter scaled up for clarity by factors of 5 (first and second rows) and 2 (bottom row). The dotted lines show the mid-IR color histograms of the SDWFS catalog sources, scaled up for clarity by factors of 30 (first and second rows) and 15 (bottom row).
implies that our source lists become significantly incomplete at $m_{3.6} \gtrsim 18$, $m_{4.5} \gtrsim 18$, $m_{5.8} \gtrsim 17$, and $m_{8.0} \gtrsim 16$.

As we emphasized in Khan et al. (2015c), point-source catalogs of the inherently crowded galaxy fields that we are surveying are bound to be crowding (confusion) limited, not just magnitude limited. While Figure 3 empirically demonstrates that our source detection peaks at a certain magnitude and then falls off rapidly, it is likely that incompleteness is affecting even the bright-star counts in crowded regions, increasing toward and through the peak. The depth and completeness of the catalogs vary across each galaxy between, e.g., the centers of galaxies compared to their outer regions or in dusty star clusters compared to more sparsely populated regions as a function of crowding, and they can only be characterized locally for small regions. Performing a conventional efficiency determination test through addition of randomly distributed artificial objects in the images therefore would lead us to either overestimate or underestimate the efficiency. For such a study to be truly useful, it would require a proper "star–star correlation function" to be employed for spatial distribution of artificial stars. Also, while we execute the point-source-detection procedures in individual bands, a source is included in the catalog only if it is independently identified as a point source in both the 3.6 and 4.5 $\mu$m bands, at least at a 3σ level by PSF fitting. Any meaningful statistical test in this context therefore would also need to account for stellar SED variations in the mid-IR to test multiband catalog completeness for a particular region of interest.

Figure 4 shows the mid-IR color histograms of all sources in the catalogs with 1σ uncertainty in color $\lesssim 0.2$, following the same representation as Figure 3. As discussed earlier in this section, the $m_{3.6} - m_{4.5}$ color distribution of M31 is skewed bluerward compared to the other galaxies. The $m_{3.6} - m_{5.8}$ and $m_{4.5} - m_{5.8}$ color distributions (middle row of Figure 4) of these more distant galaxies peak at $>1$ mag redder relative to M31 and the Bootes field, indicating that their 5.8 $\mu$m flux may be dominated by PAH emissions. This is a common feature of massive star-forming regions and star clusters (e.g., Churchwell et al. 2006) created by strong stochastic emission from PAH molecules (e.g., Whelan et al. 2011) excited by UV radiation from O- and B-type stars (see Wood et al. 2008 for a detailed treatment of this topic). Their $m_{3.6} - m_{5.0}$, $m_{4.5} - m_{5.0}$, and $m_{5.8} - m_{8.0}$ color distributions generally match those of the Bootes field but are redder than M31 (bottom row of Figure 4), consistent with significant extragalactic contamination (see Figure 5 of Khan et al. 2015c for mid-IR CMDs of the SDWFS sources).

It is important to highlight here that the color histograms do not include sources for which we could only measure a flux upper limit at the 5.8 and/or 8.0 $\mu$m bands. Since the catalogs list sources that have $>3\sigma$ detections at the 3.6 and 4.5 $\mu$m, the middle and bottom rows of Figure 4 are inherently biased toward redder sources, i.e., those with $>3\sigma$ detections at the two longer wavelength bands as well as the two shorter ones. This can exclude relatively bluer sources such as foreground dwarfs as well as O- and C-rich AGB stars in the targeted galaxies that are intrinsically less luminous at the longer wavelengths. A more rigorous pursuit of this topic requires studying near-IR to mid-IR color separations of the cataloged sources, e.g., as done for the LMC by Blum et al. (2006) utilizing 2MASS data. However, 2MASS is not deep enough to study stellar populations in other galaxies (even M31’s distance modulus is $\sim 6$ mag larger than the LMC’s distance modulus) and one would need (e.g., WFIRST’s Wide Field Instrument (Spergel et al. 2015) near-IR imaging data for this purpose.

These catalogs are a resource to improve our understanding of the 3.6–24 $\mu$m bright point-source populations in crowded extragalactic fields, and they are also an archive for studying future mid-IR transients. The JWST’s Near-IR Spectrograph (NIRSpec; Dorner et al. 2016) and Mid-IR Instrument (MIRI; Rieke et al. 2015) will cover the $\sim 1–5$ $\mu$m and $\sim 5–28$ $\mu$m wavelength ranges respectively. The JWST’s small field of view and anticipated oversubscription practically means that these catalogs will continue to be the most detailed listing of mid-IR source properties in nearby galaxies in the near future. These 3.6–24 $\mu$m point-source catalogs can be very useful to identify scientifically interesting sources for photometric and spectroscopic follow-up with NIRSpec and MIRI in general. They create a pathway for the exploration of extragalactic evolved stellar populations as well as other mid-IR-bright sources with the JWST and WFIRST, making optimal and efficient use of these flagship observatories.

We thank the referee for helpful suggestions; Krzysztof Stanek, Christopher Kochanek, and George Sonneborn for productive discussions; and Martha Boyer and Karl Gordon for providing the M31 image mosaics. This work is based on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with the National Aeronautics and Space Administration (NASA). We extend our gratitude to the SINGS Legacy Survey and the LVL Survey for making their data publicly available. This research has made use of data, which is operated by the JPL and Caltech, under contract with NASA and the HEASARC Online Service, provided by NASA’s GSFC. R.K. is supported through a JWST Fellowship hosted by the Goddard Space Flight Center and awarded as part of the NASA Postdoctoral Program operated by the Oak Ridge Associated Universities on behalf of NASA.

**Table 3**

| R.A. (degree) | Decl. (degree) | $m_{1.6}$ (mag) | $\sigma_{1.6}$ | $b_{1.6}$ | $m_{4.5}$ (mag) | $\sigma_{4.5}$ | $b_{4.5}$ | $m_{5.8}$ (mag) | $\sigma_{5.8}$ | $b_{5.8}$ | $m_{8.0}$ (mag) | $\sigma_{8.0}$ | $b_{8.0}$ | $m_{24}$ (mag) | $\sigma_{24}$ |
|--------------|---------------|----------------|--------------|----------|----------------|--------------|----------|----------------|--------------|----------|----------------|--------------|----------|----------------|-------------|
| 105.81010    | 68.73050      | 16.25          | 0.10         | 0.49     | 16.45          | 0.11         | 0.81     | 14.73          | 0.07         | 99.99    | 13.46          | 0.12         | 99.99    | 8.40           | 0.02        |
| 105.53804    | 68.81851      | 16.28          | 0.07         | -0.04    | 16.45          | 0.07         | 0.15     | 16.52          | 0.14         | -0.07    | 15.47          | 0.05         | -0.57    | 99.99          | 0.99        |
| 105.82225    | 68.74199      | 16.49          | 0.09         | 0.30     | 16.45          | 0.12         | 0.99     | 16.21          | 0.13         | 1.27     | 13.62          | 0.12         | 99.99    | 8.16           | 0.17        |
| 105.86320    | 68.69979      | 17.13          | 0.07         | 0.47     | 16.45          | 0.06         | 0.17     | 16.21          | 0.05         | -0.55    | 15.79          | 0.11         | -0.87    | 12.87          | 0.20        |
| 105.99858    | 68.69220      | 17.14          | 0.11         | 0.70     | 16.46          | 0.06         | 0.17     | 16.36          | 0.10         | 0.35     | 15.42          | 0.06         | 0.05    | 11.33           | 0.08        |

(This table is available in its entirety in machine-readable form.)
Table 4
Catalog for 6972 Point Sources in NGC 1313

| R.A. (degree) | Decl. (degree) | $m_{16}$ (mag) | $\sigma_{3,6}$ | $\delta_{3,6}$ | $m_{15}$ (mag) | $\sigma_{4,5}$ | $\delta_{4,5}$ | $m_{4,5}$ (mag) | $\sigma_{3,5}$ | $\delta_{3,5}$ | $m_{8}$ (mag) | $\sigma_{8}$ | $\delta_{8}$ | $m_{24}$ (mag) | $\sigma_{24}$ |
|--------------|---------------|----------------|----------------|---------------|----------------|----------------|---------------|----------------|----------------|---------------|----------------|--------------|---------------|----------------|--------------|
| 49.77658     | −66.41660     | 15.55          | 0.05           | 0.00          | 15.60          | 0.06           | 0.01          | 15.65          | 0.05           | 0.23          | 15.80          | 0.04          | 0.11          | 12.13          | 0.07         |

(This table is available in its entirety in machine-readable form.)

Table 5
Catalog for 10,264 Point Sources in NGC 4736 (M94)

| R.A. (degree) | Decl. (degree) | $m_{16}$ (mag) | $\sigma_{3,6}$ | $\delta_{3,6}$ | $m_{4,5}$ (mag) | $\sigma_{4,5}$ | $\delta_{4,5}$ | $m_{5,8}$ (mag) | $\sigma_{5,8}$ | $\delta_{5,8}$ | $m_{8,0}$ (mag) | $\sigma_{8,0}$ | $\delta_{8,0}$ | $m_{24}$ (mag) | $\sigma_{24}$ |
|--------------|---------------|----------------|----------------|---------------|----------------|----------------|---------------|----------------|----------------|---------------|----------------|--------------|---------------|----------------|--------------|
| 192.70675    | 41.13108      | 15.65          | 0.09           | 0.78          | 15.11          | 0.11           | 0.46          | 13.03          | 0.13           | 0.80          | 12.19          | 0.14          | 1.80          | 6.20           | 0.01         |

(This table is available in its entirety in machine-readable form.)

Table 6
Catalog for 5137 Point Sources in NGC 4826(M64)

| R.A. (degree) | Decl. (degree) | $m_{16}$ (mag) | $\sigma_{3,6}$ | $\delta_{3,6}$ | $m_{4,5}$ (mag) | $\sigma_{4,5}$ | $\delta_{4,5}$ | $m_{5,8}$ (mag) | $\sigma_{5,8}$ | $\delta_{5,8}$ | $m_{8,0}$ (mag) | $\sigma_{8,0}$ | $\delta_{8,0}$ | $m_{24}$ (mag) | $\sigma_{24}$ |
|--------------|---------------|----------------|----------------|---------------|----------------|----------------|---------------|----------------|----------------|---------------|----------------|--------------|---------------|----------------|--------------|
| 194.06033    | 21.73660      | 15.41          | 0.10           | 0.13          | 15.34          | 0.08           | 0.07          | 15.73          | 0.16           | 0.73          | 15.02          | 0.11          | −0.10         | 11.52          | 0.05         |

(This table is available in its entirety in machine-readable form.)

Table 7
Catalog for 23,331 Point Sources in NGC 5236 (M83)

| R.A. (degree) | Decl. (degree) | $m_{16}$ (mag) | $\sigma_{3,6}$ | $\delta_{3,6}$ | $m_{4,5}$ (mag) | $\sigma_{4,5}$ | $\delta_{4,5}$ | $m_{5,8}$ (mag) | $\sigma_{5,8}$ | $\delta_{5,8}$ | $m_{8,0}$ (mag) | $\sigma_{8,0}$ | $\delta_{8,0}$ | $m_{24}$ (mag) | $\sigma_{24}$ |
|--------------|---------------|----------------|----------------|---------------|----------------|----------------|---------------|----------------|----------------|---------------|----------------|--------------|---------------|----------------|--------------|
| 204.15718    | −29.85278     | 13.49          | 0.04           | −0.03         | 13.54          | 0.03           | −0.01         | 13.49          | 0.02           | −0.05        | 13.57          | 0.05          | 0.25          | 11.95          | 99.99        |

(This table is available in its entirety in machine-readable form.)
| R.A. (degree) | Decl. (degree) | $m_{54}$ (mag) | $σ_{54}$ | $δ_{54}$ | $m_{45}$ (mag) | $σ_{45}$ | $δ_{45}$ | $m_{36}$ (mag) | $σ_{36}$ | $δ_{36}$ | $m_{24}$ (mag) | $σ_{24}$ |
|-------------|---------------|----------------|----------|----------|----------------|----------|----------|----------------|----------|----------|----------------|----------|
| 199.72607   | −21.03384     | 15.92          | 0.14     | 0.83     | 15.41          | 0.11     | 0.37     | 13.75          | 0.11     | 0.71     | 11.39          | 0.04     |
| 199.73146   | −21.04449     | 15.61          | 0.13     | 0.05     | 15.41          | 0.09     | −0.10    | 13.50          | 0.09     | −0.03    | 11.48          | 0.02     |
| 199.70009   | −20.97649     | 15.48          | 0.13     | 0.88     | 15.42          | 0.13     | 0.85     | 14.22          | 0.11     | 0.88     | 11.91          | 0.06     |
| 199.73044   | −21.04431     | 15.22          | 0.14     | 0.23     | 15.43          | 0.12     | 0.40     | 13.26          | 0.11     | 0.08     | 11.00          | −0.38    |
| 199.71533   | −21.07158     | 15.37          | 0.05     | 0.02     | 15.43          | 0.04     | 0.02     | 15.08          | 0.07     | −0.38    | 13.84          | 0.07     |

(This table is available in its entirety in machine-readable form.)

| R.A. (degree) | Decl. (degree) | $m_{54}$ (mag) | $σ_{54}$ | $δ_{54}$ | $m_{45}$ (mag) | $σ_{45}$ | $δ_{45}$ | $m_{36}$ (mag) | $σ_{36}$ | $δ_{36}$ | $m_{24}$ (mag) | $σ_{24}$ |
|-------------|---------------|----------------|----------|----------|----------------|----------|----------|----------------|----------|----------|----------------|----------|
| 308.65553   | 60.13594      | 14.78          | 0.06     | −0.11    | 14.59          | 0.06     | −0.30    | 14.40          | 0.04     | 99.99    | 13.56          | 0.24     |
| 308.94799   | 59.96213      | 14.44          | 0.16     | −0.02    | 14.60          | 0.14     | 0.13     | 14.36          | 0.09     | −0.02    | 14.42          | 0.15     |
| 308.64470   | 60.09664      | 14.57          | 0.04     | −0.06    | 14.60          | 0.04     | 0.00     | 14.38          | 0.05     | −0.03    | 14.20          | 0.04     |
| 308.81946   | 60.18289      | 14.80          | 0.14     | 0.93     | 14.60          | 0.10     | 1.15     | 12.19          | 0.10     | 1.13     | 11.01          | 1.71     |
| 309.03955   | 60.09698      | 13.45          | 0.11     | 0.56     | 14.60          | 0.10     | 0.67     | 12.25          | 0.12     | 0.59     | 12.32          | 0.99     |

(This table is available in its entirety in machine-readable form.)

| R.A. (degree) | Decl. (degree) | $m_{54}$ (mag) | $σ_{54}$ | $δ_{54}$ | $m_{45}$ (mag) | $σ_{45}$ | $δ_{45}$ | $m_{36}$ (mag) | $σ_{36}$ | $δ_{36}$ | $m_{24}$ (mag) | $σ_{24}$ |
|-------------|---------------|----------------|----------|----------|----------------|----------|----------|----------------|----------|----------|----------------|----------|
| 211.20194   | 53.64062      | 18.02          | 0.05     | 0.06     | 17.17          | 0.07     | −0.19    | 16.70          | 0.11     | 99.99    | 16.18          | 0.12     |
| 211.29572   | 53.67260      | 17.25          | 0.06     | 0.02     | 17.17          | 0.06     | 0.06     | 16.88          | 0.08     | −0.09    | 15.81          | 0.12     |
| 211.25098   | 53.63765      | 18.05          | 0.16     | 1.14     | 17.18          | 0.13     | 0.80     | 16.08          | 0.09     | 0.49     | 14.49          | 0.07     |
| 211.23574   | 53.66682      | 17.37          | 0.05     | −0.07    | 17.19          | 0.04     | −0.02    | 16.71          | 0.17     | −0.32    | 15.94          | 0.11     |
| 211.29303   | 53.71026      | 17.28          | 0.08     | −0.03    | 17.21          | 0.13     | 0.45     | 17.16          | 0.15     | −0.25    | 16.12          | 0.23     |

(This table is available in its entirety in machine-readable form.)

| R.A. (degree) | Decl. (degree) | $m_{54}$ (mag) | $σ_{54}$ | $δ_{54}$ | $m_{45}$ (mag) | $σ_{45}$ | $δ_{45}$ | $m_{36}$ (mag) | $σ_{36}$ | $δ_{36}$ | $m_{24}$ (mag) | $σ_{24}$ |
|-------------|---------------|----------------|----------|----------|----------------|----------|----------|----------------|----------|----------|----------------|----------|
| 210.78059   | 54.33504      | 14.36          | 0.09     | 0.01     | 14.33          | 0.07     | 0.01     | 14.38          | 0.03     | −0.43    | 14.72          | 0.09     |
| 210.67301   | 54.19461      | 14.28          | 0.05     | 0.00     | 14.34          | 0.04     | 0.01     | 14.55          | 0.05     | 0.10     | 14.25          | 0.05     |
| 210.77003   | 54.32386      | 14.48          | 0.10     | 0.62     | 14.35          | 0.14     | 0.90     | 11.57          | 0.06     | 0.57     | 9.73           | 0.02     |
| 210.86363   | 54.31284      | 14.77          | 0.09     | 0.43     | 14.35          | 0.06     | 0.38     | 12.01          | 0.07     | 0.51     | 10.21          | 0.03     |
| 210.58743   | 54.46138      | 14.12          | 0.07     | −0.07    | 14.35          | 0.06     | 0.12     | 14.33          | 0.06     | 0.07     | 14.15          | 0.03     |

(This table is available in its entirety in machine-readable form.)

### Table 8
Catalog for 5617 Point Sources in NGC 5068

### Table 9
Catalog for 15,813 Point Sources in NGC 6946

### Table 10
Catalog for 991 Point Sources in NGC 5474

### Table 11
Catalog for 16,291 Point Sources in NGC 5457 (M101)
| R.A.   | Decl.   | $m_{3.6}$ | $m_{4.5}$ | $m_{5.8}$ | $m_{8.0}$ | $m_{24}$ |
|-------|---------|-----------|-----------|-----------|-----------|-----------|
|       |         | (mag)     | (mag)     | (mag)     | (mag)     | (mag)     |
|       |         | $\delta_{3.6}$ | $\delta_{4.5}$ | $\delta_{5.8}$ | $\delta_{8.0}$ | $\delta_{24}$ |
|       |         |           |           |           |           |           |
| 3.3601 | −23.18667 | 15.84 | 0.06 | 0.31 | 15.96 | 0.09 | 0.77 | 15.71 | 0.17 | 0.61 | 14.63 | 0.05 | 0.76 | 10.74 | 0.09 |
| 3.40049 | −23.19893 | 16.25 | 0.07 | 0.10 | 15.96 | 0.13 | 0.39 | 15.29 | 0.07 | −0.18 | 12.62 | 0.03 | 0.13 | 9.38 | 0.03 |
| 3.48302 | −23.23012 | 16.11 | 0.08 | 0.22 | 15.96 | 0.05 | 0.35 | 16.26 | 0.07 | 0.68 | 15.41 | 0.06 | 0.70 | 11.39 | 0.13 |
| 3.54977 | −23.14415 | 16.34 | 0.07 | 0.19 | 15.97 | 0.09 | 0.10 | 16.12 | 0.09 | 0.09 | 15.33 | 0.04 | −0.22 | 11.63 | 0.18 |
| 3.66439 | −23.20038 | 16.05 | 0.04 | 0.10 | 15.97 | 0.09 | −0.00 | 16.33 | 0.11 | 0.53 | 15.10 | 0.09 | 99.99 | 11.59 | 0.99 |

(This table is available in its entirety in machine-readable form.)

| R.A.   | Decl.   | $m_{3.6}$ | $m_{4.5}$ | $m_{5.8}$ | $m_{8.0}$ | $m_{24}$ |
|-------|---------|-----------|-----------|-----------|-----------|-----------|
|       |         | (mag)     | (mag)     | (mag)     | (mag)     | (mag)     |
|       |         | $\delta_{3.6}$ | $\delta_{4.5}$ | $\delta_{5.8}$ | $\delta_{8.0}$ |
|       |         |           |           |           |           |
| 202.52413 | 47.26076 | 14.32 | 0.11 | 0.68 | 15.58 | 0.06 | −0.01 | 14.33 | 0.08 | 0.02 | 13.61 | 0.05 | 0.50 | 0.10 | 0.19 |
| 202.46649 | 47.19562 | 13.53 | 0.14 | 0.59 | 15.58 | 0.11 | −0.09 | 12.37 | 0.09 | −0.19 | 11.49 | 0.07 | 0.96 | 6.96 | 0.17 |
| 202.48110 | 47.19441 | 14.27 | 0.14 | −1.19 | 13.59 | 0.08 | −0.82 | 11.41 | 0.09 | 0.04 | 9.61 | 0.08 | 0.11 | 5.43 | 0.17 |
| 202.48202 | 47.19663 | 14.19 | 0.09 | 0.39 | 13.59 | 0.05 | 0.04 | 13.08 | 0.11 | 1.11 | 10.32 | 0.11 | −0.13 | 4.76 | 0.06 |
| 202.46688 | 47.21179 | 14.03 | 0.13 | 0.57 | 13.64 | 0.06 | 0.66 | 11.39 | 0.11 | 0.71 | 9.82 | 0.06 | 0.96 | 4.65 | 0.03 |

(This table is available in its entirety in machine-readable form.)

| R.A.   | Decl.   | $m_{3.6}$ | $m_{4.5}$ | $m_{5.8}$ | $m_{8.0}$ | $m_{24}$ |
|-------|---------|-----------|-----------|-----------|-----------|-----------|
|       |         | (mag)     | (mag)     | (mag)     | (mag)     | (mag)     |
|       |         | $\delta_{3.6}$ | $\delta_{4.5}$ | $\delta_{5.8}$ |
|       |         |           |           |           |
| 143.03345 | 21.47890 | 14.79 | 0.09 | 0.78 | 14.53 | 0.12 | 0.56 | 11.80 | 0.10 | 0.46 | 9.94 | 0.03 | 0.45 | 6.05 | 0.06 |
| 142.92413 | 21.63127 | 14.47 | 0.06 | −0.00 | 14.53 | 0.06 | 0.03 | 14.61 | 0.07 | −0.01 | 14.41 | 0.08 | −0.35 | 11.75 | 0.25 |
| 143.04889 | 21.51972 | 14.85 | 0.11 | 0.34 | 14.53 | 0.13 | 0.11 | 12.76 | 0.10 | 0.10 | 10.68 | 0.06 | 0.04 | 7.46 | 0.11 |
| 142.93511 | 21.64432 | 14.49 | 0.04 | −0.02 | 14.54 | 0.11 | −0.02 | 14.80 | 0.09 | 0.01 | 14.12 | 0.04 | −0.45 | 12.26 | 99.99 |
| 142.84140 | 21.53222 | 14.60 | 0.10 | 99.99 | 14.54 | 0.12 | 99.99 | 15.95 | 0.13 | 0.67 | 14.35 | 0.05 | 99.99 | 11.30 | 99.99 |

(This table is available in its entirety in machine-readable form.)

| R.A.   | Decl.   | $m_{3.6}$ | $m_{4.5}$ | $m_{5.8}$ | $m_{8.0}$ | $m_{24}$ |
|-------|---------|-----------|-----------|-----------|-----------|-----------|
|       |         | (mag)     | (mag)     | (mag)     | (mag)     | (mag)     |
|       |         | $\delta_{3.6}$ | $\delta_{4.5}$ | $\delta_{5.8}$ |
|       |         |           |           |           |
| 36.82781 | 33.63954 | 15.73 | 0.07 | −0.01 | 15.67 | 0.10 | −0.01 | 15.66 | 0.06 | −0.25 | 15.39 | 0.07 | −0.85 | 11.90 | 0.28 |
| 36.84670 | 33.52045 | 15.99 | 0.09 | 1.12 | 15.67 | 0.12 | 1.00 | 15.64 | 0.07 | 0.93 | 14.38 | 0.06 | 1.40 | 10.47 | 0.07 |
| 36.82457 | 33.57855 | 15.79 | 0.11 | 0.28 | 15.68 | 0.13 | 0.48 | 14.56 | 0.14 | 1.16 | 12.45 | 0.10 | 0.72 | 7.97 | 0.10 |
| 36.92907 | 33.68388 | 15.63 | 0.06 | 0.00 | 15.68 | 0.09 | 0.00 | 15.94 | 0.11 | −0.42 | 15.12 | 0.14 | −0.56 | 99.99 | 99.99 |
| 36.93849 | 33.57978 | 15.93 | 0.05 | 0.15 | 15.68 | 0.09 | 0.10 | 15.61 | 0.09 | −0.01 | 14.26 | 0.05 | −0.02 | 11.85 | 0.12 |

(This table is available in its entirety in machine-readable form.)
(This table is available in its entirety in machine-readable form.)

Table 17
Catalog for 3548 Point Sources in NGC 3184

| R.A. (degree) | Decl. (degree) | $m_{16}$ (mag) | $\delta_{16}$ | $m_{14.5}$ (mag) | $\alpha_{4.5}$ | $m_{5.8}$ (mag) | $\delta_{5.8}$ | $m_{6.0}$ (mag) | $\delta_{6.0}$ | $m_{24}$ (mag) | $\sigma_{24}$ |
|--------------|---------------|----------------|-------------|-----------------|-------------|----------------|-------------|----------------|-------------|----------------|-----------|
|              |               |               |             |                 |             |                |             |                 |             |                |           |
| 154.53453    | 41.39239      | 16.82          | 0.10        | 0.22            | 16.13       | 0.06           | 0.13        | 15.70          | 0.06        | 14.37          | 0.12      |
| 154.63606    | 41.39248      | 16.35          | 0.09        | 0.19            | 16.13       | 0.04           | 0.10        | 16.29          | 0.07        | 15.34          | 0.07      |
| 154.67640    | 41.38895      | 16.47          | 0.22        | 0.12            | 16.14       | 0.09           | 0.21        | 15.76          | 0.09        | 14.63          | 0.05      |
| 154.56665    | 41.44029      | 16.09          | 0.12        | 0.39            | 16.15       | 0.12           | 0.71        | 13.72          | 0.11        | 11.16          | 0.03      |
| 154.39740    | 41.38107      | 16.75          | 0.15        | 0.08            | 16.15       | 0.08           | 0.19        | 15.20          | 0.19        | 14.70          | 0.27      |

(Here is the table in its entirety in machine-readable form.)

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