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# MIPS 24–160 μm photometry for the *Herschel*-SPIRE Local Galaxies Guaranteed Time Programs

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## ABSTRACT

We provide an overview of ancillary 24-, 70- and 160-μm data from the Multiband Imaging Photometer for *Spitzer* (MIPS) that are intended to complement the 70–500 μm *Herschel Space Observatory* photometry data for nearby galaxies obtained by the *Herschel*-SPIRE Local Galaxies Guaranteed Time Programs and the *Herschel* Virgo Cluster Survey. The MIPS data can be used to extend the photometry to wavebands that are not observed in these *Herschel* surveys and to check the photometry in cases where *Herschel* performs observations at the same wavelengths. Additionally, we measured globally integrated 24–160 μm flux densities for the galaxies in the sample that can be used for the construction of spectral energy distributions. Using MIPS photometry published by other references, we have confirmed that we are obtaining accurate photometry for these galaxies.

**Key words:** catalogues – galaxies: photometry – infrared: galaxies.

## 1 INTRODUCTION

The *Herschel*-SPIRE Local Galaxies Guaranteed Time Programs (SAG2) comprises several *Herschel Space Observatory* (Pilbratt et al. 2010) programmes that used primarily the Photodetector Array Camera and Spectrometer (PACS; Poglitsch et al. 2010) and Spectral and Photometric Imaging Receiver (SPIRE; Griffin et al. 2010) to perform far-infrared and submillimetre observations of galaxies in the nearby universe. Three of the programmes include photometric surveys of galaxies. The Very Nearby Galaxies Survey (VNGS; PI: C. D. Wilson) has performed 70–500 μm photometric and spectroscopic observations of 13 archetypal nearby galaxies that include Arp 220, M51 and M81. The Dwarf Galaxy Survey (DGS; PI: S. C. Madden) is a 70–500 μm photometric and spectroscopic survey of 48 dwarf galaxies selected to span a range of metallicities [with 12+log(O/H) values ranging from 7.2 to 8.5]. The *Herschel* Reference Survey (HRS; Boselli et al. 2010) is a 250–500 μm photometric survey of a volume-limited sample of 323 nearby galaxies designed to include both field and Virgo cluster galaxies. The HRS also significantly overlaps with the *Herschel* Virgo Cluster Survey (HeViCS; Davies et al. 2010a), a 100–500 μm survey that will image 60 $deg^2$ of the Virgo cluster, and both collaborations will be sharing their data.

The far-infrared and submillimetre photometric data from these surveys can be used to construct spectral energy distributions (SEDs) of the dust emission and to map the distribution of cold dust within these galaxies. However, the surveys benefit greatly from the inclusion of 24-, 70- and 160-μm data from the Multiband Imaging Photometer for *Spitzer* (MIPS; Rieke et al. 2004), the far-infrared photometric imager on board the *Spitzer Space Telescope* (Werner et al. 2004). The 24-μm MIPS data are particularly important either when attempting to model the complete dust emission from individual galaxies, as it provides constraints on the hot dust emission, or when attempting to measure accurate star formation rates, as 24-μm emission has been shown to be correlated with other star formation tracers (Calzetti et al. 2005, 2007; Kennicutt et al. 2007, 2009; Prescott et al. 2007; Zhu et al. 2008). The 70-μm MIPS data are less critical for the VNGS and DGS galaxies, which have been mapped with PACS at 70 μm, but the data are more important for the HRS galaxies, most of which will not be mapped with PACS at 70 μm. Nonetheless, the MIPS 70-μm data can be used to check the PACS photometry, and the data may be useful as a substitute for PACS photometry in situations where the MIPS data are able to detect emission at higher signal-to-noise ratio (S/N) levels but where the higher resolution of PACS is not needed. For galaxies without 70-μm PACS observations, the MIPS data will provide an important additional data point that is useful for constraining the part of the far-infrared SED that represents the transition between the ∼20 K dust emission from the diffuse interstellar medium and the hot dust emission from large grains in star-forming regions and very small grains. The 160-μm MIPS data are less important, as 160-μm PACS observations with equivalent sensitivities and smaller point spread functions (PSFs) have been performed on the VNGS and DGS

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samples as well as the fraction of the HRS sample that falls within the HeViCS fields. For these galaxies, the MIPS 160-μm data can primarily be used to check PACS 160-μm photometry. An additional follow-up programme (completing the PACS coverage of the HRS; PI: L. Cortese) has been submitted to perform PACS 160-μm observations on the HRS galaxies outside the HeViCS field. However, those observations have not yet been performed at the time of this writing, so the MIPS 160-μm data can serve as a substitute for the missing PACS data.

The pipeline processing from the MIPS archive is not optimized for observations of individual galaxies. The final 24-μm images may include gradients from zodiacal light emission, incomplete flatfielding, and foreground asteroids, while the 70- and 160-μm images may include short-term variations in the background signal ('drift'). Moreover, many galaxies are often observed multiple times in multiple Astronomical Observation Requests (AORs), and optimal images can often be produced by combining the data from these multiple AORs, which is something that the MIPS pipeline is not designed to do. Hence, to get the best MIPS images for analysis, it is necessary to reprocess the archival data.

Work on reprocessing the archival MIPS data for the SAG2 and HeViCS programmes has been ongoing since before the launch of *Herschel*. Either these reprocessed MIPS data or earlier versions of the data have already been used in multiple papers from the SAG2 collaboration (Cortese et al. 2010a; Eales et al. 2010; Galametz et al. 2010; Gomez et al. 2010; O'Halloran et al. 2010; Pohlen et al. 2010; Sauvage et al. 2010; Auld et al. 2012; Bendo et al. 2012; Foyle et al. 2012; Smith et al. 2012) and the HeViCS collaboration (de Looze et al. 2010; Smith et al. 2010; Davies et al. 2012), and the data have also been used in other publications outside of these collaborations (Galametz et al. 2009; Whaley et al. 2009; Wilson et al. 2009; Young, Bendo & Lucero 2009; Bendo et al. 2010; Cortese et al. 2010b; de Looze et al. 2011). The data processing has been described with some details in some of these papers but not in others. Global photometry measurements (printed numerical values, not just data points shown in figures) have only been published for 11 galaxies, and some of the measurements are based either on older versions of the data processing or on images created before all of the MIPS data for the targets were available.

The goal of this paper is to describe the MIPS data processing for SAG2 in detail and to present photometry for all of the SAG2 galaxies as well as the 500-μm flux-limited sample of HeViCS galaxies published by Davies et al. (2012). While the MIPS data are incomplete for the DGS, HRS and HeViCS samples and hence cannot be used to create statistically complete data sets, the data are still useful for constructing SEDs for individual galaxies and subsets of galaxies in the SAG2 and HeViCS samples. The paper is divided into two primary sections. Section 2 describes the data processing in detail. Section 3 describes the globally integrated photometry for these galaxies, which can be used as a reference for other papers, and also discusses how the photometry compares to the MIPS photometry from other surveys.

## 2 DATA PROCESSING

### 2.1 Overview of MIPS

This section gives a brief overview of the MIPS instrument and the type of data produced by the instrument. Additional information on the instrument and the arrays can be found in the MIPS Instrument Handbook (MIPS Instrument and MIPS Instrument Support Teams 2011).[1]

MIPS has four basic observing modes, but most observations were performed in one of the two imaging modes. The photometry map mode produced maps of multiple dithered frames that were usually ∼5 arcmin in size. The observing mode could also be used to produce raster maps or could be used in cluster mode to produce maps of multiple objects that are close to each other. Although intended to be used for observing sources smaller than 5 arcmin, the mode was sometimes used to image larger objects. Because the 24-, 70- and 160-μm arrays are offset from each other in the imaging plane, observations in each waveband need to be performed in separate pointings. The scan map observing mode was designed to be used primarily for observing objects larger than 5 arcmin. The telescope scans in a zigzag pattern where each of the arrays in the instrument pass over the target region in each scan leg. In typical observations, the telescope scans a region that is 1° in length, although longer scan maps were also produced with the instrument. In both observing modes, a series of individual data frames are taken in a cycle with the telescope pointing at different offsets from the target. These cycles include stim-flash observations, which are frames in which the arrays are illuminated with an internal calibration source. Between six and 32 frames may be taken during a photometry map observation. In scan map observations, the number of frames per cycle may vary, but the data are always bracketed by stim-flash frames. In typical 1° long scan map legs taken with the medium scan rate, each scan leg contains 4 cycles of data and each cycle contains 25 frames.

The other two observing modes were a 65–97 μm low-resolution spectroscopy mode using the 70-μm array and a total power mode that could be used to measure the total emission from the sky. However, since our interest is in working with photometric images of individual galaxies, we did not use the data from either of these observing modes.

Details on the three arrays are given in Table 1. The 70-μm array is actually a 32 × 32 array, but half of the array was effectively unusable, so the array effectively functions as a 32 × 16 array. Details on the effective viewing area are given in the table. Also, the 70-μm array can be used in wide field-of-view and super-resolution modes for producing photometry maps, but virtually no super-resolution data were taken for our target galaxies, so we only list data for the wide field-of-view mode.

### 2.2 Overview of data

#### 2.2.1 Archival data

*Spitzer* observations of multiple galaxies within the SAG2 samples were performed in other survey programmes before SAG2 began working on the MIPS analysis and data reduction. The only *Spitzer* observing programme devoted to SAG2 photometry that was awarded observing time was a programmes that included MIPS 24-μm observations for 10 of the DGS galaxies, which is described in the next subsection. All other MIPS data originate from an assortment of programmes. Some galaxies were observed as specific targets in surveys of nearby galaxies. Others were observed in surveys of wide fields, such as wide field surveys of the Virgo cluster. Still

[1] The MIPS Instrument Handbook is available at http://irsa.ipac.caltech.edu/data/SPITZER/docs/mips/mipsinstrumenthandbook/MIPS_Instrument_Handbook.pdf.

**Table 1.** Data on the three MIPS arrays.[a]

| Waveband (μm) | Pixel size (arcsec) | Array size (pixels) | (arcmin) | PSF FWHM[b] (arcsec) | Flux conversion factors ($\mathrm{MJy\,sr^{-1}}$) $[\mathrm{MIPS\ unit}]^{-1}$ | Calibration uncertainty (per cent) |
|---|---|---|---|---|---|---|
| 24 | 2.5 × 2.6 | 128 × 128 | 5.4 × 5.4 | 6[c] | $4.54 \times 10^{-2}$ [c] | 4[c] |
| 70 | 9.9 × 10.1 | 32 × 16 | 5.2 × 2.6 | 18[d] | 702[d] | 10[d] |
| 160 | 16 × 18 | 2 × 20 | 2.1 × 5.3 | 38[e] | 41.7[e] | 12[e] |

[a]Except where noted, these data come from the MIPS Instrument Handbook (MIPS Instrument and MIPS Instrument Support Teams 2011).
[b]This is the full width at half-maximum (FWHM) of the point spread function (PSF).
[c]Data are from Engelbracht et al. (2007).
[d]Data are from Gordon et al. (2007).
[e]Data are from Stansberry et al. (2007).

others were serendipitously imaged in observations with other targets. Both photometry map and scan map data are available for these galaxies. Consequently, the observed areas vary significantly among the galaxies. The coverage (the number of data frames covering each pixel in the final mosaics) and on-source integration times also vary among the galaxies.

Given the inhomogeneity of the data as well as the incomplete coverage of the galaxies in the sample, we opted to utilize all usable data available for every galaxy to produce the best images for each galaxy. This means that the data set will not be uniform and that the noise levels in the data will vary among the galaxies in the sample, but the resulting images will be the best on hand for analysis. While we generally attempted to use all available data, we made some judgments on selecting data for final images. When both scan map and photometry map data were available for individual galaxies, we used only the scan map data to create final images if the optical discs of the galaxies were larger than the areas covered in the photometry maps or if the background area in the photometry map was too small to allow us to apply data processing steps that rely on measurements from the background in on-target frames. We also did not use observations that covered less than half of the optical discs of individual objects. When multiple objects fell within regions covered in multiple overlapping or adjacent AORs, we made larger mosaics using all of the data whenever technically feasible. Also, for photometry map data, we often used the serendipitous data taken when individual arrays were in off-target positions if those fields covered galaxies in our samples, and when multiple fields were observed using the cluster option in the photometry map data (see the MIPS Instrument Handbook by the MIPS Instrument and MIPS Instrument Support Teams 2011), we combined the data from all pointings that covered SAG2 or HeViCS galaxies.

#### 2.2.2 *SAG2 observations of dwarf galaxies*

10 of the dwarf galaxies were observed by DGS with MIPS in cycle 5 as part of the programme Dust Evolution in Low-Metallicity Environments: Bridging the Gap Between Local Universe and Primordial Galaxies (PI: F. Galliano; ID: 50550). Since these were objects smaller than 5 arcmin in diameter and since SAG2 intended to rely upon *Herschel* for 70- and 160-μm photometry, these galaxies were mapped only at 24 μm using the photometry map mode. One AOR was performed per object. Each observation uses a dither pattern to cover a ∼6 arcmin square region around the targets, and the integration times were set to 3 s per frame, giving a total time of 328 s per AOR.

### 2.3 Data processing for individual data frames

The raw data from the *Spitzer* archive were reprocessed using the MIPS Data Analysis Tools (DAT; Gordon et al. 2005) along with additional processing steps, some of which are performed by software from the MIPS Instrument Team and some of which are performed by independently developed software. The scan map data processing is a variant of the data processing pipeline used in the fourth data delivery of MIPS data from the *Spitzer* Infrared Nearby Galaxies Survey (SINGS; Kennicutt et al. 2003), although changes have been made to the background subtraction, and an asteroid removal step has been added to the 24-μm data processing. Although other data processing software for MIPS is available from the Spitzer Science Center, we have continued to use the MIPS DAT because of our familiarity with the software and because we have developed an extensive range of tools to work with the intermediate and final data products produced by the MIPS DAT.

Separate sections are used to describe the processing steps applied to the 24-μm data frames and the steps applied to the 70- and 160-μm data frames, as the data from the 24-μm silicon-based detectors differ somewhat from the data from the 70- and 160-μm germanium–gallium detectors. The tools for processing photometry map data frames differ slightly from the tools for the scan map data frames. However, the differences are small enough that it is possible to describe the data processing for both observing modes in the same sections. The mosaicking and post-processing steps applied to all data are very similar, and so these steps are described in the last subsection.

#### 2.3.1 *MIPS 24-μm data frame processing*

The raw 24-μm data consist of slopes to the ramps measured by the detectors (the counts accumulated in each pixel during non-destructive readouts). The following data processing steps were applied to MIPS 24-μm data frames.

(1) The MIPS DAT program MIPS_SLOPER was applied to the frames. This applies a droop correction, which removes an excess signal in each detector that is proportional to the signal in the entire array, a dark current subtraction and an electronic non-linearity correction.

(2) The MIPS DAT program MIPS_CALER was applied to the data frames. This corrects the detector responsivity using a mirror-position-dependent flatfield that removes spots from the images caused by material on the scan mirror. This data processing step also included a correction for variations in the readout offsets between different columns in the data frames.

(3) To remove latent images from bright sources, pixels with signals above 2500 MIPS units in individual frames were masked

out in the following three frames. In a few cases, this threshold was lowered to remove additional latent image effects.

(4) When some 24-μm data frames were made, the array was hit by strong cosmic rays that also caused severe 'jailbar' effects or background offsets in the data. When we have identified data frames with these problems or other severe artefacts, we masked out those data frames manually at this stage in the data processing.

(5) A mirror-position-independent flatfield was created from on-target frames falling outside 'exclusion' regions comprising the optical discs of target galaxies and bright foreground or background sources. These flatfields correct for responsivity variations in the array that are specific to each observation. This flatfield was then applied to the data frames. In the case of some photometry map data, not enough background area was available for properly making flatfields. In these cases, data from the off-target pointings were used to build the mirror-position-independent flatfields that were then applied to the data.

(6) Gradients in the background signal, primarily from zodiacal light, were then subtracted from the data frames. This step differs between the photometry and scan map modes. For photometry map data, the background signal outside the exclusion regions in each frame was fitted with a plane, and then this plane was subtracted from the data (although this step was skipped if not enough area was available in the data frames to measure the background). In the scan map data, two different approaches were used. Before applying either of these methods, we typically discarded the first five frames of data from each scan leg because the background signal was often ramping up to a stable background level; these frames usually did not cover any targets. In the standard approach, the background was subtracted in two steps. First, the median signal for data outside the exclusion regions in each data frame was fitted with a second-order polynomial that was a function of time, and then this function was subtracted from the data. Secondly, we measured the mean residual background signal as a function of the frame position within a stim-flash cycle and subtracted these background variations from the data. The alternate background subtraction approach relies upon using data from multiple scan legs; it was generally applied when the standard approach did not properly subtract the background. It was also sometimes used in place of the standard approach on data that did not scan 1° with the medium scan rate (6.5 arcsec $s^{-1}$), as the code was simply more flexible to use. For all forward scan leg data or all reverse scan leg data, we measured the median background level as a position of location within the scan leg. This gives the background signal as a function of position in a scan leg and scan direction that is then applied to each scan leg. Note that these steps will also remove large-scale structure outside of the exclusion regions from the data but do not significantly affect signal from compact and unresolved sources.

(7) In cases where we had data from multiple AORs that overlapped similar regions, we compared the data from pairs of AORs to perform asteroids removal in a three-step process. In the first step, we used MIPS_ENHANCER in the MIPS DAT to make preliminary mosaics of the data from each AOR. In the second step, we subtracted the data from each AOR to produce difference maps in which asteroids and other transient sources will appear as either bright or dark sources but where stationary objects will appear as noise. To identify locations that contained signal from asteroids, we looked for data where signal in either of the AORs was above a set S/N threshold, where the signal in the difference maps was above a set S/N threshold, and where the coverage was above a set threshold; these thresholds needed to be manually adjusted for each comparison. When performing this step, we visually confirmed that the software was identifying transient sources and not stationary sources or background noise. In the final step, we went through the data frames from each AOR and masked out data within 5 pixels (∼12.5 arcsec) of the locations identified as containing emission from the asteroids. When bright asteroids were present, we may identify multiple pixels containing signal from asteroids, and so we often masked out regions significantly larger than 11 pixels.

#### 2.3.2 *MIPS 70–160 μm data frame processing*

The raw 70- and 160-μm data consist of the counts accumulated in each pixel during non-destructive readouts, which are referred to as ramps. We applied the following processing steps to the 70- and 160-μm data frames.

(1) The MIPS DAT program MIPS_SLOPER was applied to the individual data frames to convert the ramps into slopes. This step also removes cosmic rays and readout jumps and includes an electronic non-linearity correction.

(2) The MIPS DAT program MIPS_CALER was applied to adjust the detector responsivity relative to the stim flashes observed during the observations and to apply illumination corrections. This step also includes flux non-linearity and dark current corrections.

(3) Short-term drift in the signal was removed from the data on a pixel-by-pixel basis. The background signal was measured in data falling outside the optical discs of the galaxies and other sources that we identified in exclusion regions similar to those described in the 24-μm data processing. In the 70-μm photometry map data, the background was measured as a function of time and then subtracted from the data. The 160-μm photometry map observations often did not include enough background data to perform this step properly, and the background variations in the 160-μm data were not problematic. However, when the 160-μm photometry map data were to be combined with scan map data, we did measure median background signals in the areas outside the exclusion regions on a frame-by-frame basis and subtract these backgrounds from the data. In the case of the scan map data, the median background signal was measured for each pixel during each stim-flash cycle, a spline procedure was used to describe the background signal as a function of time during the entire AOR, and then this background was subtracted from the data. This procedure also removes gradients and large-scale structure from regions outside the exclusion regions but will generally not affect compact and unresolved sources.

(4) In scan map data, residual variations in the background signal as a function of time since the last stim flash were measured in data outside the exclusion regions and then subtracted from the data.

(5) Any problematic data that we have identified, such as individual 160-μm detector pixels with very poor drift correction over a subset of the data frames or cosmic ray hits on 160-μm detectors that were not filtered out in the previous data processing steps, were masked out manually.

### 2.4 Mosaicking data and post-processing

Final images for the galaxies were created using all suitable AORs using MIPS_ENHANCER in a two-step process. In the first step, MIPS_ENHANCER is used to identify pixels from individual frames that are statistical outliers compared to cospatial pixels from other frames. These pixels are then masked out in enhanced versions of the data frames. In the second step, MIPS_ENHANCER is used to create the final maps. In these images, north is up, east is to the left, and the pixel scales are set to 1.5, 4.5 and 9.0 arcsec $pixel^{-1}$. The pixel scales are based on a convention originally adopted by SINGS, as it allows for fine sampling of PSF substructure and as the pixel scales are integer multiples of each other, which allows for easier comparisons among the images.

The coordinate system reference pixel (CRPIX) keywords in the final flexible image transport system (FITS) images correspond to the centres of the optical discs of the individual target galaxies as given by the NASA/IPAC Extragalactic Database (NED). In cases where two or more galaxies fell in contiguous areas, we typically produced separate final mosaics for each galaxy in which the final maps were constructed using different CRPIX values. We also attempted to do this for a large amount of contiguous data for the Virgo cluster covering a $\sim5^\circ$ region centred on a point near NGC 4486 and an overlapping $\sim2\overset{\circ}{.}5$ region approximately centred on right ascension (RA) 12:28:10 and declination (Dec.) +80:31:35. While we succeeded at doing this with the 70- and 160-μm data, MIPS_ENHANCER failed to execute properly when we attempted this with the 24-μm data, probably because of the relatively large angular area compared to the pixel size. We therefore produced final 24-μm mosaics of each galaxy in this region based on subsets of the contiguous data. In doing this, we ensured that, when producing a 24-μm image of an individual galaxy, we mosaicked all AORs that covered each galaxy that was being mapped. NGC 4380 is an exception as it lies near the ends of a $\sim5^\circ$ scan to the north and a $\sim2\overset{\circ}{.}5$ scan to the south. We therefore measured the 24-μm flux density for this galaxy in the map produced for NGC 4390, which is nearby and which falls in almost all of the scan maps centred on or to the north of NGC 4380. We also had problems with producing 24-μm maps of NGC 4522 with the CRPIX values set to the central coordinates of the galaxy, so we measured the flux density for NGC 4522 in the map centred on NGC 4519. In the cases of NGC 3226/NGC 3227 and NGC 4567/NGC4568, where the galaxies appear close enough that their optical discs overlap, we only made one map with the central position set to the centre of the galaxy that is brighter at optical wavelengths.

We performed a few post-processing steps to the final mosaics. We applied the flux calibration factors given in Table 1 to produce maps in units of MJy sr$^{-1}$. Next, we applied a non-linearity correction to 70-μm pixels that exceeded 66 MJy sr$^{-1}$. This correction, given by Dale et al. (2007) as

$$f_{70\,\mu\mathrm{m}}(\mathrm{true}) = 0.581[f_{70\,\mu\mathrm{m}}(\mathrm{measured})]^{1.13}, \quad (1)$$

is based on data from Gordon et al. (2007). When applying this correction, we adjusted the calculations to include the median background signal measured in the individual data frames before the drift removal steps. We then measured and subtracted residual background surface brightnesses outside the optical discs of the galaxies in regions that did not contain any nearby, resolved galaxies (regardless of whether they were detected in the MIPS bands) or point-like sources. In the case of the 24-μm data, we used multiple small circular regions around the centres of targets. For the 70- and 160-μm images, we used whenever possible two or more regions that were as large as or larger than the optical discs of the target galaxies and that straddled the optical disc of the galaxy. In some of the smaller photometry maps, however, we could not often do this, so we made our best effort to measure the background levels within whatever background regions were observed. In cases where multiple galaxies fall within the final mosaics, we only performed this background subtraction for the central galaxy, although when performing photometry on the other galaxies in these fields, we measured the backgrounds in the same way around the individual targets.

The final images have a few features and artefacts that need to be taken into consideration when using the data. First of all, the large-scale structure outside of the target galaxies in the images has been mostly removed. Although the images, particularly the 160-μm images, may contain some cirrus structure, most of the large-scale features in the cirrus have been removed. Secondly, all scan map data may contain some residual striping. Additionally, the 70-μm images for bright sources are frequently affected by latent image effects that manifest themselves as positive or negative streaks aligned with the scan direction. Finally, many objects falling within the Virgo cluster as well as a few objects in other fields were observed in fields covered only with MIPS scan map data taken using the fast scan rate. The resulting 160-μm data contain large gaps in the coverage, and the data appear more noisy than most other 160-μm data because of the poor sampling.

## 3 PHOTOMETRY

### 3.1 Description of measurements

For most galaxies, we performed aperture photometry within elliptical apertures with major and minor axes that were the greater of either 1.5 times the axis sizes of the $D_{25}$ isophotes given by de Vaucouleurs et al. (1991) or 3 arcmin. The same apertures were used in all three bands for consistency. The lower limit of 3 arcmin on the measurement aperture dimensions ensures that we can measure the total flux densities of 160-μm sources without needing to apply aperture corrections. We performed tests with measuring some unresolved sources in the DGS with different aperture sizes and found that the fraction of the total flux not included within a 3 arcmin aperture for these sources is below the 12 per cent calibration uncertainty of the 160-μm band. In galaxies much larger than 3 arcmin, we found that apertures that were 1.5 times the $D_{25}$ isophote contained all of the measurable signal from the target galaxies. The measured flux densities in apertures larger than this did not change significantly, but the measured flux densities decreased if we used smaller apertures.

For the elliptical galaxies NGC 3640, NGC 4125, NGC 4365, NGC 4374, NGC 4406, NGC 4472, NGC 4486, NGC 4552, NGC 4649, NGC 4660 and NGC 5128, however, we used measurement apertures that were the same size as the $D_{25}$ isophotes. Additionally, for the nearby dwarf elliptical galaxy NGC 205, we used a measurement aperture that was 0.5 times the size of the $D_{25}$ isophote. These were all cases where the 70- and 160-μm emission across most of the optical disc is within 5$\sigma$ of the background noise, and in many cases the emission from the galaxies is not detected. Using smaller apertures in these specific cases allows us to avoid including background sources and artefacts from the data processing, thus allowing us to place better constraints on the flux densities. We also treated NGC 4636 as a special case in which, at 160 μm, we only measured the flux density for the central source because of issues with possible background sources falling within the optical disc of the galaxy (although the background sources are not as problematic at 24 μm, and so the 24-μm measurement is still for the entire optical disc). Additional details on NGC 4636 are given in Section 3.1.1.

A few galaxies in the various samples are so close to each other or so close to other galaxies at equivalent distances that attempting to separate the infrared emission from the different sources would be very difficult. Objects where this is the case are Mrk 1089 (within NGC 1741), NGC 3395/3396, NGC 4038/4039, NGC 4567/4568, NGC 5194/5195 and UM 311 (within NGC 450). In these cases, we

**Table 2.** Special measurement apertures.

| Galaxy | RA (J2000) | Dec. (J2000) | Axis sizes (arcmin) | Position angle[a] (°) |
|---|---|---|---|---|
| Mrk 1089 | 05:01:37.8 | −04:15:28 | 3.0 × 3.0 | 0 |
| NGC 891 | 02:22:33.4 | +42:20:57 | 20.3 × 10.0 | 22 |
| NGC 3395/3396 | 10:49:50.1 | +32:58:58 | 6.0 × 6.0 | 0 |
| NGC 4038/4039 | 12:01:53.0 | −18:52:10 | 10.4 × 10.4 | 0 |
| NGC 4567/4568 | 12:36:34.3 | +11:14:20 | 8.5 × 8.5 | 0 |
| NGC 5194/5195 | 13:29:52.7 | +47:11:43 | 19.6 × 19.6 | 0 |
| NGC 6822 | 19:44:56.6 | −14:47:21 | 30.0 × 30.0 | 0 |
| UM 311 | 01:15:30.4 | −00:51:39 | 4.7 × 3.5 | 72 |

[a]Position angle is defined as degrees from north through east.

used measurement apertures that were large enough to encompass the emission from the target galaxy and all other nearby sources. Details on these special apertures are given in Table 2.

Many of the galaxies in the DGS do not have optical discs defined by de Vaucouleurs et al. (1991), and some do not have optical discs defined anywhere in the literature. These are generally galaxies smaller than the minimum 3 arcmin diameter aperture that we normally use, so we used measurement apertures of that size in many cases. However, for sources fainter than 100 mJy in the 24-μm data, we found that background noise could become an issue when measuring 24-μm flux densities over such large apertures; although the galaxy would clearly be detected at a level much higher than $5\sigma$ in the centre of the aperture, the integral of the aperture would make the detection appear weaker. Hence, for 24-μm DGS sources that were fainter than 10 mJy and did not appear extended in the 24-μm data, we used apertures with 1 arcmin diameters and divided the data by 0.93, which is an aperture correction that we derived empirically from bright point-like sources in the DGS.

NGC 891 and NGC 6822 were treated as special cases for selecting the measurement apertures. Details are given in the photometry notes below, and the parameters describing the measurement apertures are given in Table 2.

Before performing the photometry on individual galaxies, we identified and masked out emission that appeared to be unrelated to the target galaxies. We visually identified and masked out artefacts from the data processing in the final mosaics, such as bright or dark pixels near the edges of mapped fields and streaking in the 70-μm images related to latent image effects. We also statistically checked for pixels that were $5\sigma$ below the background, which are almost certainly associated with artefacts except when this becomes statistically probable in apertures containing large numbers of pixels. In cases where we determined that the $<-5\sigma$ pixels were data processing artefacts or excessively noisy pixels, we masked them out. When other galaxies appeared close to individual galaxies in which we were measuring flux densities but when the optical discs did not overlap significantly, we masked out the adjacent galaxies. We also masked out emission from unresolved sources, particularly unresolved 24-μm sources, that did not appear to be associated with the target galaxies and that appeared significantly brighter than the emission in the regions where we measured the background. Most of these sources appeared between the $D_{25}$ isophote and the measurement aperture. In cases where the galaxies contained very compact 24-μm emission (as is the case for many elliptical and S0 galaxies), we also masked out unresolved sources within but near the $D_{25}$ isophote. A few unresolved sources within the $D_{25}$ isophote appeared as bright, unresolved sources in Digitized Sky Survey or Two Micron All Sky Survey data, indicating that they were foreground stars, and we masked them out as well. In many 24-μm images, the measured flux densities changed by less than 4 per cent (the calibration uncertainty) when the unresolved sources were removed.

As stated above, in cases where the MIPS 160-μm data for individual galaxies consist of only scan map data taken at the fast scan rate, our final 160-μm maps include gaps in the coverage. To make 160-μm measurements, we have interpolated the signal across these gaps using nearest neighbour sampling techniques. We also applied this interpolation technique to 160-μm data for the regions in the optical discs (but not in the whole measurement aperture, which may fall outside the scan region) of IC 1048, NGC 4192, NGC 4535 and NGC 5692. In many other cases, the observed regions did not completely cover the optical discs of the target galaxies. We normally measured the flux densities for the regions covered in the observed regions. Cases where the observed regions did not cover $\gtrsim 90$ per cent of the optical discs are noted in the photometry tables. Although we believe that these data are reliable (especially since the observations appear to cover most of the emission that is seen in the other bands), people using these data should still be aware of the limitations of these data.

As a quality check on the photometry, we examined the 24/70-, 24/160- and 70/160-μm flux density ratios to identify any galaxies that may have discrepant colours (e.g. abnormally high 24/70-μm and low 70/160-μm colours, which would be indicative of problems with unmasked negative pixels in the final 70-μm images). In such discrepant cases, we examined the images for unmasked artefacts, masked out the artefacts when identified, and repeated the photometry.

The globally integrated flux densities for the galaxies in the four different samples are listed in Tables 3–6. No colour corrections have been applied to these data. We include three sources of uncertainty. The first source is the calibration uncertainty. The second source is the uncertainty based on the error map. Each pixel in the error map is based on the standard deviation of the overlapping pixels from the individual data frames; the uncertainties will include both instrumental background noise and shot noise from the astronomical sources. To calculate the total uncertainty traced by the data in the error map, we used the square root of the sum of the square of the error map pixels in the measurement region. The third source of uncertainty is from background noise (which includes both instrumental and astronomical sources of noise) measured in the background regions. The total uncertainties are calculated by adding these three sources of uncertainty in quadrature. Sources that are less than $5\sigma$ detections within the measurement apertures compared to the combination of the error map and background noise are reported as $5\sigma$ upper limits. Sources in which the surface brightness within the measurement aperture is not detected at the $5\sigma$ level for regions unaffected by foreground/background sources or artefacts are reported as upper limits; in these cases, the integrated flux densities within the apertures are used as upper limits. This second case occurs when the target aperture includes emission from diffuse, extended emission (as described for NGC 4552 below) or large-scale artefacts that are impossible to mask out for the photometry.

### *3.1.1 Notes on photometry*

Aside from typical issues described above with the data processing and photometry, we encountered multiple problems that were unique to individual targets. Notes on these issues (in the order in which the galaxies appear in the table) are listed below.

**Table 3.** Photometry for the Very Nearby Galaxies Survey.

| Galaxy | Optical disc RA (J2000)[a] | Dec. (J2000)[a] | Axes (arcmin)[b] | Position angle[b,c] (°) | Wavelength (μm) | Flux density measurement (Jy) | Flux density uncertainty (Jy)[d] Calibration | Error map | Background | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| NGC 205 | 00:40:22.0 | +41:41:07 | 21.9 × 11.0 | 170 | 24 | 0.1089 | 0.0044 | 0.0005 | 0.0008 | 0.0044 |
| | | | | | 70 | 1.302 | 0.130 | 0.019 | 0.023 | 0.134 |
| | | | | | 160 | 8.98 | 1.08 | 0.03 | 0.05 | 1.08 |
| NGC 891[e] | 02:22:33.4 | +42:20:57 | 13.5 × 2.5 | 22 | 24 | 6.4531 | 0.2581 | 0.0005 | 0.0007 | 0.2581 |
| | | | | | 70 | 97.122 | 9.712 | 0.045 | 0.018 | 9.712 |
| | | | | | 160 | 287.27 | 34.47 | 8.72 | 0.04 | 35.56 |
| NGC 1068 | 02:42:40.7 | −00:00:48 | 7.1 × 6.0 | 70 | 24 | | | | | |
| | | | | | 70 | 189.407 | 18.941 | 0.491 | 0.058 | 18.947 |
| | | | | | 160 | 237.39 | 28.49 | 5.53 | 0.06 | 29.02 |
| NGC 2403 | 07:36:51.4 | +65:36:09 | 21.9 × 12.3 | 127 | 24 | 6.0161 | 0.2406 | 0.0022 | 0.0019 | 0.2407 |
| | | | | | 70 | 81.710 | 8.171 | 0.057 | 0.052 | 8.171 |
| | | | | | 160 | 221.04 | 26.53 | 0.24 | 0.11 | 26.53 |
| NGC 3031 | 09:55:33.1 | +69:03:55 | 26.9 × 14.1 | 157 | 24 | 5.2748 | 0.2110 | 0.0017 | 0.0024 | 0.2110 |
| | | | | | 70 | 81.049 | 8.105 | 0.063 | 0.080 | 8.106 |
| | | | | | 160 | 316.30 | 37.96 | 0.97 | 0.40 | 37.97 |
| NGC 4038[f] | | | | | 24 | 5.8226 | 0.2329 | 0.0073 | 0.0012 | 0.2330 |
| | | | | | 70 | 45.949 | 4.595 | 0.148 | 0.035 | 4.597 |
| | | | | | 160 | 80.28 | 9.63 | 3.62 | 0.06 | 10.29 |
| NGC 4125 | 12:08:06.0 | +65:10:27 | 5.8 × 3.2 | 95 | 24 | 0.0790 | 0.0032 | 0.0002 | 0.0003 | 0.0032 |
| | | | | | 70 | 1.014 | 0.101 | 0.008 | 0.008 | 0.102 |
| | | | | | 160 | 1.37 | 0.16 | 0.01 | 0.01 | 0.17 |
| NGC 4151 | 12:10:32.5 | +39:24:21 | 6.3 × 4.5 | 50 | 24 | 4.5925 | 0.1837 | 0.0104 | 0.0005 | 0.1840 |
| | | | | | 70 | 5.415 | 0.541 | 0.027 | 0.013 | 0.542 |
| | | | | | 160 | 9.38 | 1.13 | 0.02 | 0.02 | 1.13 |
| NGC 5128 | 13:25:27.6 | −43:01:09 | 25.7 × 20.0 | 35 | 24 | 24.0374 | 0.9615 | 0.0135 | 0.0028 | 0.9616 |
| | | | | | 70 | 263.165 | 26.316 | 0.226 | 0.068 | 26.318 |
| | | | | | 160 | 582.51 | 69.90 | 22.50 | 0.14 | 73.43 |
| NGC 5194[f] | | | | | 24 | 14.2309 | 0.5692 | 0.0037 | 0.0015 | 0.5693 |
| | | | | | 70 | 151.000 | 15.100 | 0.123 | 0.045 | 15.101 |
| | | | | | 160 | 458.44 | 55.01 | 7.80 | 0.11 | 55.56 |
| NGC 5236 | 13:37:00.9 | −29:51:57 | 12.9 | | 24 | 40.4266 | 1.6171 | 0.0263 | 0.0017 | 1.6173 |
| | | | | | 70 | 312.808 | 31.281 | 0.290 | 0.051 | 31.282 |
| | | | | | 160 | 798.23 | 95.78 | 9.95 | 0.13 | 96.30 |
| Arp 220 | 15:34:57.1 | +23:30:11 | 1.5 | | 24 | | | | | |
| | | | | | 70 | 74.976 | 7.498 | 0.309 | 0.023 | 7.504 |
| | | | | | 160 | 54.88 | 6.59 | 1.38 | 0.02 | 6.73 |

[a]Data are from NED.
[b]Data are from de Vaucouleurs et al. (1991) unless otherwise specified. If de Vaucouleurs et al. (1991) specify both the major-to-minor axis ratio and the position angle, then both axes and the position angle are listed. If de Vaucouleurs et al. (1991) did not specify either of these data, then we performed photometry on circular regions, and so only the major axis is specified.
[c]The position angle is defined as degrees from north through east.
[d]Details on the sources of these uncertainties are given in Section 3.1.
[e]A special measurement aperture was used for NGC 891. See Table 2.
[f]These objects consist of two galaxies with optical discs that overlap. See Table 2 for the dimensions of the measurement apertures for these objects.

*Notes on the VNGS data. Arp 220*. The centre of the galaxy, which is unresolved in the MIPS bands, saturated the 24-μm detector, and so no 24-μm flux density is reported for the source. The 160-μm error map contains two anomalously high pixels (pixels with error map values at least an order of magnitude higher than the image map values) located off the peak of the emission. We ascertained that the corresponding image map pixels did not look anomalous compared to adjacent pixels, so the unusually high values in the error map were probably some type of artefact of the data reduction possibly related to a combination of high surface brightness issues and coverage issues. We therefore excluded these pixels when calculating the error map uncertainty.

*NGC 891*. This is an edge-on spiral galaxy in which the central plane is very bright, and so features that look similar to Airy rings (except that they are linear rather than ring shaped) appear above and below the plane of the galaxy in the 160-μm image. The measurement aperture we used for all three bands has a major axis corresponding to 1.5 times the $D_{25}$ isophote but a much broader minor axis that encompasses the vertically extended emission. Note that this is the only edge-on galaxy where we have encountered this problem.

*NGC 1068*. This is another galaxy that is unresolved in the MIPS bands and that saturates the 24-μm detector. It is not practical to perform 24-μm photometry measurements on this galaxy. The 160-μm error map contains a few anomalously high pixels (pixels

**Table 4.** Photometry for the Dwarf Galaxies Survey.

| Galaxy | Optical disc | | | | Wavelength (μm) | Flux density measurement (Jy) | Flux density uncertainty (Jy)[d] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RA (J2000)[a] | Dec. (J2000)[a] | Axes (arcmin)[b] | Position angle[b,c] (°) | | | Calibration | Error map | Background | Total |
| IC 10 | 00:20:17.3 | +59:18:14 | 6.3 | | 24 | 9.8188 | 0.3928 | 0.0136 | 0.0013 | 0.3930 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| HS 0017+1055 | 00:20:21.4 | +11:12:21 | | | 24 | 0.0237 | 0.0009 | 0.0005 | 0.0009 | 0.0014 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| Haro 11 | 00:36:52.4 | −33:33:19 | | | 24 | 2.3046 | 0.0922 | 0.0123 | 0.0005 | 0.0930 |
| | | | | | 70 | 4.912 | 0.491 | 0.038 | 0.007 | 0.493 |
| | | | | | 160 | 2.01 | 0.24 | 0.01 | 0.02 | 0.24 |
| HS 0052+2536 | 00:54:56.3 | +25:53:08 | | | 24 | 0.0207 | 0.0008 | 0.0004 | 0.0008 | 0.0012 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| UM 311[e] | | | | | 24 | 0.3289 | 0.0132 | 0.0008 | 0.0009 | 0.0132 |
| | | | | | 70 | 3.075 | 0.308 | 0.008 | 0.008 | 0.308 |
| | | | | | 160 | 6.62 | 0.79 | 0.02 | 0.01 | 0.79 |
| NGC 625 | 01:35:04.6 | −41:26:10 | 5.8 × 1.9 | 92 | 24 | 0.8631 | 0.0345 | 0.0016 | 0.0003 | 0.0346 |
| | | | | | 70 | 6.252 | 0.625 | 0.036 | 0.012 | 0.626 |
| | | | | | 160 | 7.87 | 0.94 | 0.03 | 0.02 | 0.95 |
| UGCA 20 | 01:43:14.7 | +19:58:32 | 3.1 × 0.8 | 153 | 24 | <0.0085 | | | | |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| UM 133 | 01:44:41.2 | +40:53:26 | | | 24 | 0.0094 | 0.0004 | 0.0002 | 0.0003 | 0.0005 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| UM 382 | 01:58:09.3 | −00:06:38 | | | 24 | | | | | |
| | | | | | 70 | <0.070 | | | | |
| | | | | | 160 | | | | | |
| NGC 1140 | 02:54:33.5 | −10:01:40 | 1.7 × 0.9 | 10 | 24 | 0.3764 | 0.0151 | 0.0009 | 0.0006 | 0.0151 |
| | | | | | 70 | 3.507 | 0.351 | 0.020 | 0.008 | 0.351 |
| | | | | | 160 | 3.67 | 0.44 | 0.01 | 0.01 | 0.44 |
| SBS 0335−052 | 03:37:44.0 | −05:02:40 | | | 24 | 0.0768 | 0.0031 | 0.0005 | 0.0005 | 0.0032 |
| | | | | | 70 | 0.051 | 0.005 | 0.005 | 0.006 | 0.009 |
| | | | | | 160 | <0.07 | | | | |
| NGC 1569 | 04:30:49.0 | −64:50:53 | 3.6 × 1.8 | 120 | 24 | 7.7189 | 0.3088 | 0.0091 | 0.0010 | 0.3089 |
| | | | | | 70 | 46.120 | 4.612 | 0.068 | 0.029 | 4.613 |
| | | | | | 160 | 33.49 | 4.02 | 0.11 | 0.02 | 4.02 |
| NGC 1705 | 04:54:13.5 | −53:21:40 | 1.9 × 1.4 | 50 | 24 | 0.0532 | 0.0021 | 0.0000 | 0.0001 | 0.0021 |
| | | | | | 70 | 1.315 | 0.132 | 0.002 | 0.004 | 0.132 |
| | | | | | 160 | 1.29 | 0.16 | 0.01 | 0.01 | 0.16 |
| Mrk 1089[e] | | | | | 24 | 0.5252 | 0.0210 | 0.0008 | 0.0003 | 0.0210 |
| | | | | | 70 | 1.123 | 0.112 | 0.004 | 0.004 | 0.112 |
| | | | | | 160 | | | | | |
| II Zw 40 | 05:55:42.6 | +03:23:32 | | | 24 | 1.6545 | 0.0662 | 0.0063 | 0.0006 | 0.0665 |
| | | | | | 70 | 5.438 | 0.544 | 0.031 | 0.011 | 0.545 |
| | | | | | 160 | | | | | |
| Tol 0618−402 | 06:20:02.5 | −40:18:09 | | | 24 | <0.0015 | | | | |
| | | | | | 70 | <0.037 | | | | |
| | | | | | 160 | <0.42 | | | | |
| NGC 2366 | 07:28:54.6 | +69:12:57 | 8.1 × 3.3 | 25 | 24 | 0.6919 | 0.0277 | 0.0013 | 0.0007 | 0.0277 |
| | | | | | 70 | 5.230 | 0.523 | 0.021 | 0.019 | 0.524 |
| | | | | | 160 | 5.50 | 0.66 | 0.21 | 0.03 | 0.69 |
| HS 0822+3542 | 08:25:55.5 | +35:32:32 | | | 24 | 0.0032 | 0.0001 | 0.0001 | 0.0002 | 0.0003 |
| | | | | | 70 | 0.043 | 0.004 | 0.004 | 0.006 | 0.008 |
| | | | | | 160 | <0.04 | | | | |
| He 2−10 | 08:36:15.1 | −26:24:34 | | | 24 | 5.7368 | 0.2295 | 0.0262 | 0.0007 | 0.2310 |
| | | | | | 70 | 17.969 | 1.797 | 0.102 | 0.009 | 1.800 |
| | | | | | 160 | 13.41 | 1.61 | 0.05 | 0.01 | 1.61 |
| UGC 04483 | 08:37:03.0 | +69:46:31 | | | 24 | 0.0101 | 0.0004 | 0.0001 | 0.0003 | 0.0005 |
| | | | | | 70 | 0.142 | 0.014 | 0.003 | 0.006 | 0.016 |
| | | | | | 160 | 0.27 | 0.03 | 0.01 | 0.00 | 0.03 |

**Table 4** – *continued*

| Galaxy | Optical disc | | | | Wavelength ($\mu$m) | Flux density measurement (Jy) | Flux density uncertainty (Jy)[d] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RA (J2000)[a] | Dec. (J2000)[a] | Axes (arcmin)[b] | Position angle[b,c] (°) | | | Calibration | Error map | Background | Total |
| I Zw 18 | 09:34:02.0 | +55:14:28 | | | 24 | 0.0061 | 0.0002 | 0.0001 | 0.0002 | 0.0003 |
| | | | | | 70 | 0.042 | 0.004 | 0.002 | 0.004 | 0.006 |
| | | | | | 160 | <0.12 | | | | |
| Haro 2 | 10:32:31.9 | +54:24:03 | | | 24 | 0.8621 | 0.0345 | 0.0015 | 0.0001 | 0.0345 |
| | | | | | 70 | 3.988 | 0.399 | 0.019 | 0.005 | 0.399 |
| | | | | | 160 | 3.09 | 0.37 | 0.01 | 0.01 | 0.37 |
| Haro 3 | 10:45:22.4 | +55:57:37 | | | 24 | 0.8514 | 0.0341 | 0.0027 | 0.0004 | 0.0342 |
| | | | | | 70 | 4.898 | 0.490 | 0.018 | 0.007 | 0.490 |
| | | | | | 160 | 3.93 | 0.47 | 0.01 | 0.01 | 0.47 |
| Mrk 153 | 10:49:05.0 | +52:20:08 | | | 24 | 0.0358 | 0.0014 | 0.0003 | 0.0005 | 0.0015 |
| | | | | | 70 | 0.260 | 0.026 | 0.004 | 0.007 | 0.027 |
| | | | | | 160 | | | | | |
| VII Zw 403 | 11:27:59.8 | +78:59:39 | | | 24 | 0.0329 | 0.0013 | 0.0002 | 0.0005 | 0.0014 |
| | | | | | 70 | 0.425 | 0.043 | 0.005 | 0.007 | 0.043 |
| | | | | | 160 | 0.31 | 0.04 | 0.00 | 0.01 | 0.04 |
| Mrk 1450 | 11:38:35.6 | +57:52:27 | | | 24 | 0.0570 | 0.0023 | 0.0003 | 0.0004 | 0.0023 |
| | | | | | 70 | 0.264 | 0.026 | 0.004 | 0.005 | 0.027 |
| | | | | | 160 | 0.15 | 0.02 | 0.00 | 0.01 | 0.02 |
| UM 448 | 11:42:12.4 | +00:20:03 | | | 24 | 0.6425 | 0.0257 | 0.0018 | 0.0007 | 0.0258 |
| | | | | | 70 | 3.703 | 0.370 | 0.021 | 0.015 | 0.371 |
| | | | | | 160 | 2.67 | 0.32 | 0.01 | 0.01 | 0.32 |
| UM 461 | 11:51:33.3 | −02:22:22 | | | 24 | 0.0344 | 0.0014 | 0.0002 | 0.0029 | 0.0032 |
| | | | | | 70 | 0.090 | 0.009 | 0.003 | 0.011 | 0.014 |
| | | | | | 160 | 0.10 | 0.01 | 0.00 | 0.01 | 0.01 |
| SBS 1159+545 | 12:02:02.3 | +54:15:50 | | | 24 | 0.0062 | 0.0002 | 0.0001 | 0.0002 | 0.0004 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| SBS 1211+540 | 12:14:02.4 | +53:45:17 | | | 24 | 0.0033 | 0.0001 | 0.0001 | 0.0002 | 0.0003 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| NGC 4214 | 12:15:39.1 | +36:19:37 | 8.5 | | 24 | 2.1044 | 0.0842 | 0.0015 | 0.0012 | 0.0842 |
| | | | | | 70 | 24.049 | 2.405 | 0.043 | 0.032 | 2.406 |
| | | | | | 160 | 38.18 | 4.58 | 0.34 | 0.05 | 4.59 |
| Tol 1214−277 | 12:17:17.0 | −28:02:33 | | | 24 | 0.0068 | 0.0003 | 0.0001 | 0.0002 | 0.0003 |
| | | | | | 70 | 0.073 | 0.007 | 0.004 | 0.005 | 0.010 |
| | | | | | 160 | | | | | |
| HS 1222+3741 | 12:24:36.7 | +37:24:37 | | | 24 | | | | | |
| | | | | | 70 | 0.062 | 0.006 | 0.004 | 0.007 | 0.010 |
| | | | | | 160 | | | | | |
| Mrk 209 | 12:26:16.0 | +48:29:37 | | | 24 | 0.0587 | 0.0023 | 0.0003 | 0.0005 | 0.0024 |
| | | | | | 70 | 0.466 | 0.047 | 0.004 | 0.004 | 0.047 |
| | | | | | 160 | 0.18 | 0.02 | 0.00 | 0.01 | 0.02 |
| NGC 4449 | 12:28:11.8 | +44:05:40 | 6.2 × 4.4 | 45 | 24 | 3.2863 | 0.1315 | 0.0010 | 0.0008 | 0.1315 |
| | | | | | 70 | 43.802 | 4.380 | 0.053 | 0.019 | 4.381 |
| | | | | | 160 | 78.09 | 9.37 | 0.70 | 0.03 | 9.40 |
| SBS 1249+493 | 12:51:52.4 | +49:03:28 | | | 24 | 0.0043 | 0.0002 | 0.0001 | 0.0002 | 0.0003 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| NGC 4861 | 12:59:02.3 | +34:51:34 | 4.0 × 1.5 | 15 | 24 | 0.3657 | 0.0146 | 0.0012 | 0.0008 | 0.0147 |
| | | | | | 70 | 1.971 | 0.197 | 0.012 | 0.010 | 0.198 |
| | | | | | 160 | 2.00 | 0.24 | 0.01 | 0.02 | 0.24 |
| HS 1304+3529 | 13:06:24.1 | +35:13:43 | | | 24 | 0.0122 | 0.0005 | 0.0004 | 0.0007 | 0.0009 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| Pox 186 | 13:25:48.6 | −11:36:38 | | | 24 | 0.0108 | 0.0004 | 0.0005 | 0.0009 | 0.0011 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| NGC 5253 | 13:39:55.9 | −31:38:24 | 5.0 × 1.9 | 45 | 24 | | | | | |
| | | | | | 70 | 23.626 | 2.363 | 0.074 | 0.015 | 2.364 |
| | | | | | 160 | 17.35 | 2.08 | 0.05 | 0.03 | 2.08 |

**Table 4** – *continued*

| Galaxy | Optical disc RA (J2000)[a] | Dec. (J2000)[a] | Axes (arcmin)[b] | Position angle[b,c] (°) | Wavelength (μm) | Flux density measurement (Jy) | Flux density uncertainty (Jy)[d] Calibration | Error map | Background | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| SBS 1415+437 | 14:17:01.3 | +43:30:05 | | | 24 | 0.0187 | 0.0007 | 0.0003 | 0.0005 | 0.0009 |
| | | | | | 70 | 0.177 | 0.018 | 0.004 | 0.006 | 0.019 |
| | | | | | 160 | <0.06 | | | | |
| HS 1424+3836 | 14:26:28.1 | +38:22:59 | | | 24 | | | | | |
| | | | | | 70 | <0.024 | | | | |
| | | | | | 160 | | | | | |
| HS 1442+4250 | 14:44:12.8 | +42:37:44 | | | 24 | 0.0066 | 0.0003 | 0.0001 | 0.0001 | 0.0003 |
| | | | | | 70 | 0.079 | 0.008 | 0.004 | 0.006 | 0.010 |
| | | | | | 160 | <0.10 | | | | |
| SBS 1533+574 | 15:34:13.8 | +57:17:06 | | | 24 | | | | | |
| | | | | | 70 | 0.270 | 0.027 | 0.004 | 0.005 | 0.028 |
| | | | | | 160 | | | | | |
| NGC 6822[f] | 19:44:56.6 | −14:47:21 | 15.5 | | 24 | 4.5230 | 0.1809 | 0.0027 | 0.0032 | 0.1810 |
| | | | | | 70 | 52.413 | 5.241 | 0.082 | 0.096 | 5.243 |
| | | | | | 160 | 109.44 | 13.13 | 0.61 | 0.20 | 13.15 |
| Mrk 930 | 23:31:58.2 | +28:56:50 | | | 24 | 0.1985 | 0.0079 | 0.0005 | 0.0006 | 0.0080 |
| | | | | | 70 | 1.159 | 0.116 | 0.007 | 0.006 | 0.116 |
| | | | | | 160 | 0.96 | 0.12 | 0.01 | 0.02 | 0.12 |
| HS 2352+2733 | 23:54:56.7 | +27:49:59 | | | 24 | 0.0026 | 0.0001 | 0.0001 | 0.0003 | 0.0003 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |

[a]Data are from NED.
[b]Data are from de Vaucouleurs et al. (1991) unless otherwise specified. If de Vaucouleurs et al. (1991) specify both the major-to-minor axis ratio and the position angle, then both axes and the position angle are listed. If de Vaucouleurs et al. (1991) did not specify either of these data, then we performed photometry on circular regions, and so only the major axis is specified. If no optical dimensions are specified, then we performed photometry on a 3 arcmin diameter circular region centred on the source (although in 24-μm data where the source is fainter than 10 mJy, we used a 1-arcmin diameter circle; see the text for details).
[c]The position angle is defined as degrees from north through east.
[d]Details on the sources of these uncertainties are given in Section 3.1.
[e]Special measurement apertures were used for these targets because of the presence of nearby associated sources. See Table 2.
[f]A special measurement aperture was used for NGC 6822. See Table 2.

with error map values at least an order of magnitude higher than the image map values). This seemed similar to the phenomenon described for the anomalous 160-μm error map pixels for Arp 220. We excluded these pixels when calculating the error map uncertainty.

*NGC 3031*. The 160-μm image includes residual cirrus emission between the $D_{25}$ isophote and the measurement aperture that was masked out when calculating the 160-μm flux density. See Sollima et al. (2010) and Davies et al. (2010b) for details on the features.

*NGC 3034*. The galaxy saturates the MIPS detectors in all three bands and causes unusually severe artefacts to appear in the data, and so we report no photometric measurements for this galaxy.

*NGC 4038/4039*. The 70-μm image is strongly affected by streaking from latent image effects.

*NGC 5128*. The centre of the galaxy produced latent image effects in the 70-μm data that appear as a broad streak in the final image. The artefact was masked out when photometry was performed.

*NGC 5236*. The central 8 arcsec of the galaxy saturated the 24- and 160-μm data, but this region appears to contribute a relatively small fraction of the total emission from NGC 5236. We think the 24-μm measurements should still be reliable to within the calibration uncertainty of 4 per cent. As for the 160-μm image, we interpolated across the single central saturated pixel to estimate the flux density for the pixel; the correction is much smaller than the calibration uncertainty.

*Notes on the DGS data. HS 0052+2536*. The 24-μm image shows an unresolved 24-μm source at the central position of HS 0052+2536 and an unresolved 24-μm source with a similar surface brightness at the central position of HS 0052+2537, which is located ∼15 arcsec to the north. We masked out HS 0052+2537 when performing photometry.

*IC 10*. This galaxy was observed with MIPS in only the photometry map mode. However, the photometry map mode is intended for objects smaller than 5 arcmin, while the optical disc of IC 10 and the infrared emission from it are much more extended than this. While $\gtrsim$90 per cent of the optical disc was covered at 24 μm, only part of the galaxy was observed at 70 and 160 μm, and a significant fraction of the infrared emission may have fallen outside the observed regions. Given this, we will not report 70- and 160-μm measurements for this galaxy.

*Mrk 153*. In the 160-μm image, the galaxy becomes blended with another galaxy to the east. We therefore do not report 160-μm flux densities for this galaxy.

*NGC 5253*. This is another case where the galaxy is unresolved in the MIPS bands and where the galaxy saturated the 24-μm detector, which is why we report no 24-μm flux density for this galaxy.

*NGC 6822*. The galaxy has an extension to the south (Cannon et al. 2006) that is not included within the optical disc given by de Vaucouleurs et al. (1991), so for photometry, we used a 30 arcmin diameter circle centred on the optical position of the galaxy given by NED. This galaxy also lies in a field with cirrus structure with the same angular scale as the galaxy. The version of the 70- and 160-μm data processing that we applied has removed the gradient in the cirrus emission present in this part of the sky, which causes the

**Table 5.** Photometry for the *Herschel* Reference Survey. (This table is available in its entirety in the online journal. A portion is shown here for guidance regarding its form and content.)

| Galaxy | HRS | Optical disc | | | | Wavelength | Flux density | Flux density uncertainty (Jy)[e] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | number[a] | RA (J2000)[b] | Dec. (J2000)[b] | Axes (arcmin)[c] | Position angle[c,d] (°) | (μm) | measurement (Jy) | Calibration | Error map | Background | Total |
| NGC 3226 | 3 | 10:23:27.4 | +19:53:55 | 3.2 × 2.8 | 15 | 24 | 0.0250 | 0.0010 | 0.0003 | 0.0006 | 0.0012 |
| | | | | | | 70 | 0.459 | 0.046 | 0.009 | 0.011 | 0.048 |
| | | | | | | 160 | | | | | |
| NGC 3227 | 4 | 10:23:30.5 | +19:51:54 | 5.4 × 3.6 | 155 | 24 | 1.7173 | 0.0687 | 0.0067 | 0.0010 | 0.0690 |
| | | | | | | 70 | 9.033 | 0.903 | 0.044 | 0.018 | 0.905 |
| | | | | | | 160 | 18.19[f] | 2.18 | 0.05 | 0.02 | 2.18 |
| NGC 3254 | 8 | 10:29:19.9 | +29:29:31 | 5.0 × 1.6 | 46 | 24 | 0.0927 | 0.0037 | 0.0005 | 0.0007 | 0.0038 |
| | | | | | | 70 | | | | | |
| | | | | | | 160 | | | | | |
| NGC 3338 | 15 | 10:42:07.5 | +13:44:49 | 5.9 × 3.6 | 100 | 24 | 0.4578 | 0.0183 | 0.0003 | 0.0005 | 0.0183 |
| | | | | | | 70 | | | | | |
| | | | | | | 160 | | | | | |
| NGC 3370 | 17 | 10:47:04.0 | +17:16:25 | 3.2 × 1.8 | 148 | 24 | 0.3836 | 0.0153 | 0.0005 | 0.0009 | 0.0154 |
| | | | | | | 70 | 5.194 | 0.519 | 0.018 | 0.012 | 0.520 |
| | | | | | | 160 | 10.30 | 1.24 | 0.02 | 0.02 | 1.24 |
| NGC 3395 | 20 | | | | | 24 | 1.1400 | 0.0456 | 0.0013 | 0.0010 | 0.0456 |
| /3396[h] | /(N/A) | | | | | 70 | 11.927 | 1.193 | 0.025 | 0.027 | 1.193 |
| | | | | | | 160 | 17.26 | 2.07 | 0.03 | 0.04 | 2.07 |
| NGC 3414 | 22 | 10:51:16.2 | +27:58:30 | 3.5 | | 24 | 0.0430 | 0.0017 | 0.0004 | 0.0007 | 0.0019 |
| | | | | | | 70 | 0.428 | 0.043 | 0.011 | 0.016 | 0.047 |
| | | | | | | 160 | | | | | |
| NGC 3424 | 23 | 10:51:46.3 | +32:54:03 | 2.8 × 0.8 | 112 | 24 | 0.7181 | 0.0287 | 0.0012 | 0.0005 | 0.0288 |
| | | | | | | 70 | 9.398 | 0.940 | 0.035 | 0.012 | 0.941 |
| | | | | | | 160 | 15.93 | 1.91 | 0.04 | 0.03 | 1.91 |
| NGC 3430 | 24 | 10:52:11.4 | +32:57:02 | 4.0 × 2.2 | 30 | 24 | 0.4101 | 0.0164 | 0.0004 | 0.0006 | 0.0164 |
| | | | | | | 70 | 5.683 | 0.568 | 0.015 | 0.021 | 0.569 |
| | | | | | | 160 | 14.36 | 1.72 | 0.03 | 0.02 | 1.72 |
| NGC 3448 | 31 | 10:54:39.2 | +54:18:19 | 5.6 × 1.8 | 65 | 24 | 0.5782 | 0.0231 | 0.0009 | 0.0005 | 0.0232 |
| | | | | | | 70 | 6.730 | 0.673 | 0.024 | 0.012 | 0.673 |
| | | | | | | 160 | 9.43[f] | 1.13 | 0.20 | 0.47 | 1.24 |

[a] The HRS number corresponds to the numbers given by Boselli et al. (2010).
[b] Data are from NED.
[c] Data are from de Vaucouleurs et al. (1991) unless otherwise specified. If de Vaucouleurs et al. (1991) specify both the major-to-minor axis ratio and the position angle, then both axes and the position angle are listed. If de Vaucouleurs et al. (1991) did not specify either of these data, then we performed photometry on circular regions, and so only the major axis is specified.
[d] The position angle is defined as degrees from north through east.
[e] Details on the sources of these uncertainties are given in Section 3.1.
[f] These measurements are from data in which significant portions of the optical discs (>10 per cent) of the galaxies were not covered in this specific waveband. The measurements here are for the region that was covered in the MIPS data. We have applied no corrections for the missing flux density.
[g] These 160-μm measurements are for galaxies that were covered in scan map observations in which the final 160-μm images for these galaxies contain NaN values within the optical disc as a consequence of incomplete coverage. This typically occurs when scan maps are performed using the fast scan rate, although NaN values within the optical discs of galaxies occasionally appear in other data. The 160-μm measurements for these galaxies are based upon interpolating over these pixels; see the text for details.
[h] These objects consist of two galaxies with optical discs that overlap. See Table 2 for the dimensions of the measurement apertures for these objects.

final map to appear significantly different from the SINGS version of the map for this specific galaxy.

*SBS 1249+493*. The 24-μm image includes a bright central source and a fainter source ∼12 arcsec to the south. It is unclear as to whether this source is associated with the galaxy; we masked it out before performing flux density measurements.

*Tol 0618−402*. The brightest feature in the 160-μm photometry map image is a streak-like feature running from north-west to south-east near the location of the galaxy. It is unclear from this image alone if this is an artefact of the data processing or a real large-scale feature, although based on what we have seen in similar 160-μm photometry map data, the latter may be more likely. No feature in the image appears to correspond to the source itself, and so we reported the integrated 160-μm flux density within the 3 arcmin diameter aperture on the source as the upper limit on the emission, using regions flanking this region as the best background measurements available.

*Tol 1214−277*. We excluded a marginally resolved source at approximately RA = 12:17:17.7, Dec. = −28:02:56 from the 24- and 70-μm measurements, as this is likely to be a background galaxy. However, the source became blended with Tol 1214−277 at 160 μm, so we do not report 160-μm flux density measurements for Tol 1214−277.

*II Zw 40*. The 160-μm image contains only a few arcmin$^2$ of background. The 160-μm background appears to contain a significant surface brightness gradient, which may be expected given that the galaxy lies at a galactic latitude of ∼−11. Additionally, we had difficulty reproducing the 160-μm flux density published by

**Table 6.** Photometry for additional *Herschel* Virgo Cluster Survey galaxies.[a]

| Galaxy | Optical disc RA (J2000)[b] | Dec. (J2000)[b] | Axes (arcmin)[c] | Position angle[c,d] (°) | Wavelength (μm) | Flux density measurement (Jy) | Flux density uncertainty (Jy)[e] Calibration | Error map | Background | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| NGC 4165 | 12:12:11.7 | +13:14:47 | 1.3 × 0.9 | 160 | 24 | 0.0264 | 0.0011 | 0.0003 | 0.0004 | 0.0012 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| NGC 4234 | 12:17:09.1 | +03:40:59 | 1.3 | | 24 | 0.1547 | 0.0062 | 0.0002 | 0.0003 | 0.0062 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| NGC 4252 | 12:18:30.8 | +05:33:34 | 1.5 × 0.4 | 48 | 24 | 0.0098 | 0.0004 | 0.0002 | 0.0002 | 0.0005 |
| | | | | | 70 | 0.183 | 0.018 | 0.005 | 0.005 | 0.020 |
| | | | | | 160 | 0.46 | 0.06 | 0.00 | 0.02 | 0.06 |
| NGC 4266 | 12:19:42.3 | +05:32:18 | 2.0 × 0.4 | 76 | 24 | 0.0329 | 0.0013 | 0.0004 | 0.0005 | 0.0015 |
| | | | | | 70 | 0.494 | 0.049 | 0.007 | 0.011 | 0.051 |
| | | | | | 160 | 2.04 | 0.24 | 0.01 | 0.02 | 0.25 |
| NGC 4273 | 12:19:56.0 | +05:20:36 | 2.3 × 1.5 | 10 | 24 | 1.0295 | 0.0412 | 0.0011 | 0.0005 | 0.0412 |
| | | | | | 70 | 12.387 | 1.239 | 0.030 | 0.013 | 1.239 |
| | | | | | 160 | 18.50 | 2.22 | 0.03 | 0.02 | 2.22 |
| NGC 4299 | 12:21:40.9 | +11:30:12 | 1.7 × 1.6 | 26 | 24 | 0.2350 | 0.0094 | 0.0002 | 0.0002 | 0.0094 |
| | | | | | 70 | 3.346 | 0.335 | 0.008 | 0.006 | 0.335 |
| | | | | | 160 | 4.32 | 0.52 | 0.02 | 0.01 | 0.52 |
| NGC 4309 | 12:22:12.3 | +07:08:40 | 1.9 × 1.1 | 85 | 24 | 0.0620 | 0.0025 | 0.0003 | 0.0003 | 0.0025 |
| | | | | | 70 | | | | | |
| | | | | | 160 | | | | | |
| IC 3258 | 12:23:44.4 | +12:28:42 | 1.6 | | 24 | 0.0764 | 0.0031 | 0.0005 | 0.0007 | 0.0032 |
| | | | | | 70 | 0.776 | 0.078 | 0.014 | 0.019 | 0.081 |
| | | | | | 160 | 0.87 | 0.10 | 0.01 | 0.02 | 0.11 |
| NGC 4411 | 12:26:30.1 | +08:52:20 | 2.0 | | 24 | 0.0234 | 0.0009 | 0.0005 | 0.0006 | 0.0012 |
| | | | | | 70 | 0.474 | 0.047 | 0.014 | 0.017 | 0.052 |
| | | | | | 160 | 1.40 | 0.17 | 0.01 | 0.01 | 0.17 |
| UGC 7557 | 12:27:11.0 | +07:15:47 | 3.0 | | 24 | 0.0326 | 0.0013 | 0.0007 | 0.0010 | 0.0018 |
| | | | | | 70 | 0.659 | 0.066 | 0.020 | 0.029 | 0.075 |
| | | | | | 160 | 1.55[f] | 0.19 | 0.03 | 0.04 | 0.19 |
| NGC 4466 | 12:29:30.5 | +07:41:47 | 1.3 × 0.4 | 101 | 24 | 0.0243 | 0.0010 | 0.0005 | 0.0007 | 0.0013 |
| | | | | | 70 | 0.602 | 0.060 | 0.014 | 0.020 | 0.065 |
| | | | | | 160 | 1.13[f] | 0.14 | 0.01 | 0.02 | 0.14 |
| IC 3476 | 12:32:41.8 | +14:03:02 | 2.1 × 1.8 | 30 | 24 | 0.1881 | 0.0075 | 0.0006 | 0.0007 | 0.0076 |
| | | | | | 70 | 1.961 | 0.196 | 0.016 | 0.019 | 0.198 |
| | | | | | 160 | 2.88[f] | 0.35 | 0.01 | 0.02 | 0.35 |
| NGC 4531 | 12:34:15.8 | +13:04:31 | 3.1 × 2.0 | 155 | 24 | 0.0351 | 0.0014 | 0.0006 | 0.0009 | 0.0018 |
| | | | | | 70 | 0.539 | 0.054 | 0.017 | 0.023 | 0.061 |
| | | | | | 160 | 2.76[f] | 0.33 | 0.02 | 0.04 | 0.33 |

[a]These are galaxies that are not in the HRS but that appear in the 500-μm-selected sample published by Davies et al. (2012).
[b]Data are from NED.
[c]Data are from de Vaucouleurs et al. (1991) unless otherwise specified. If de Vaucouleurs et al. (1991) specify both the major-to-minor axis ratio and the position angle, then both axes and the position angle are listed. If de Vaucouleurs et al. (1991) did not specify either of these data, then we performed photometry on circular regions, and so only the major axis is specified.
[d]The position angle is defined as degrees from north through east.
[e]Details on the sources of these uncertainties are given in Section 3.1.
[f]These 160-μm measurements are for galaxies that were covered in scan map observations in which the final 160-μm images for these galaxies contain NaN values within the optical disc as a consequence of incomplete coverage. This typically occurs when scan maps are performed using the fast scan rate, although NaN values within the optical discs of galaxies occasionally appear in other data. The 160-μm measurements for these galaxies are based upon interpolating over these pixels; see the text for details.

Engelbracht et al. (2008). Given this, we did not feel confident reporting a 160-μm flux density for this source.

*Notes on the HRS data. NGC 4356*. The galaxy falls near a 24-μm artefact we describe as also affecting the NGC 4472 data (see below). However, the feature appears relatively faint and broad in the vicinity of NGC 4356, and so we treat it as part of the background.

*NGC 4472*. The 24-μm image in the scan map data from AORs 22484480, 22484736, 22484992 and 22455248 was affected by two streak-like regions that run roughly perpendicular to the scan map direction. These features do not appear in overlapping maps taken on other dates during the mission. We were unable to identify the origin of this line. All we can say is that the positions of these streaks vary with respect to the scan leg position and that the width of the features is variable. One of these streak-like regions runs across the optical disc of NGC 4472, and we masked it out before making 24-μm flux density measurements.

*NGC 4486*. The 160-μm data within the optical disc of NGC 4486 were notably affected by residual striping. Two strips approximately 3 arcmin in width to the north and south of the nucleus were affected and were masked out when the 160-μm flux density was measured.

*NGC 4526*. Both the 70- and 160-μm images cover only the central 3 arcmin of the galaxy, and the 160-μm image does not include a section on the western side of the optical disc that is 2 arcmin in width. However, the emission is relatively centralized, so these problems may not significantly affect the photometry.

*NGC 4552*. In the 160-μm data, a cirrus feature oriented roughly east–west can be seen crossing through the optical disc of this galaxy. We otherwise detect no 160-μm emission; we found no 160-μm counterparts to the 24- and 70-μm central source in this galaxy. Hence, we are reporting the integrated flux density as an upper limit even though we get a $>5\sigma$ detection for the integrated flux density within the optical disc and we detect surface brightness features at $>5\sigma$ level.

*NGC 4567/4568*. The 70-μm data near this galaxy are heavily affected by latent image effects.

*NGC 4636*. This is an elliptical galaxy with an optical disc with a size of 6.0 × 4.7 arcmin (de Vaucouleurs et al. 1991). At 160 μm, we detect multiple off-centre point sources within the optical disc of the galaxy that are approximately half the brightness of the central source and that do not appear to correspond to structure within the galaxy. We assume that the central source is associated with the galaxy and the off-central sources are background galaxies, but masking out the off-central sources was equivalent to masking out the equivalent of most of the optical disc. We therefore perform a 160-μm measurement within a circle with a diameter of 80 arcsec and then apply the multiplicative aperture correction of 1.745 given by Stansberry et al. (2007) for a 30 K source (which, among the spectra used to calculate aperture corrections, is the closest to the expected spectrum for this object).

*NGC 4647/4649*. While the optical disc of these two galaxies overlap, NGC 4649 produces relatively compact 24-μm emission and no detectable 70- or 160-μm emission. We assume that the optical disc of NGC 4647 contains negligible emission from NGC 4649. Hence, we are able to report separate flux densities for each source at 24 μm, flux densities for NGC 4647 at 70 and 160 μm, and upper limits for the 70- and 160-μm flux densities for NGC 4649 using the part of NGC 4649 that does not include NGC 4647. Also, the 70-μm image is strongly affected by latent image artefacts.

*NGC 4666*. This galaxy was observed in photometry map mode. The galaxy is observed in such a way that the latent image removal in the 24-μm data processing leaves a couple of 'not a number' (NaN) values near the centre of the galaxy. These pixels correspond to locations between peaked emission, so it is clear that the data are not related to saturation of the detectors. We interpolated over these pixels before performing photometric measurements.

### 3.2 Comparisons of photometry to previously published results

The MIPS calibration at this point is very well established, and comparisons between MIPS and *IRAS* photometry have already been performed (Engelbracht et al. 2007). Therefore, we believe that the most appropriate check of our photometry would be to compare our measurements to other published MIPS photometry measurements. As indicated above, MIPS photometric measurements have previously been published for a significant fraction of the data that we used. While it is impractical to cite every paper that has been published based on the MIPS data for these galaxies, three papers have published MIPS data for significant subsets of galaxies in the SAG2 and HeViCS samples. We use these papers to check our data processing and photometry results.

#### *3.2.1 Comparisons with SINGS data*

SINGS was a survey with all of the *Spitzer* instruments that observed a cross-section of a representative sample of galaxies within 30 Mpc. A total of 15 galaxies from the SAG2 surveys and in HeViCS were originally observed with MIPS in SINGS. Preliminary photometry for the survey was published by Dale et al. (2005), while the final photometry was published by Dale et al. (2007). We compared our data to the data from Dale et al. (2007). However, we exclude NGC 5194/5195 because we are reporting one set of measurements for the system while Dale et al. report separate flux densities for each galaxy.

The ratio of the Dale et al. (2007) 24-μm flux densities to ours is 0.97 ± 0.08, which is very good. The largest outlier is NGC 6822, where we measure a ∼30 per cent higher flux density than Dale et al. However, as we indicated above, this is a galaxy that is large in angular size and that has infrared emission that extends outside its optical disc. Additionally, the emission from foreground cirrus structure is relatively strong compared to the diffuse emission from the galaxy itself. Ultimately, this may be a case where measuring the diffuse emission from the target galaxy is simply fraught with uncertainty. Aside from this case, however, the comparison has produced very pleasing results.

In comparing the Dale et al. (2007) 70-μm flux densities to our own, we found one galaxy with a factor of ∼5 difference in the flux densities. This was NGC 4552, an elliptical galaxy with relatively weak emission from a central source. Dale et al. reported a flux density of 0.52 ± 0.11 Jy for this galaxy, which is a factor of 5 higher than our measurement. The Dale et al. number could be a factor of 10 too high because of a typographical error; when we measured the flux density the SINGS Data Release 5 (DR5) data[2] using the same apertures that we used for our data, we obtained 0.04 ± 0.02 Jy. This measurement from the SINGS data is a factor of 2 lower than the measurement from our mosaic. However, our image of this galaxy was made using both SINGS data and additional 70-μm data that were taken after the SINGS photometry was published, and so the measurement from our new mosaic may be more reliable.

At 160 μm for NGC 4552, we reported an upper limit that is a factor of ∼1.5 lower than the Dale et al. (2007) measurement. Again, we think that our measurement could be more reliable because we combined SINGS data with other scan map data not available to Dale et al., and so the S/N in our data should be better.

Excluding NGC 4552, the ratio of the Dale et al. (2007) 70-μm flux densities to ours is 1.11 ± 0.07. At 160 μm, the ratio of the Dale et al. flux densities to ours is 1.20 ± 0.07. This shows that some systematic effects cause the Dale et al. measurements to be slightly higher than ours, although the agreement is close to the calibration uncertainty of the data, and the scatter in the ratios is very small.

If Dale et al. used the data in DR5, then their 160-μm measurements would have been based on data in which the flux calibration factor is 5 per cent higher than the one we used, which

[2] Available at http://data.spitzer.caltech.edu/popular/sings/20070410_enhanced_v1/.

could explain part of the discrepancy at 160 μm. However, this does not completely explain the discrepancy, and since the flux calibration factor in the SINGS DR5 70-μm data is the same as ours, differences in the factor cannot explain the discrepancies in that waveband. Although we used data not available to Dale et al. to produce some of our images, we still see the systematic effects in the cases where we used exactly the same data as SINGS, so differences in the data used should not lead to differences in the photometry.

One possible cause for the systematic offsets in the photometry could be the differences in the way the short-term drift was removed. The other possible cause is differences in the way flux densities were measured and handled. While we used relatively large apertures (1.5 times the $D_{25}$ isophote) to measure flux densities, Dale et al. used the $D_{25}$ isophotes as apertures and then applied aperture corrections. To check whether the data processing was primarily the culprit for the discrepancy, we downloaded the SINGS DR5 data and performed photometry on those data using the same software and apertures that we had applied to our own (after correcting the 160-μm flux calibration to match ours). The ratio of the measurements from the SINGS DR5 data to the measurements from our data is $0.95 \pm 0.07$ at 70 μm and $1.08 \pm 0.04$ in the 160-μm data. This shows that the measurement techniques are responsible for a significant part of the systematic offsets between the Dale et al. measurements and ours, while the data processing differences probably cause an additional offset in the 160-μm data.

Overall, we are satisfied with how our measurements compare to the data from Dale et al. (2007). The scatter in the measurements is relatively small when difficult cases are excluded. The remaining differences are at levels that are comparable to the calibration uncertainties and are in part related to the measurement techniques, and these differences probably reflect limitations in the photometric accuracy that can be achieved with MIPS data for nearby galaxies in general.

#### *3.2.2 Comparisons with Engelbracht et al. (2008) data*

Engelbracht et al. (2008) published a survey of starburst galaxies that spanned a broad range of metallicities. 22 of the 66 galaxies overlap with the SAG2 sample: 21 of the galaxies are in the DGS and NGC 5236 is in the VNGS. Although Engelbracht et al. applied colour corrections while we have not, it is still useful to compare the data.

The ratio of the Engelbracht et al. (2008) 24-μm measurements to our 24-μm measurements is $1.00 \pm 0.13$, indicating that our measurements agree with the Engelbracht et al. to within 13 per cent. However, this includes some infrared-faint galaxies where both Engelbracht et al. and we report >10 per cent uncertainties in the flux density measurements. If we use data where the 24-μm flux densities from both data sets are >0.1 Jy, the ratio becomes $1.00 \pm 0.05$. The remaining dispersion is equivalent to the uncertainty in the flux calibration, which is very good.

Engelbracht et al. report 24-μm flux densities for two objects for which we do not report flux densities. For Tol 0618−402, we have reported an upper limit of 0.0015 Jy, while Engelbracht et al. have reported a $\sim 4\sigma$ detection [$(4.4 \pm 1.2) \times 10^{-4}$ Jy]. We are reporting $<5\sigma$ detections as upper limits, so, given the S/N in the Engelbracht et al. measurement, we would not report a flux density for this galaxy. Nonetheless, our upper limit for Tol 0618−402 is consistent with the Engelbracht et al. flux density. The other object is NGC 5253, for which we reported no flux density measurement because the 24-μm emission originates from an unresolved source that saturates the 24-μm array. Engelbracht et al. report a flux density for this galaxy but made no special notes about it. Although the saturation may not be too difficult to deal with when measuring the flux density, we prefer to be more conservative and report no flux density for this object.

In comparing the Engelbracht et al. (2008) 70-μm data to ours, we found one galaxy where the flux density measurements differ by a factor of 2. For Tol 1214−277, our 70-μm flux density measurement is $0.073 \pm 0.010$ Jy, whereas Engelbracht et al. report $0.031 \pm 0.003$ Jy. The signal from the source is hardly $5\sigma$ above the noise in our image of this galaxy. We also probably used a broader measurement aperture than that of Engelbracht et al. They used apertures that were adjusted to radii that encompassed all pixels with emission above a set S/N level, whereas we used a 3 arcmin diameter aperture, which was our standard aperture for point-like sources. Our aperture may have included additional signal not included by Engelbracht et al.

Excluding Tol 0618−402 [where we report an upper limit and Engelbracht et al. (2008) report a ~1.5 detection] and Tol 1214−277 (discussed above), our 70-μm flux density measurements agree well with those from Engelbracht et al. The ratio of the Engelbracht et al. (2008) 70-μm measurements to ours is $1.04 \pm 0.17$. For sources above 1 Jy, where the S/N is primarily limited by the calibration uncertainty, the ratio is $1.02 \pm 0.09$, which is comparable to the calibration uncertainty of 10 per cent.

A comparison of the Engelbracht et al. (2008) 160-μm measurements with ours (for galaxies we detected above the $5\sigma$ level and where we did not encounter problems with photometry) does not show agreement that is as good as for the 24- and 70-μm data. Aside from non-detections, the ratio of the Engelbracht 160-μm flux densities to ours is $0.88 \pm 0.28$. Measurements for UGC 4483 and UM 461 are particularly discrepant. We measure 160-μm flux densities that are greater than a factor of 2 higher than the Engelbracht et al. measurements. However, these are very faint galaxies; the flux densities are <0.2 Jy. The Engelbracht et al. measurements are at the $<3\sigma$ level, and we used 160-μm data that would have been unavailable when the Engelbracht et al. results were published, so the improved S/N in our data could have allowed us to make more accurate measurements for these faint galaxies. Excluding UGC 4483 and UM 461, the ratio of Engelbracht et al. 160-μm measurements to ours is $0.96 \pm 0.19$. The scatter in the ratio is still larger than the calibration uncertainty of 12 per cent, but this may reflect issues with simply measuring 160-μm flux densities in the MIPS data for these dwarf galaxies, many of which are fainter than 1 Jy or in small fields. Additionally, the colour correction applied by Engelbracht et al. could have increased the dispersion in the ratios.

Overall, this comparison has shown excellent agreement between the 24- and 70-μm flux densities measured by us and by Engelbracht et al. (2008). In the 160-μm data, we found two discrepancies that cause some concern, but we think these are unique cases. Our 160-μm flux densities for other DGS sources were in general agreement with the Engelbracht et al. measurements, thus demonstrating the reliability of our data reduction and photometry for these data.

#### *3.2.3 Comparisons with Ashby et al. (2011) data*

Ashby et al. (2011) published a multiwavelength survey of 369 nearby star-forming galaxies that includes 24-μm data. 23 of the galaxies in the HRS and two of the additional HeViCS galaxies overlap with the galaxies in the Ashby et al. sample. Ashby et al. used SExtractor to measure flux densities and then applied appropriate aperture corrections, which is notably different from the aperture photometry that we applied.

We have one galaxy where our 24-μm measurements differ notably from Ashby et al. (2011). For NGC 3430, we measured 0.4101 ± 0.0164 Jy, but Ashby et al. measured 0.17 ± 0.01 Jy. The IRAS 25-μm flux density measurements of 0.27 ± 0.04 Jy given by the Faint Source Catalog (Moshir et al. 1990) and 0.78 ± 0.05 Jy given by Surace, Sanders & Mazzarella (2004) are also higher than the Ashby et al. (2011) measurement but still disagree with ours and with each other. However, Ashby (private communication) indicated that the measurement published by Ashby et al. (2011) for this galaxy was inaccurate because of a poor background model. After correcting the background model, they measure 0.30 ± 0.02 Jy, which is within ∼27 per cent of our measurement and which is within $1\sigma$ of the IRAS Faint Source Catalog measurement. The remaining discrepancy between this new SExtractor-based measurement and our aperture-based measurement may be the result of the different techniques that were used including the methods used to subtract the background.

Excluding NGC 3430, the ratio of the Ashby et al. (2011) measurements to ours is 0.90 ± 0.09. Ashby et al. assume that their uncertainties are 8 per cent, so the dispersion in the ratio of measurements is reasonably good. The systematic offset may be a consequence of differences between the flux density measurement methods. The second largest mismatch between our measurements and the measurements from Ashby et al. is for NGC 4688, a late-type galaxy with significant diffuse, low surface brightness 24-μm emission; Ashby et al. measure a flux density ∼30 per cent lower than ours for this galaxy. Ashby et al. also noted differences between the flux densities measured for NGC 4395 by themselves and by Dale et al. (2009), which they thought could be the result of incorrectly measuring diffuse emission in NGC 4395 using SExtractor. We suspect that this could also be the reason for the mismatch between the flux density measurements for NGC 4688 and may be the reason for the ∼10 per cent offset in flux density measurements between the reported flux densities from their catalogue and ours.

## 4 SUMMARY

We have gathered together raw 24-, 70- and 160-μm MIPS data for galaxies within the SAG2 and HeViCS surveys and reprocessed the data to produce maps for the analysis of these galaxies. We have also performed aperture photometry upon the galaxies in the surveys that can be used to study the global SEDs of these sources. The flux density measurements and the images will be distributed to the community through the Herschel Database in Marseille (Roehlly et al., in preparation)[3] so that the broader astronomical community can benefit from these data.

As tests of our data processing and photometry, we have performed comparisons between our photometric measurements and measurements published by Dale et al. (2007), Engelbracht et al. (2008) and Ashby et al. (2011). Our measurements generally agree well with the measurements from these other catalogues, and we have documented and attempted to explain any major discrepancies or systematic offsets between their measurements and ours. Given the good correspondence between our measurements and the measurements from these other surveys, we are confident about the reliability of our photometry measurements.

[3] Available at http://hedam.oamp.fr/.

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## SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

**Table 5.** Photometry for the *Herschel* Reference Survey.

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