SAGE-Spectroscopy:
The life-cycle of dust and gas in the Large Magellanic Cloud

(PI: F. Kemper, PID: 40159)

Data delivery document v1.0

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Contents

Chapter 1

SAGE-Spec overview

1.1 Introduction to the goals of the SAGE-Spec program

The SAGE-Spectroscopy legacy proposal (SAGE-Spec; PI: F. Kemper, PID: 40159; Kemper et al. 2009) is the spectroscopic follow-up to the successful SAGE-LMC legacy program (Meixner et al. 2006; PI: M. Meixner, PID: 20203) that mapped the Large Magellanic Cloud (LMC) with all bands of the IRAC and MIPS instruments on board Spitzer. The acronym SAGE stands for Surveying the Agents of Galaxy Evolution, and thus the project aims to make an inventory of the budget of gas and dust involved in the life-cycle of matter in the Magellanic Clouds.

The SAGE-Spec legacy program has used IRS and the SED mode on MIPS to obtain spectroscopic information of a representative sample of point sources and extended regions in the LMC, with two goals in mind:
The first goal is to study the composition and properties of gas and dust in environments relevant to the life-cycle of matter, from evolved stars to the interstellar medium and ultimately to star-forming regions. Combining this information with statistics obtained from the SAGE-LMC project will allow us to get a complete picture of the cycle of gas and dust in terms of mass *and* in terms of composition and physical properties.
Secondly, sources in the SAGE-LMC point source catalogue will be classified using a classification scheme tested against the SAGE-Spec sample. In addition to the observations made within the context of the SAGE-Spec proposal, we will extend the sample to contain *all* IRS and MIPS-SED observations within the original SAGE-LMC footprint.

In total, 224.6 hours of observations were made and 196 point sources were observed with the IRS instrument, 48 point sources were observed with MIPS in SED mode and 20 extended regions were also targeted with MIPS: 10 H II regions and 10 diffuse regions. In addition, the reduction and delivery of all the IRS and MIPS-SED spectroscopic data within the SAGE-LMC footprint adds a further $\sim$800 IRS point sources and several other extended regions. A paper giving an overview of the project is currently in preparation (F. Kemper et al. 2009, in prep.)

Of the 196 point sources observed with IRS, all were observed using the SL module ($\lambda \approx 5$–$14\,\mu$m), and 128 were also observed using LL ($\lambda \approx 14$–$37\,\mu$m). Upon examination, the LL observation of one source, SS16 (GV 60), picked up another target rather than the intended target. Thus there are 197 distinct point sources in the sample at this point. Spectra of a number of serendipitous objects were obtained, and these will be delivered in a future data release. 48 of the brightest sources were also targeted with MIPS in SED mode. For our source selection strategy, please see the overview publication for the project, Kemper et al. (2009).

1.2 Description of the observations in the current release

In this first delivery of SAGE-Spec data we deliver IRS staring mode spectra of 197 point sources and MIPS-SED spectra of 48 point sources selected from the SAGE catalogue. The IRS staring mode spectra are complemented by matching photometry from SAGE (IRAC and MIPS; Meixner et al. 2006), MCPS (Zaritsky et al. 2004), 2MASS (Skrutskie et al. 2006) and IRSF (Kato et al. 2007). A source list follows (Table A.1), showing availability of photometry and spectroscopy for sources observed in IRS staring mode. See Table 1.1 for a list of sources observed in MIPS-SED mode. We also deliver Postscript plots of the 197 IRS spectra and associated photometry.

1.3 Description of the observations in future releases and delivery timeline

Further data deliveries will be made to the Spitzer Science Center (SSC) on a six-monthly basis, as follows:

Spring 2010: Delivery of SAGE-Spec IRS Mapping mode observations, delivery of IRS spectra of point sources from the Spitzer archive within the SAGE footprint, delivery of MIPS-SED data for SAGE-Spec extended sources, delivery of MIPS-SED data for archival sources; delivery of SAGE-Spec IRS point source classifications and spectral classifications.
Autumn 2010: Delivery of enhanced SAGE-Spec and archival IRS staring data, using an optimal point source extraction.
Spring 2011: Further delivery, as needed.

Table 1.1: Point sources observed in MIPS-SED mode

ID	Source name	Co-ordinates (J2000)	ID	Source name	Co-ordinates (J2000)
500	SSTISAGE1C J043727.60-675435.0	4h37m27.61s, -67d54m35.	501	IRAS04515-6710	4h51m37.82s, -67d05m17.
502	IRAS04530-6916	4h52m45.70s, -69d11m49.	503	IRAS04537-6922	4h53m30.11s, -69d17m49.
504	LHA120-N89	4h55m06.53s, -69d17m08.	505	IRAS04553-6825	4h55m10.48s, -68d20m29.
506	IRAS04557-6639	4h55m50.59s, -66d34m34.	507	IRAS04562-6641	4h56m22.59s, -66d36m56.
508	HD268835	4h56m47.08s, -69d50m24.	509	HV269006	5h02m07.40s, -71d20m13.
510	IRAS05047-6644	5h04m47.00s, -66d40m30.	511	LHA120-N97	5h04m51.97s, -68d39m09.
512	SMP-LMC-28	5h07m57.62s, -68d51m47.	513	MSX-LMC45	5h10m39.60s, -68d36m04.
514	IRAS05137-6914	5h13m24.66s, -69d10m48.	515	MSX-LMC222	5h13m41.99s, -69d35m26.
516	MSX-LMC349	5h17m26.93s, -68d54m58.	517	IRAS05216-6753	5h21m29.68s, -67d51m06.
518	SSTISAGE1C_J052222.95-684101.0	5h22m22.96s, -68d41m01.	519	HS270-IR1	5h23m53.93s, -71d34m43.
520	IRAS05257-7135	5h24m55.08s, -71d32m56.	521	HD36402	5h26m01.22s, -67d30m11.
522	SNR0525-66.1	5h26m03.10s, -66d05m17.	523	MSX-LMC577	5h26m30.60s, -67d40m36.
524	IRAS05281-7126	5h27m23.14s, -71d24m26.	525	IRAS05280-6910	5h27m40.06s, -69d08m04.
526	IRAS05291-6700	5h29m07.59s, -66d58m15.	527	IRAS05298-6957	5h29m24.53s, -69d55m15.
528	IRAS05325-6629	5h32m31.95s, -66d27m15.	529	IRAS05328-6827	5h32m38.59s, -68d25m22.
530	RP775	5h32m44.40s, -69d30m05.	531	IRAS05329-6708	5h32m51.36s, -67d06m51.
532	MSX-LMC783	5h32m55.44s, -69d20m26.	533	HV2671	5h33m48.92s, -70d13m23.
534	MSX-LMC741	5h35m25.83s, -71d19m56.	535	HD37974	5h36m25.85s, -69d22m55.
536	30Dor-17	5h37m28.09s, -69d08m47.	537	LHA120-N158B	5h38m44.53s, -69d24m38.
538	LI-LMC1501E	5h39m41.86s, -69d46m11.	539	N160	5h39m59.49s, -69d37m30.
540	LHA120-N159S	5h40m00.67s, -69d47m13.	541	UFO1	5h40m11.83s, -70d10m04.
542	WOH-G457	5h40m11.95s, -70d09m15.	543	RP85	5h40m33.57s, -70d32m40.
544	30Dor	5h40m43.18s, -70d11m10.	545	MSX-LMC1794	5h40m44.00s, -69d25m54.
546	MSX-LMC956	5h40m49.27s, -70d10m13.	547	IRAS05458-6710	5h45m44.80s, -67d09m28.

1.4 Format of the database at the Spitzer Science Center

The SAGE-Spec database can be reached via the Legacy page on the Spitzer Science Center website, or via direct link: http://ssc.spitzer.caltech.edu/legacy/sagespechistory.html

The database is made up of a tables of metadata and associated data products (plots of spectra and associated photometry). The format of these tables is slightly different for the IRS staring data and the MIPS-SED data.

1.4.1 IRS staring

The IRS staring spectra have an associated metadata file, which is in IPAC tbl format. This has columns as follows:
SAGESpecID: This is a unique identifier for each point source. SAGE-Spec sources are labelled with numbers 1–197, which are obtained by ordering the sources sequentially according to Right Ascension (R.A.). Archival sources will be labelled starting at 1000 in the next delivery.
label: This is a unique identifier for each spectrum. It is constructed by concatenating R.A. (to 4 decimal places) and declination (dec; to 4 decimal places), instrument name (i.e., IRSX or MIPS) and module name with nod or processing information, for example:
79.7943-69.5629_IRSX_SL_(scaled). For further details, see **modules**, below).
ra: Right ascension Field-Of-View (FOV) co-ordinates (J2000)[1].
dec: Declination FOV co-ordinates (J2000)[1].
SAGEIRACID: Associated SAGE-LMC IRAC source designation.
SAGEMIPSID: Associated SAGE-LMC MIPS 24 μm source designation.
AORkey: Astronomical Observation Request (AOR) number of the Spitzer observation.
progid: Program ID in which data were obtained (for SAGE-Spec this is 40159).
instrument: IRSX for Infrared Spectrograph, MIPS for Multiband Imaging Photometer for Spitzer.
modules: One of:

SL, LL (scaled)

SL, LL (unscaled)

SL (scaled)

SL (unscaled)

LL (scaled)

LL (unscaled)

[1]We purposefully choose FOV co-ordinates (i.e., ra_fov and dec_fov in the FITS headers) over requested co-ordinates (ra_rqst and dec_rqst, also found in FITS headers, and which are those obtained when one queries via Leopard, for example) since the FOV co-ordinates most accurately determine the region of space the telescope is pointing at. In general, FOV co-ordinates differ from requested co-ordinates by $\approx 0\farcs75$. However, in extreme cases, there can be a difference of up to $\approx 5\farcs7$ between the two in the SAGE-Spec IRS sample.

SL Order 1 Nod 1

SL Order 1 Nod 2

SL Order 2 Nod 1 plus bonus order

SL Order 2 Nod 2 plus bonus order

LL Order 1 Nod 1

LL Order 1 Nod 2

LL Order 2 Nod 2 plus bonus order

LL Order 2 Nod 1 plus bonus order

SL

LL

In most cases, the end user will require just the SL, LL (scaled) version of the spectrum.
pipelineVersion: Spitzer data reduction pipeline version.
objectName: Chosen name for object, usually the oldest historically.
alternateName: Other useful identifiers.

Spectra are then available seperately as single files or a large archive, with or without additional photometry points. Please see the README file for further information.

1.4.2 MIPS-SED

The MIPS-SED data are available as separate files with incorporated metadata. Column headings are:
SAGESpecID: This is a unique identifier for each point source. MIPS-SED sources are labelled with numbers 500-547, which are obtained by ordering the sources sequentially according to Right Ascension (R.A.).
label: This is a unique identifier for each spectrum. It is constructed by concatenating R.A. (to 4 decimal places) and declination (dec; to 4 decimal places) and instrument name (MIPSED), for example: 69.3650-67.9097_MIPSED.
ra: Right ascension co-ordinates (J2000)
dec: Declination co-ordinates
objectName: Chosen name for object.
quality: This can be one of "good", "ok", "poor" and "bad". These terms are explained in Section 3.1.3.
waveLength: wavelength in microns.
flux: flux in Jansky units.
fluxUnc: flux uncertainty in Jansky units.
SN: signal-to-noise ratio.
sky: sky noise.

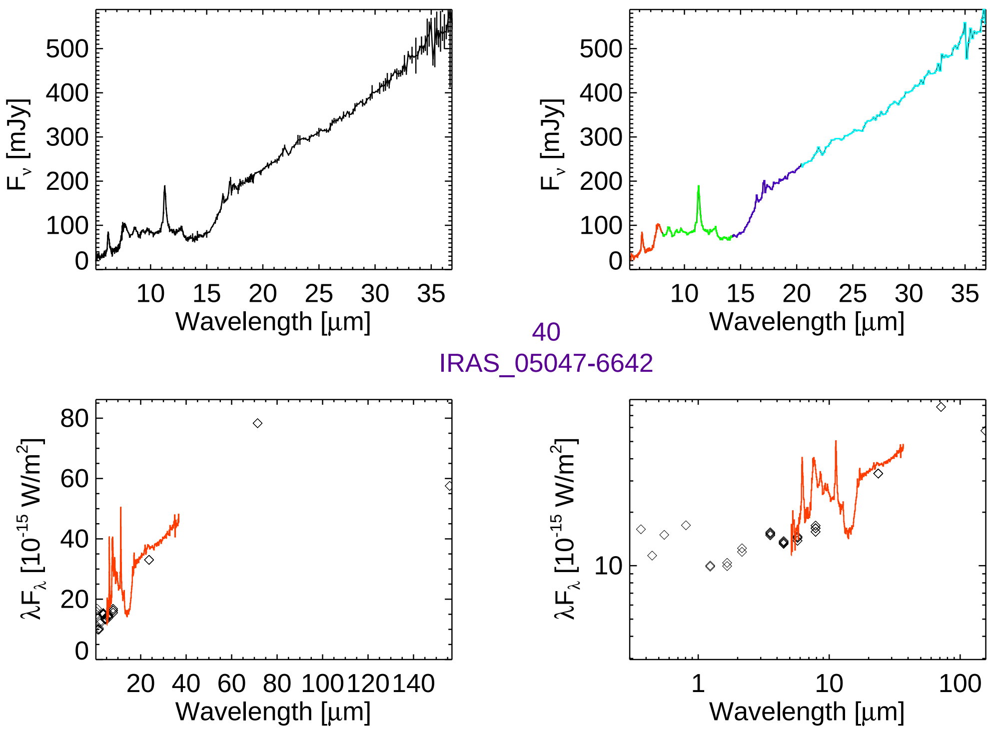

Figure 1.1: An example plot of the IRS staring data for SAGE-Spec source 40 (see text).

1.5 Format of the plots which accompany the data delivery

Each plot, which has a filename of `<label>.ps` (e.g., 76.2155-66.6354_IRSX_SL_LL_scaled.ps), is composed of four panels (see Fig. 1.1). Clockwise from the top-left these panels represent:

Full IRS spectrum plotted with error bars.

Full IRS spectrum plotted with modules in different colours to show where the joins lie.

Spectral energy distribution with photometric points and IRS spectrum, shown in log scale.

Spectral energy distribution with photometric points and IRS spectrum, shown in linear scale.

Each plot also includes the SAGE-Spec ID and the chosen point source name.

1.6 Photometric matching

For each SAGE-Spec source a cone search using a radius of 20″is performed against the SAGE-LMC photometric database. The possible matches are retained in the following manner:

1. Only the closest match in each of the categories below are chosen.
2. Each of these closest matches is further restricted:

(a) IRAC (3.6, 4.5, 5.8, 8.0 μm) matches must be within $3''$.

(b) MIPS 24μm matches must be within $3''$.

(c) MIPS 70μm matches must be within $10''$.

(d) MIPS 160μm matches must be within $20''$.

(e) 2MASS (JHK) matches must be within $3''$.

(f) IRSF (JHK) matches must be within $3''$.

(g) MCPS (UVBI) matches must be within $3''$.

1.7 Core team members

Ciska Kemper (University of Manchester): PI, science overview, observing strategy.
Karl Gordon (Space Telescope Science Institute): IRS extended region and MIPS-SED data reduction.
Margaret Meixner (Space Telescope Science Institute): science overview, observing strategy, database, SAGE-LMC photometry liaison.
Remy Indebetouw (University of Virginia/NRAO): quality control, IRS extended region data reduction.
Massimo Marengo (Harvard CfA/Iowa State University): source classification.
Greg Sloan (Cornell University): IRS staring data reduction, observing strategy.
Xander Tielens (Leiden Observatory): science overview.
Jacco van Loon (Keele University): observing strategy, quality control.
Paul Woods (University of Manchester): Project Manager, quality control, source classification.

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MCPS data are publicly available from http://ngala.as.arizona.edu/dennis/mcsurvey.html
The IRSF website is at: http://www.z.phys.nagoya-u.ac.jp/ irsf/index_e.html

Chapter 2

IRS spectroscopy

2.1 Point sources

2.1.1 Observation settings

All IRS observations in this data delivery were obtained in staring mode, using the SL and LL modules. Each target was observed after a high-accuracy peak-up, usually on the target itself. In cases where the target was too bright or faint or in a crowded region, the telescope peaked up on a nearby 2MASS source. Within each module, the number and length of integration cycles for the two apertures matched, in order to maximize the options for background subtraction.

All SAGE-Spec IRS staring data were obtained by the Spitzer Space Telescope from IRS Campaigns 47 to 53. These covered the period from January 9 to August 16 2008.

2.1.2 Data processing

The IRS data in this delivery were processed using the SSC pipeline S17.2. Before spectra were extracted, the background was subtracted from each image, and the resulting difference image was cleaned to replace pixels flagged as bad with data from neighbouring pixels. Spectra were extracted from individual images, then calibrated and co-added.

For SL, the default background subtraction was an aperture difference, where an image with the source in one aperture served as the background for the image with the source in the other aperture, but the same nod position. For example, for SL1 nod 1, the background image was SL2 nod 1. For LL, the default was a nod difference, where the image with the source in one nod position served as the background for the image with the source in the other nod position in same aperture. Thus LL1 nods 1 and 2 served as backgrounds for each other, and likewise for LL2 nods 1 and 2.

In many cases, complex backgrounds or additional sources in the on-target aperture or off-target aperture forced us to modify the background subtraction. In addition to aperture or nod differences, we occasionally resorted to cross differences (other aperture, other nod). In some cases, no suitable background subtraction was possible, which could result in compromised or useless spectroscopy. See Section 2.1.3 for more detailed information.

We relied on the bmask images supplied with each data image by the SSC and the campaign rogue masked produced by the SSC to identify bad pixels. Any pixel with a bmask value of 4096 or higher was replaced. Any pixel which was identified as a rogue in any two campaigns from the start of the mission through Camp. 54 was also replaced. Additionally, all NaNs in the data were replaced.

To replace bad pixels, we applied the imclean.pro IDL procedure written at Cornell University. This algorithm now serves as the core of the pixel-replacement within irsclean.pro, which is provided by the SSC. To replace a bad pixel, the spatial profile of neighbouring rows are scaled to the row with the bad pixel. A replacement value is constructed from good data in the same column. This algorithm assumes that spatial structure of the source is unchanged over the rows in question and thus it could break down in the vicinity of spectral changes in spatial structure, such as spatially extended emission from a forbidden line near an unresolved continuum source.

To extract spectra from the spectral images, we used the profile, ridge, and extract modules of the SSC pipeline. These are available within SPICE. The resulting extraction is equivalent to a tapered-column extraction within SMART, with the extraction aperture two pixels wide in the dispersion direction and increasing in width in the cross-dispersion (spatial) direction linearly with wavelength. The S17.2 data are actually a mixture of pipeline versions, with SL calibrated to S15.3 and LL effectively unchanged since S15.3. Thus we used the S15.3 wavesamp and psf_fov (Point-spread function field of view) files when extracting. These set the extraction apertures as follows:

order	width (pix)	wavelength (μm)
SL2	4.000	6.0
SL-bonus	5.333	8.0
SL1	8.000	12.0
LL2	4.250	16.0
LL-bonus	5.445	20.5
LL1	7.172	27.0

Spectra are extracted from each spectral image in a given nod position, then calibrated from digital units to flux density units (Janskys). The spectral correction is based on comparison of similarly processed spectra of calibration stars to spectral templates for those stars produced at Cornell. (A paper describing this process is in preparation.) HR 6348 (K0 III) served as the calibrator for all SL data. It and two later K giants, HD 166780 (K4 III) and HD 173511 (K5 III) served as the calibrators for all LL data.

The spectrum reported for each nod position includes the mean of the individually extracted spectra in that position, and the formal uncertainty in the mean (standard deviation / square root of the number of images). The individual nod spectra are included in this data delivery.

To produce a complete spectrum for SL and LL, which are also included in this delivery, we average the spectra from the two nods, and we append the data from the three orders to each other. When combining the nods, spikes and divots which appear in only one nod but not the other are rejected. In these cases, only the data from the better-behaved nod are used. New uncertainties in the mean are calculated (before spike rejection, not after), and if they are larger than the propagated error from the two nods, are used in their place. Note that the formal uncertainty in the mean of two data is just half the difference in the data.

Thus this data delivery includes five spectra from SL and five from LL (the combined spectrum from the module and the four components from both nods in both apertures). In addition, we also provide a combined low-resolution spectrum, produced by appending the LL data to the SL, and a final low-resolution spectrum, corrected for discontinuities between segments (stitched), and with extraneous data removed (trimmed).

To produce this final spectrum, we assume that the discontinuities between spectral segments arise from pointing errors, which lead to partial truncation of mispointed sources by the slit edges. Thus, segments are calibrated upwards to the presumably best-centered segment. This usually means that SL is scaled upward to LL, since pointing errors have more impact in the smaller SL slit. The corrections are multiplicative scalar corrections and have no dependence on wavelength. This assumption is reasonable for corrections of roughly 10% or less. For larger corrections, the general shape of the continuum can no longer be relied upon as accurate. The bonus-order data have been combined with overlapping first- and second-order data before spectra are corrected for discontinuities. The corrections are calculated using the wavelengths of overlap betwen adjacent spectral segments. In the case of SL2 and LL2, the bonus order which were taken at the same time, and with the target at the same place in the aperture, provide the overlap needed between first- and second-order data.

Two more modifications have been made to spectra in the final delivered product. Any uncertainty which suggests a signal/noise ratio greater than 500 is reset so that the S/N equals 500. Finally, spectra are truncated to delete data which cannot be calibrated, using the wavelength ranges in the table below:

order	wavelength range (μm)
SL2	5.10 – 7.59
SL-bonus	7.73 – 8.39
SL1	7.59 – 14.33
LL2	14.20 – 20.54
LL-bonus	19.28 – 21.23
LL1	20.46 – 37.00

Note that from 20.46 to 20.54 μm, all three LL segments are valid. The regions of overlap between segments are the regions used to determine corrections for discontinuity.

2.1.3 Quality control of the data

The Basic Calibrated Data (BCD) generated by the Spitzer pipeline was checked visually by members of the SAGE-Spec team. Various data errors were flagged, and BCDs which would require deviation from the standard processing (Sect. 2.1.2) were noted. Errors found included FUDL (Fast Uplink Downlink) errors, caused by improper data transmission from the spacecraft, cosmic ray hits on the CCD, spectral images which contained more than one spectral trace (i.e., detection of a nearby source in addition to the targeted source) and "jailbarring",

where repeating vertical patterns (residuals) every four columns are left by Spitzer's A/D converters in cases of a high background on the peak-up arrays (e.g., if the emission from a bright source happens to fall on a peak-up array). In addition, background emission or gradients may have required a change in the standard subtraction algorithm, as detailed above (Sect. 2.1.2). One DCE (Data Collection Event) was visually examined per EXPID (exposure ID), of which there were usually several per module in each BCD. In general, these errors were corrected by:
FUDL errors: The spectra from the affected images were dropped from further consideration. In addition, images with FUDL errors were not used for background subtraction.
cosmic rays: Most cosmic ray hits were flagged as such and replaced by our `imclean.pro` procedure. Images with unflagged cosmic ray hits were treated in the same way as images with FUDL errors if the affected pixels were in the vicinity of the source (or the source in another image if the affected image was used as a background).
multiple sources and background issues: These generally required that we modify the background subtraction scheme. In some cases, we were forced to drop one of the nod spectra from consideration because there was no way to avoid problems caused by other sources or background gradients (either in the target image or in a background image). In a few cases, we were unable to mitigate for the problems, and these are noted in Table B.1.

2.1.4 Caveats

Users of the staring-mode IRS spectra should be sure to examine the error bars to the spectra because these they indicate confidence limits and potential problems with the data. In particular, large error bars throughout a spectral segment indicate that the two spectra from the individual nod positions do not agree, probably due to additional sources or background gradients in the slit which we were unable to correct. Also, a large error bar for a single pixel when surrounded by much smaller error bars indicates that at that wavelength, one of the two nod spectra contained a large spike or divot that was rejected when the nods were combined into a single spectrum. The error bar was calculated based on the rejected datum and retained.

Users should also be aware that the LL slit is significantly larger than the SL slit (10″across compared to 3.6″), and that many of the SAGE-Spec sources show some spatial structure. Often, the SL segments were normalized up to the LL segments more than the $\sim$10–15% expected for random pointing errors for unresolved sources. The CORRSL2, CORRSL1, CORRLL2, and CORRLL1 keywords in the spectral file headers contain the factors by which each segment was divided to align the spectra; anything smaller than 0.85 indicates a spatially extended source.

The large LL slit often contains excess background emission, which will result in the spectrum beginning to rise in the LL1 spectral segment. This rise to the red is often, but not always, accompanied by larger error bars, since the spectra from the sky subtraction will have differing degrees of success in the two nods in these cases.

2.2 Extended sources

IRS mapping data will be delivered in the future.

Chapter 3

MIPS-SED observations

3.1 Point sources

3.1.1 Observation settings

All the MIPS-SED observations in this data delivery were obtained using the standard MIPS-SED point source template. The chop distance and total exposure time was adjusted based on the nearby sources seen in the MIPS 70 μm image and the measured MIPS 70 μm photometry, respectively.

3.1.2 Data processing

The MIPS-SED data were processed through the MIPS Data Analysis Tool (DAT, v3.10, 3 Jul 2007). The details of the MIPS DAT are given by Gordon et al. (2005). The produce of the MIPS DAT is both off-source background subtracted and on-source only rectified mosaics combining all observations in an AOR. For the majority of the sources, the off-source chop position data was used to remove the majority of the background emission and residual instrumental signatures.

The spectra were extracted from the 2D rectified mosaics. First, a spatial profile was created by collapsing the 2D mosaic along the wavelength axis. In most cases, the maximum in the spatial profile identified the source position along the slit. The extraction was done using the standard width of 5 pixels with residual background subtraction done using two regions 3 pixels wide located on either side of the source. In the few cases where the off-source chop position was contaminated by another source, the on-source data was used and the background subtraction using the two background regions on either side of the source. For a few, faint sources, the source position was fixed to the default location.

The extracted spectra were trimmed to reject all data beyond 95 microns as these wavelengths are contaminated by 2nd order flux. The spectra were corrected to infinite aperture and calibrated using the results given by Lu et al. (2008).

3.1.3 Quality control of the data

The quality control on the MIPS-SED observations was focused on examining the mosaics and spatial profile of the source. The quality of a spectrum was deemed as "good" if there was no source in the off-source position and the spatial profile was distinctly a point source. A source was "ok" if there was a faint source in the off-source position or if its spatial profile was not as simple as a single point source, but still enough like a point source to get a decent extraction. A source was "poor" if there was a bright source in the off-source mosaic or it was very extended. A source was "bad" if there was no reasonable source to be extracted.

3.2 Extended sources

MIPS-SED mapping data will be delivered in the future.

Appendix

Appendix A

Availability of spectra and photometry

Table A.1: Photometry and spectroscopy for sources observed in IRS staring mode.

SAGE-Spec source ID	UBVI	JHK	IRAC	MIPS	SL	LL	MIPS-SED
1	BVI	✓	✓	24	✓	—	—
2	—	✓	✓	24, 70	✓	✓	✓
3	✓	✓	✓	24	✓	✓	—
4	✓	✓	✓	24	✓	✓	—
5	BVI	✓	✓	24, 70	✓	✓	—
6	✓	✓	✓	24	✓	✓	—
7	BVI	✓	✓	24	✓	✓	—
8	BVI	✓	✓	24	✓	✓	—
9	—	—	✓	24	✓	✓	—
10	BVI	✓	✓	24, 70	✓	✓	—
11	✓	✓	✓	✓	✓	✓	—
12	BVI	✓	✓	24	✓	—	—
13	✓	✓	✓	24	✓	—	—
14	UBV	✓	✓	✓	✓	✓	—
15	—	✓	✓	24	✓	—	—
16	UBV	✓	✓	70	✓	—	—
17	UBV	✓	✓	70	—	✓	✓
18	—	—	✓	24	✓	✓	—
19	—	✓	✓	24	✓	—	—
20	✓	✓	✓	24, 160	✓	✓	—
21	✓	✓	✓	24	✓	✓	—
22	✓	✓	✓	24	✓	✓	—
23	✓	✓	✓	24	✓	—	—
24	✓	JH	3.6, 4.5	24	✓	—	—

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Table A.1 – continued from previous page

SAGE-Spec source ID	UBVI	JHK	IRAC	MIPS	SL	LL	MIPS-SED
25	✓	✓	✓	24, 70	✓	✓	—
26	✓	✓	✓	24	✓	✓	—
27	✓	✓	✓	24	✓	✓	—
28	✓	✓	✓	24	✓	✓	—
29	✓	✓	✓	24	✓	✓	—
30	✓	✓	✓	24	✓	—	—
31	✓	✓	✓	24	✓	—	—
32	✓	✓	✓	24	✓	—	—
33	✓	✓	✓	24	✓	—	—
34	✓	✓	✓	✓	✓	✓	—
35	✓	✓	✓	24	✓	—	—
36	✓	✓	✓	24	✓	—	—
37	✓	✓	✓	24	✓	—	—
38	✓	✓	✓	24	✓	✓	—
39	✓	✓	✓	24	✓	✓	—
40	✓	✓	✓	✓	✓	✓	—
41	UBV	✓	✓	24	✓	—	—
42	✓	✓	✓	24	✓	✓	—
43	✓	✓	✓	24	✓	—	—
44	BVI	✓	✓	24, 70	✓	✓	—
45	—	✓	✓	24	✓	—	—
46	—	✓	✓	24	✓	—	—
47	—	✓	✓	24	✓	—	—
48	—	✓	✓	24	✓	—	—
49	—	✓	✓	24	✓	—	—
50	✓	✓	✓	24	✓	✓	—
51	—	✓	✓	24	✓	✓	—
52	—	✓	✓	24, 70	✓	✓	—
53	BV	✓	✓	24, 70	✓	✓	—
54	BVI	✓	✓	24	✓	✓	—
55	BVI	✓	✓	24	✓	✓	—
56	✓	✓	✓	24	✓	✓	—
57	✓	✓	✓	24	✓	—	—
58	✓	✓	✓	24	✓	—	—
59	BV	✓	4.5, 5.8, 8.0	24	✓	—	—
60	✓	✓	✓	24	✓	✓	—
61	✓	✓	✓	24	✓	✓	—
62	✓	✓	✓	24, 70	✓	✓	—
63	BVI	✓	✓	24	✓	—	—

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Table A.1 – continued from previous page

SAGE-Spec source ID	UBVI	JHK	IRAC	MIPS	SL	LL	MIPS-SED
64	✓	✓	✓	24	✓	✓	—
65	—	✓	✓	24	✓	✓	—
66	BVI	✓	✓	24	✓	✓	—
67	✓	✓	✓	24	✓	—	—
68	UBV	✓	✓	24	✓	—	—
69	✓	✓	✓	24, 70	✓	✓	—
70	—	K	4.5, 5.8, 8.0	24	✓	✓	—
71	—	✓	✓	24	✓	✓	—
72	✓	✓	✓	24	✓	—	—
73	✓	✓	✓	24	✓	✓	—
74	✓	✓	✓	24, 70	✓	✓	—
75	✓	✓	✓	24	✓	✓	—
76	✓	✓	✓	24	✓	—	—
77	✓	✓	✓	24	✓	—	—
78	BVI	✓	✓	✓	✓	✓	—
79	BVI	✓	✓	24	✓	—	—
80	✓	✓	✓	24	✓	✓	—
81	✓	✓	✓	24	✓	—	—
82	✓	✓	✓	24	✓	✓	—
83	BVI	✓	✓	24	✓	—	—
84	✓	✓	✓	24, 70	✓	✓	—
85	✓	✓	✓	24	✓	✓	—
86	✓	✓	✓	24	✓	—	—
87	—	✓	✓	24	✓	—	—
88	✓	✓	✓	—	✓	—	—
89	✓	✓	✓	24	✓	—	—
90	✓	✓	✓	24	✓	✓	—
91	—	✓	✓	24	✓	—	—
92	✓	✓	✓	24, 70	✓	✓	—
93	✓	✓	✓	24	✓	✓	—
94	✓	✓	✓	24	✓	✓	—
95	✓	✓	✓	24	✓	✓	—
96	✓	✓	✓	24	✓	✓	—
97	✓	✓	✓	✓	✓	✓	✓
98	BVI	✓	✓	24	✓	✓	—
99	BVI	✓	✓	24	✓	—	—
100	✓	✓	✓	24	✓	✓	—
101	BV	✓	✓	✓	✓	✓	—
102	—	✓	✓	24, 70	✓	✓	✓

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Table A.1 – continued from previous page

SAGE-Spec source ID	UBVI	JHK	IRAC	MIPS	SL	LL	MIPS-SED
103	—	✓	✓	24	✓	✓	—
104	UBV	✓	✓	✓	✓	✓	—
105	BVI	✓	✓	24	✓	✓	—
106	✓	✓	✓	24, 70	✓	✓	—
107	✓	✓	✓	24	✓	✓	—
108	✓	✓	✓	✓	✓	✓	—
109	✓	✓	✓	24, 70	✓	✓	—
110	✓	✓	✓	24	✓	—	—
111	✓	✓	✓	24	✓	✓	—
112	UBV	—	✓	24	✓	—	—
113	✓	✓	✓	24	✓	✓	—
114	✓	✓	✓	24, 70	✓	✓	✓
115	✓	✓	✓	24	✓	—	—
116	✓	✓	✓	24	✓	✓	—
117	UBI	✓	✓	24	✓	✓	—
118	✓	✓	✓	24	✓	✓	—
119	✓	✓	✓	24	✓	✓	—
120	✓	✓	✓	24	✓	—	—
121	✓	✓	✓	24, 70	✓	✓	—
122	UB	✓	✓	24	✓	✓	—
123	UB	✓	✓	24	✓	✓	—
124	✓	✓	✓	24	✓	—	—
125	✓	✓	3.6, 4.5, 5.8	24, 70	✓	✓	—
126	✓	✓	✓	24	✓	✓	—
127	✓	✓	✓	24	✓	—	—
128	UBV	✓	✓	24	✓	✓	—
129	UBV	✓	✓	24	✓	✓	—
130	BVI	✓	✓	24	✓	✓	—
131	✓	✓	✓	24	✓	✓	—
132	—	✓	✓	24	✓	—	—
133	BVI	✓	✓	24, 160	✓	—	—
134	UBV	✓	✓	24	✓	—	—
135	BV	✓	✓	24	✓	✓	—
136	—	✓	✓	24	✓	—	—
137	✓	✓	✓	24	✓	✓	—
138	✓	✓	✓	24, 70	✓	✓	—
139	✓	✓	✓	24	✓	—	—
140	BV	✓	✓	24	✓	✓	—
141	✓	✓	✓	24	✓	✓	—

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Table A.1 – continued from previous page

SAGE-Spec source ID	UBVI	JHK	IRAC	MIPS	SL	LL	MIPS-SED
142	✓	✓	✓	24	✓	—	—
143	✓	✓	✓	24	✓	—	—
144	✓	✓	✓	24, 70	✓	✓	—
145	BVI	✓	✓	24	✓	✓	—
146	✓	✓	✓	24	✓	✓	—
147	UBV	✓	✓	24	✓	✓	—
148	✓	✓	✓	24	✓	—	—
149	✓	✓	✓	24	✓	✓	—
150	✓	✓	✓	24, 70	✓	✓	—
151	✓	✓	✓	24	✓	✓	—
152	✓	✓	✓	24	✓	—	—
153	✓	✓	✓	24	✓	—	—
154	✓	✓	✓	24, 70	✓	✓	—
155	BVI	✓	✓	24	✓	—	—
156	BVI	✓	✓	24	✓	✓	—
157	✓	✓	✓	24	✓	✓	—
158	BV	✓	✓	24	✓	✓	—
159	✓	✓	✓	24	✓	—	—
160	✓	✓	✓	24	✓	✓	—
161	✓	✓	✓	24	✓	—	—
162	✓	✓	✓	24	✓	✓	—
163	✓	✓	✓	24, 70	✓	✓	✓
164	BVI	HK	✓	24, 70	✓	✓	—
165	✓	✓	✓	24	✓	✓	—
166	✓	✓	✓	24	✓	✓	—
167	—	—	✓	24	✓	✓	—
168	UBV	✓	✓	24, 70	✓	✓	—
169	UBV	✓	✓	24	✓	✓	—
170	UBV	✓	✓	24	✓	✓	—
171	UBV	✓	✓	24	✓	✓	—
172	✓	✓	✓	24	✓	✓	—
173	✓	✓	✓	24	✓	—	—
174	✓	✓	✓	24	✓	✓	—
175	✓	✓	✓	24	✓	✓	—
176	BVI	✓	✓	24	✓	—	—
177	✓	✓	✓	24	✓	✓	—
178	✓	✓	✓	24	✓	—	—
179	BVI	✓	✓	24	✓	—	—
180	✓	✓	✓	24	✓	✓	—

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Table A.1 – continued from previous page

SAGE-Spec source ID	UBVI	JHK	IRAC	MIPS	SL	LL	MIPS-SED
181	✓	✓	✓	24	✓	✓	—
182	✓	✓	✓	24	✓	✓	—
183	✓	✓	✓	24, 70	✓	✓	—
184	BVI	✓	✓	24, 70	✓	✓	—
185	—	✓	✓	24	✓	✓	—
186	✓	✓	✓	24	✓	✓	—
187	✓	✓	✓	24	✓	✓	—
188	✓	✓	✓	24	✓	—	—
189	BVI	✓	✓	24	✓	—	—
190	BVI	—	✓	24, 70	✓	✓	—
191	✓	✓	✓	24	✓	—	—
192	✓	✓	✓	24	✓	✓	—
193	✓	✓	✓	24	✓	✓	—
194	BVI	✓	✓	24	✓	—	—
195	—	✓	✓	24	✓	—	—
196	✓	✓	✓	24, 70	✓	✓	—
197	✓	✓	✓	24	✓	—	—

Appendix B

Quality control results for IRS spectra

Table B.1: Data processing summary (see key below table).

ID	Reduction method	SL	LL	Notes
1	default	—		
2	default	—	—	
3	default	—	—	
4	default	J-Wa	—	
5	default	—	—	
6	modified	Ray-Mc-Notes	B-Wa	SL – 0300: Ray
7	default	—	N-Wa	
8	default	—	—	
9	default	—	—	
10	modified	—	S-Mc-1Dx,2Da	
11	default	—	—	
12	default	J-Wa		
13	modified	B-Mc-Dn		
14	default	—	—	
15	default	J-Wa		
16	default	—		
17	modified		—	
18	default	—	—	
19	default	J-Wa		
20	modified	X-Mc-Notes	—	SL – 0200: FUDL, 0400: Dx
21	default	—	—	
22	modified	P-Mc-2Dn	S-Wa	
23	default	—		
24	modified	F-Mi-Dn		
25	modified	B-Mc-Dn	B-Mc-C2	
26	default	J-Wa	—	
27	default	S-Wa	—	
28	default	S-Wa	S-Wa	
29	default	J-Wa	—	

continued on next page. . .

Table B.1 – continued from previous page

ID	Reduction method	SL	LL	Notes
30	default	J-Wa		
31	default	J-Wa		
32	default	—		
33	default	J-Wa		
34	modified	B,X-Mc-Notes	—	SL – 0400: bad pixel block
35	default	—		
36	default	—		
37	default	—		
38	modified	J,Ray-Wa-Notes	—	SL – 0502: Ray
39	modified	—	S-Mc-Da	
40	default	—	—	
41	default	—		
42	default	—	—	
43	default	—		
44	modified	B-Wa	S-Mc-1Da	
45	default	J-Wa		
46	default	—		
47	default	—		
48	default	J-Wa		
49	modified	B-Mc-Dn		
50	modified	B-Mc-Dn,Notes	B-Mc-Da	SL – 14.2μm spike
51	modified	—	S-Mc-1C1	
52	default	—	—	
53	default	—	—	
54	default	J-Wa	—	
55	modified	—	N-Mc-1Da	
56	modified	B-Mc-1Dn	S-Wa	
57	default	—		
58	modified	X-Mc-Notes		SL – 0404: bad pixel block
59	default	S-Wa		
60	modified	—	N-Mc-1Da	
61	default	—	S-Wa	
62	default	—	—	
63	default	—		
64	default	—	—	
65	modified	—	S-Mc-1C1	
66	default	—	B-Mc-1Da1,1Dx2	
67	default	—		
68	default	—		
69	modified	B-Mi-Dn	B-Mi-1Da	
70	default	E-Wa	—	
71	modified	—	N-Mi-Da	
72	modified	S-Mc-Dn		
73	default	—	B-Wa	
74	default	—	—	
75	default	—	S-Wa	

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Table B.1 – continued from previous page

ID	Reduction method	SL	LL	Notes
76	default	—		
77	default	—		
78	default	J-Wa	—	
79	default	—		
80	modified	—	S-Mc-C1	
81	default	—		
82	default	—	—	
83	default	N-Wa		
84	default	—	—	
85	modified	J-Wa	S-Mc-1Cn1	
86	default	—		
87	modified	B,J-Mi-1Dn		
88	modified	B,S-Mi-Dn		
89	default	S-Wa		
90	default	—	—	
91	modified	B-Mc-2Dn		
92	modified	X-Mc-Notes	—	SL – 0402: FUDL, 0202: Dx, 0302: Ray
93	modified	—	B,S-Mc-Da	
94	default	—	—	
95	modified	B-Mc-1Dn	B-Mc-1Da	
96	default	—	—	
97	default	—	—	
98	modified	—	S-Mc-Notes	LL – 0802: FUDL, 0902: Da
99	default	—		
100	default	—	N-Wa	
101	default	—	—	
102	default	—	—	
103	modified	—	S-Mc-1Da	
104	modified	J,Ray-Mc-Notes	—	SL – 0502: Ray
105	modified	J-Wa	B-Mi-1Dx,2Da	
106	modified	—	B-Mc-1C1	
107	default	—	—	
108	modified	B-Mi-Dn	S-Mc-Da	
109	modified	—	S-Mc-1Cn2	
110	default	—		
111	default	—	—	
112	default	—		
113	modified	—	S-Mc-1Da	
114	default	J-Wa	N-Wa	
115	default	—		
116	modified	J,S-Mc-Notes	S-Mc-2Da	SL – 0401: Ray, 0202: FUDL, 0402: Dx
117	modified	S-Mc-Notes	N,S-Fa	SL – Ridge constrained
118	default	—	—	
119	modified	—	S-Mi-Da	
120	default	—		
121	default	—	—	

continued on next page…

Table B.1 – continued from previous page

ID	Reduction method	SL	LL	Notes
122	default	—	S-Wa	
123	modified	—	B-Mc-1Da	
124	default	—		
125	default	—	—	
126	default	—	—	
127	default	S-Wa		
128	modified	—	S-Mc-Da	
129	default	—	—	
130	default	—	—	
131	modified	J-Wa	B-Mc-Da	
132	default	—		
133	default	—		
134	default	—		
135	default	—	—	
136	default	—		
137	default	—	B-Wa	
138	default	—	—	
139	default	B-Wa		
140	default	—	—	
141	default	J-Wa	B,S-Wa	
142	default	—		
143	default	—		
144	default	—	—	
145	default	—	B,S-Wa	
146	default	—	N-Wa	
147	default	—	—	
148	modified	B-Mc-1Dn		
149	default	—	N-Wa	
150	default	—	—	
151	default	—	—	
152	default	B-Wa		
153	default	—		
154	default	—	—	
155	default	—		
156	modified	B,S-Mc-Dn	B,S,N-Wa	
157	default	—	—	
158	modified	S-Mc-2Dn	S-Wa	
159	default	—		
160	modified	B,J-Mc-Dn	N-Fa	
161	modified	J,P-Mi-Dn		
162	modified	N-Wa	S-Mc-1Da	
163	default	—	S-Wa	
164	modified	B,J-Mi-1Dn	—	
165	modified	Ray-Wa	S-Mi-Da	
166	default	—	—	
167	modified	—	B-Mc-1Cn1	

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Table B.1 – continued from previous page

ID	Reduction method	SL	LL	Notes
168	default	—	—	
169	modified	B-Mc-1Dn	B-Mi-Cn2	
170	modified	—	S-Mi-1Da	
171	modified	S-Mc-Notes	S-Mi-Notes	SL – 0401: FUDL, 0201: Dx LL – 1Da, 2Dn1, 2Dx2
172	modified	—	S-Mc-Da	
173	modified	B-Mc-1Dn		
174	modified	F-Mi-Dn	F-Wa	
175	modified	X-Mc-Notes	—	SL – 0301: Ray, not dropped, 0501: Dx
176	default	—		
177	default	—	—	
178	default	—		
179	modified	B-Mc-1Dn		
180	default	—	N-Wa	
181	default	—	—	
182	default	—	B,N-Wa	
183	default	—	—	
184	modified	—	N-Mc-1Da	
185	default	—	—	
186	default	J-Wa	—	
187	default	—	—	
188	default	—		
189	default	—		
190	default	—	—	
191	modified	B-Mi-Dn		
192	default	—	—	
193	default	—	—	
194	default	—		
195	default	—		
196	default	—	—	
197	default	—		

KEY: –

Reduction method *default* – as described in Sect. 2.1.2; *modified* – the default method of background subtraction, extraction and coadding of spectra was changed in some way, as detailed in a three-part code, constructed as: <problem>-<severity>-<solution>

Problem
J – jailbars in the data.
N – significant difference in appearance between two nods.
FUDL – FUDL (data download) error.
Ray – cosmic ray strike.
P – peak-up related problem.
B – background issue.
S – additional source.
E – excess emission.
F – very faint source.
M – no source.
X – other issue.

Severity
Wa – defective data, however no repair was attempted because defect was deemed minor, i.e., did not affect the extraction.
Mc – reduction procedure was modified and successfully corrected issue.
Mi – reduction procedure was modified and improved the issue but could not fully correct it.
Fa – there was an issue with the data which could not be improved upon.

Solution
#*Da*# – aperture difference (rather than nod difference). Where numbers are included in the code, the first number is the order number, and the second the nod, e.g., 1Da2 is LL1, nod 2
#*Dn*# – nod difference (rather than aperture difference).
#*Dx*# – cross difference.
#*C*# – co-add was changed (usually by using only one nod).

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