# Release notes for the *Herschel* Very Nearby Galaxies Survey SPIRE FTS Spectroscopy

The Very Nearby Galaxies Survey (VNGS; KPGT_cwilso01_1; PI: C. D. Wilson) focuses on a deliberately diverse sample of 13 nearby galaxies, within roughly 80 Mpc. The sample includes star-forming spiral galaxies (NGC 5194, M81, NGC 2403, NGC 891, M83), the starburst M82, merging systems (NGC 4038/39, Arp 220), Seyfert galaxies (NGC 4151, NGC 1068) and elliptical galaxies (Centaurus A, NGC 4125, NGC 205). The overall goals of the VNGS are to investigate and characterise the cool gas and dust of the interstellar medium (ISM) in galaxies of different evolutionary stages on resolved scales. This allows us to search for variations in the properties of the ISM within these galaxies in addition to comparing their global properties with one another. This document gives an overview of the processing of the SPIRE FTS spectroscopy data products delivered to the *Herschel* Science Archive under the User Provided Data Products.

## 1 Notes on the sample and observing modes

Twelve of the thirteen galaxies in the VNGS sample were observed with the SPIRE FTS; only the elliptical galaxy **NGC 4125** was not observed. All the VNGS FTS data were obtained using the high spectral resolution mode of the FTS. However, the spatial sampling mode varied depending on the expected strength of the emission. Individual galaxies were observed using either sparse spatial sampling, intermediate spatial sampling, or full spatial sampling as described below. For a few iconic galaxies **(M82, NGC 1068, Cen A)**, both full spatial sampling maps and a deep pointed spectrum on the nuclear region were obtained.

The data included in this release have been presented in a series of papers published between 2010 and 2015. Over this time, the data processing

techniques and the version of hipe used have changed several times. In addition, the methods used to improve and analyze the data have varied from one source to the next. Thus, we have chosen to deliver the data *as published* rather than attempting a uniform reprocessing of the entire data set. Also, the quality of the Level 2 data products available from the Herschel Science Archive has been improving steadily. Anyone desiring a more uniformly processed data set is encouraged to start with the products from the Herschel Science Archive, which can be compared with the data in this release for reference.

The data in this data release is significantly more heterogeneous in its processing and post processing than previously released data sets in this series. We urge anyone interested in using these data to consult the original published papers for full details of the data reduction and post-processing.

## 1.1 Data not included in this release

Three of the galaxies **(M81, NGC 2403, and NGC 205)** were observed using the sparse spatial sampling mode and have not yet been published by us. Anyone interested in the spectra of these galaxies should use the latest products available in the Herschel Science Archive.

**NGC 891** was observed in intermediate spatial sampling mode. An analysis of the [NII] 205 $\mu$m line was published in Hughes et al. (2015) and the data are provided as part of this release. The CO spectral lines have not yet been published by us and so are not provided in this release. Anyone interested in the CO emission for NGC 891 should use the latest products available in the Herschel Science Archive.

**Cen A** was observed in both full spatial sampling mode and with a deep, sparse spatial sampled spectrum to obtain better signal-to-noise on its active nucleus. An analysis of the [NII] 205 $\mu$m fully sampled map was published in Parkin et al. (2014) and those data are provided as part of this release. The CO spectral line maps have not yet been published by us and so are not provided in this release. Anyone interested in the CO emission for Cen A should use the latest products available in the Herschel Science Archive.

# 2 Notes on data sets for individual galaxies

## 2.1 Arp 220

Although its emission was expected to be relatively bright, Arp 220 was observed using sparse spatial sampling because of its compact size. The spectrum and its analysis were published in Rangwala et al. (2011). The spectrum reveals a wealth of emission and absorption lines from a wide variety of molecules, atoms, and ions.

The data processing of this compact (2″ source used standard point-source procedures. However, the high quality of the resulting spectrum was enhanced by the use of an especially deep dark spectrum that was made available to us; see Rangwala et al. (2011) for details.

This data delivery contains the single spectrum for Arp 220.

## 2.2 M82

As one of the closest starburst galaxies, M82 was observed in our dual mode, with a deep spectrum with sparse spatial sampling centred on the starburst and a more shallow map made with full spatial sampling. An initial analysis of the data was published in the Herschel Special Issue (Panuzzo et al., 2010) and a more complete analysis was published by Kamenetzky et al. (2012).

The deep spectrum was reduced with HIPE version 7, SPIRE calibration 7, with point source calibration (Jy). It is referenced to the 43.5″ beam size by multiplying the entire spectrum by the same source-beam coupling factor as in Panuzzo et al. (2010). This factor was derived by convolving the M82 SPIRE photometer 250 m map with appropriate profiles to produce the continuum light distribution seen with the FTS.

The maps (data cubes and integrated flux line maps) were also reduced with HIPE version 7, SPIRE calibration 7. We converted the extended source calibration to point source (Jy) and used our own custom map making procedure, based on the Naive Projection algorithm in HIPE, and described in Kamenetzky et al. 2012 Section 2.2. We present maps using 9.5″ pixels for the SLW and SSW detectors, and maps using 17.5″ pixels for the SLW detector only. We also present maps that are both unconvolved (using the native beams size of the detectors, which vary by frequency) and convolved to the 43.5″ beam of CO 4-3 using kernels described in Kamenetzky et al. (2012), Section 2.3. This section also describes the line fitting procedure used to

create integrated flux maps.

This delivery contains the data from Kamenetzky et al. (2012), specifically

- one deep spectrum pointed at the center of M82

  `M82_deep_v7_cal7_pnt_unapod_beamcorr.fits`

- 7 Unconvolved Integrated Line Flux Maps with 17.5″ pixels and 13 Unconvolved Integrated Line Flux Maps with 9.5″ pixels

  `M82_map_v7_cal7_NP_point_09p5_[line].fits,`
  `M82_map_v7_cal7_NP_point_17p5_[line].fits`

- 7 Convolved Integrated Line Flux Maps with 17.5″ pixels and 13 Convolved Integrated Line Flux Maps with 9.5″ pixels

  `M82_map_v7_cal7_NP_point_09p5_convol_[line].fits,`
  `M82_map_v7_cal7_NP_point_17p5_convol_[line].fits`

- 3 unconvolved data cubes (SSW with 9.5″ pixels, SLW with both 9.5″ and 17.5″ pixels)

  `M82_cube_v7_cal7_NP_point_09p5_SLW.fits,`
  `M82_cube_v7_cal7_NP_point_09p5_SSW.fits,`
  `M82_cube_v7_cal7_NP_point_17p5_SLW.fits`

- 3 Convolved Data Cubes (SSW with 9.5″pixels , SLW with both 9.5″ and 17.5″ pixels)

  `M82_cube_v7_cal7_NP_point_09p5_convol_SLW.fits,`
  `M82_cube_v7_cal7_NP_point_09p5_convol_SSW.fits,`
  `M82_cube_v7_cal7_NP_point_17p5_convol_SLW.fits`

## 2.3 NGC 1068

As the closest Seyfert 2 galaxies, NGC 1068 was observed in our dual mode, with a deep spectrum with sparse spatial sampling centred on the starburst and a more shallow map made with full spatial sampling. The analysis has been published in Spinoglio et al. (2012).

Both the deep spectrum and the maps were reduced using point source calibration factors. For measurements of the extended emission, the SLW maps and the [NII] 205 $\mu$m map were also convolved to have a uniform 42$''$ beam. See Spinoglio et al. (2012) for further details.

This delivery includes the following data for NGC 1068:

- one deep spectrum pointed at the center of NGC1068

  `NGC1068_spire_fts.fits`

- maps at their native resolution for CO J=4-3 to CO J=8-7 as well as the [CI] 1-0 and [CI] 2-1 lines and the [NII] 205 $\mu$m line

  `NGC1068_13.8_[line}_poly.fits, NGC1068_11_NII_poly.fits`

- convolved maps for CO J=4-3 to CO J=8-7 as well as the [CI] 1-0 and [CI] 2-1 lines

  `NGC1068_13.8_[line]_conv.fits`

- SLW and SSW data cubes produced using the point source calibration

  `NGC1068_SLW_unapod_13.8_cube.fits,NGC1068_SSW_unapod_11_cube.fits`

## 2.4 NGC 4151

The FTS spectrum of NGC 4151 has been published as part of the analysis of a larger sample of AGN by Pereira-Santaella et al. (2013). The nuclear spectra from the central bolometers (SLWC3 and SSWD4) were reduced using the standard pipeline (HIPE9). Then we estimated the residual instrument and telescope background by averaging the spectra from the other bolometers without galaxy emission. Finally, this residual emission was subtracted from the nuclear spectra.

This data delivery contains the single spectrum for NGC 4151.

## 2.5 M51

The [NII] 205 $\mu$m map of M51 has been published as part of Parkin et al. (2013). The map has intermediate spatial sampling. For comparison with fine structure line images from PACS (Parkin et al., 2013), the [NII] map was produced using point source calibration.

The CO and [CI] data have been published in Schirm et al. (2015). These maps also have intermediate spatial sampling. For the analysis, the data cubes were corrected using the semi-extended source corrections (Wu et al., 2013) before extracting the maps.

This delivery includes the following data for M51:

- SLW and SSW data cubes calibrated using the semi-extended source corrections as described in Wu et al. (2013)

  `M51_HR_SLW_10_cube.fits, M51_HR_SSW_10_cube.fits`

- maps of CO J=4-3 to CO J=8-7 as well as [CI] 1-0 and [CI] 2-1 extracted from the semi-extended data cube

  `M51_HR_SLW_10__K_[line].fits`

- map of the [NII] 205 $\mu$ line produced with point source calibration

  `M51_4_NII_poly_Hz.fits`

## 2.6 NGC 4038/39

The analysis of the CO, [CI] and [NII] lines of NGC4038/9 has been published in Schirm et al. (2014). The spectra were obtained with full spatial sampling with two slightly overlapping fields to cover the full emission from this pair of interacting galaxies. Maps were produced at the native resolution as described in Schirm et al. (2014) and then convolved to a common 42″ beam for further analysis.

This delivery includes the following data for NGC 4038/9:

- maps at the native resolution for CO J=4-3 to CO J=8-7, [CI] 1-0 and [CI] 2-1

`NGC4038_unconv_[line]_UA.fits`

- convolved maps for these same 7 lines

  `NGC4038_[line]_UA.fits`

- the kernels used to change the resolution (4 maps total)

  `kernel[size]_15align.fits`

- SLW and SSW data cubes combining both pointings

  `NGC4038_SLW_15_cube.fits, NGC4038_SSW_15_cube.fits`

- map of the [NII] 205 $\mu$ line produced with point source calibration

  `NGC4038_unconv_NII_UA.fits`

## 2.7 M83

The analysis of the CO, [CI] and [NII] lines of M83 has been published in Wu et al. (2015). The data were obtained with full spatial sampling. Maps were produced at the native resolution as described in Wu et al. (2015) and then convolved to a common 42″ beam using updated convolution kernels for further analysis. In addition, we produced a central spectrum corrected using the semi-extended source correction method from Wu et al. (2013).

This delivery includes the following data for M83:

- central spectrum corrected using the semi-extended correction method
- original maps for CO J=4-3 to CO J=13-12, [CI] 1-0 and [CI] 2-1, and [NII] 205 $\mu$m

  `M83_[line].fits`

- convolved maps for CO J=5-4 to J=13-12, [CI] 1-0 and [CI] 2-1, and [NII] 205 $\mu$m

  `M83_[line]_conv.fits`

## 2.8 NGC 891 (NII only)

The [NII] 205 $\mu$m for NGC 891 map published as part of Hughes et al. (2015). The map has intermediate spatial sampling. For comparison with fine structure line images from PACS (Hughes et al., 2015), the [NII] map was produced using point source calibration; the other fine structure lines were convolved and resampled to match the resolution and sampling of the [NII] map.

This delivery includes the point-source calibrated map of the [NII] 205 micron line for NGC 891.

## 2.9 Cen A (NII only)

The [NII] 205 $\mu$m map of Cen A was published as part of Parkin et al. (2014). (The deep spectrum of Cen A was published by another research group (Israel et al., 2014); we do not include their spectrum as part of this release.) The map is fully spatially sampled. For comparison with fine structure line images from PACS (Parkin et al., 2014), the [NII] map was produced using point source calibration; the other fine structure lines were convolved and resampled to match the resolution and sampling of the [NII] map.

This delivery includes the point-source calibrated map of the [NII] 205 $\mu$m line for Cen A.

# References


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