Release notes for the *Herschel* Very Nearby Galaxies Survey PACS 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 PACS spectroscopy data products delivered to the *Herschel* Science Archive under the User Provided Data Products.

1 Level 0 to Level 2 Processing

1.1 Processing for Sources Observed using Chop/Nod Mode

NGC 205 and NGC 4125 were mapped using the chop/nod observing mode. We processed the Level 0 data up to Level 2 using the standard pipeline for chop/nod observations in the Herschel Interactive Processing Environment (HIPE; Ott, 2010). From level 0 to level 0.5 reduction steps include masking saturated, bad and/or noisy pixels, converting the units of the signal to V s^{-1}, converting the time of the observations from that of the observatory to UTC, and updating the observations to include the locations of calibration blocks, 'ON' and 'OFF' positions, and adding pointing information. The wavelengths of the observations are also established and are corrected for the velocity of the observatory. Lastly, the data are flagged where the chopper and/or grating were in motion.

From Level 0.5 to Level 1, the processing steps include masking glitches in the data, subtracting the 'OFF' signal is subtracted from the 'ON' signal, applying flux calibrations and converting units to Jy. At this stage we produce an unbinned data cube for each raster in the observation. From Level 1 to Level 2, the only pipeline step we apply to the cubes is the flagging of outliers. The resulting unbinned raster cubes are exported as FITS files for the next stage of processing, with PACSman (Lebouteiller et al., 2012), the IDL package we utilize to carry out the line fitting and map making tasks (see Section 2 for details). The remaining standard pipeline processing between Level 1 and Level 2 (rebinning the data, combining the 'nods' and creating a projected cube including all rasters for a single source) is carried out in PACSman.

For a detailed description of all of the processing steps applied in the standard pipeline, please refer to the PACS Data Reduction Guide (DRG) for Spectroscopy.[1]

1.2 Processing for Sources Observed using Unchopped Mode

The remaining targets in the VNGS were mapped in the unchopped observing mode. For these observations we use the standard pipeline for unchopped mode in HIPE to process the data from Level 0 to Level 2. From Level 0 to Level 0.5 the reduction steps are the same as for the chop/nod mode, with the exception of one additional step only applicable to unchopped observations. This step extracts information regarding which data were taken on-source, and which data were taken off-source.

Masking glitches, determining the dark and instrument response, removing the dark from the data, and applying flux calibrations are the primary steps to process the data from Level 0.5 to Level 1. Next, a correction is applied to remove transients due to cosmic rays in the data; however, we opt to use the task included with PACSman to do this step, instead of using the native task in the standard pipeline. For a description of this task and its

[1] Available at the ESA Herschel Science Centre http://herschel.esac.esa.int/hcss-doc-12.0/index.jsp#pacs_spec:pacs_spec

advantages over the pipeline, see Lebouteiller et al. (2012). Lastly, a flat-field correction is done, the 'OFF' frames are subtracted from the 'ON' frames, and a data cube is produced. This cube is then flagged for outliers in the data and exported to PACSman, as is done with the chop/nod data. Again, the remaining pipeline steps between Level 1 and Level 2 are done within PACSman. Details on the unchopped pipeline can be found in the PACS DRG for spectroscopy.

2 Line fitting and Map Making

The unbinned data cubes produced in HIPE are exported as FITS files that are passed to the line-fitting routine in PACSman. There is one cube per raster position for each observation done in unchopped mode, and two cubes per raster for each observation done in chop/nod mode (one cube per 'nod'). The line-fitting program iterates through each spaxel of each raster and fits the continuum with a polynomial and the line with a Gaussian function. The results of these fits are stored in an IDL data product, which is then passed to the map-making program.

The stored information regarding each line fit is then used to produce mosaicked maps of the flux (or intensity), the radial velocity, the line full-width at half-maximum and the continuum. These maps are produced by projecting each individual raster onto an oversampled common grid, with a pixel size of 3.13333". These maps are stored as a FITS cube, where each plane corresponds to a specific map (see below for details). For a more thorough description of the line-fitting and map-making routines, please refer to Lebouteiller et al. (2012).

3 File Name Conventions

Unbinned data cubes are found in the "cubes" folder and are named *cubeX.fits*, where 'X' is the raster number of the cube. For example,*cube1.fits* is the data cube for the first raster position in any given unchopped observation. Note that for observations done in chop/nod mode the cubes are labelled *cubeAX* or *cubeBX*, where A and B represent the two nod positions. The positions of each individual raster in the final map can be determined by looking at the image named *OBJECT_LINE******_Footprints.png*, where $******$ is the spectral line (e.g. CII157 or NII122).

The folder labelled "spectra_plots" contains plots showing the best baseline and line fits to the unbinned spectral line data for each spaxel of each raster. Each file is named *rasterX_YY.eps*, where 'X' corresponds to the raster number and 'YY' corresponds to the spaxel number. For example, *raster2_33.eps* indicates the plot for the spectral line in spaxel (3,3) of raster 2. The file *******_fitresults_cube.txt* contains the details of each fit for each spaxel, where ****** is the spectral line.

The file called *cube.sav* is an IDL product containing output from the PACSman line fitting program. It stores all of the relevant information regarding each spaxel (and raster) such as the integrated flux, flux error, velocity, RA, DEC, etc., and it is this file that is passed to the map-making routine. It can be loaded into pacsman_map.fits where the maps can be reproduced and inspected interactively.

The file called *OBJECT_LINE******_Flux.fits* contains the projected mosaicked maps for the line ******. It is a FITS cube with 8 planes, where each plane contains the following maps:

1. Integrated intensity map in units of W m^{-2} sr^{-1}.
2. Integrated intensity error map in units of W m^{-2} sr^{-1}.
3. Velocity map in units of km s^{-1}.
4. Velocity error map in units of km s^{-1}.
5. Full-width at half-maximum map of the line fit in units of km s^{-1}.
6. Full-width at half-maximum error map in units of km s^{-1}.
7. Continuum map in Jy.
8. Continuum error map in Jy.

4 Details for Individual Galaxies

NGC5194 We have combined square maps and strips of [C II](158 μm), [N II](122 μm) and [O I](63 μm), where the strips extend from just outside the centre outward. We only have strips of observations for [O I](145 μm) and [O III](88 μm); however, these strips start right at the centre and extend outward. The data were processed using HIPE v9.0.2634 w/ calibration set FM,32 and PACSman v3.51 and have been published in Parkin et al. (2013).

NGC891 We have maps of the central region in the [C II](158 μm), [N II](122 μm) and [O I](63 μm), as well as strips extending radially outward along one half of the disk starting near the nucleus. The [O I](145 μm) and [O III](88 μm) lines are only observed in radial strips starting from the nucleus and extending along one half of the disk. The The data were processed using HIPE v9.0.2649 w/ calibration set FM,41, and PACSman v3.2.

M81 We have observed the nuclear region in the [C II](158 μm), [N II](122 μm), [O I](63 μm) and [O III](88 μm) lines. In addition, we have observed a small strip across a spiral arm in the same four lines. The data were processed using HIPE v9.0.2649 w/ calibration set FM,41 and PACSman v3.51.

NGC2403 We mapped the central region of the galaxy in [C II](158 μm), [N II](122 μm) and [O I](63 μm) as well as radial strips extending from near centre out across a spiral arm. We also have a radial strip in [O III](88 μm) extending radially from the centre. The data were processed using HIPE 9.0.2649 w/calibration set FM,41 and PACSman v3.2.

Cen A Observations of [C II](158 μm), [N II](122 μm), [O I](63 μm), [O I](145 μm), and [O III](88 μm) were carried out in strips along the eastern half of the disk of Cen A, starting just east of centre (the centre was covered in a different program). The data were processed using HIPE v9.2 w/ calibration set FM,41 and PACSman v3.52. They have been published in Parkin et al. (2014).

M83 We observed a radial strip in the [C II](158 μm), [N II](122 μm), [O I](63 μm), [O I](145 μm), and [O III](88 μm) lines. The strip does not include the nucleus. The data were processed using HIPE v9.0.2649 w/ calibration set FM,41 and PACSman v3.2.

NGC205 We have observed the [C II](158 μm) line in a map covering the nuclear region, as well as the [O I](63 μm) line in two single pointings, one on the nucleus and one centred on the peak of CO emission. The data were processed with HIPE 11.1.0 w/ FM,56 and PACSman v3.52. An older reduction of these data are published in De Looze et al. (2012), using HIPE 7.0.0 w/ calibration set FM,32 and PACSman v3.2.

NGC4125 We observed a single pointing centred on the nucleus in the [C II](158 μm), [N II](122 μm) and [O I](63 μm) lines. The data were processed in HIPE v10.0.0 w/ calibration set FM,48 and PACSman v3.52. These data have been published in Wilson et al. (2013).

NGC5195 We have observed maps centred on the nucleus of the [C II](158 μm), [N II](122 μm), [O I](63 μm), [O I](145 μm), and [O III](88 μm) line. The [O I](145 μm) and [O III](88 μm) maps are slightly smaller than the other three lines. The data were processed using HIPE v9.0.2649 w/ calibration set FM,41 and PACSman v3.52.

References

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