KINGFISH –
Key Insights on Nearby Galaxies: a Far Infrared Survey with Herschel
Data Products Delivery – DR2
User's Guide
June 7th, 2012

1. Introduction

This document describes the second delivery (DR2) of the high level data products of the Herschel Open Time Key Project KINGFISH (Key Insights on Nearby Galaxies: a Far Infrared Survey with Herschel; P.I.: R.C. Kennicutt; Deputy-P.I.: D. Calzetti) to the Herschel Science Center.

KINGFISH consists of a sample of 61 galaxies (the SPIRE maps for 6 of which, NGC4254, NGC4321, NGC4536, NGC4569, NGC4579, and NGC4725, were obtained as part of the Eales et al. Herschel Reference Survey and re-reduced by us), which have been mapped with both PACS (3 bands) and SPIRE (3 bands) and measured spectroscopically with PACS. This delivery includes the PACS and SPIRE imaging of the 61 galaxies in KINGFISH, except for the PACS maps of NGC584, whose original observations failed and has been re-observed.

More details can be found in the paper by Kennicutt et al. (2011, PASP, 123, 1347).

2. Content of the Second Data Delivery

2.1 Sample and Summary of Data Products

The galaxies in the KINGFISH sample are listed in Table 1.

Table 1: Galaxies in the KINGFISH sample (listed in order of increasing RA)

Name	Name	Name	Name	Name	Name
NGC0337	IC0342	NGC3049	NGC3627	NGC4625	NGC5474
NGC0584	NGC1482	NGC3077	NGC3773	NGC4631	NGC5713
NGC0628	NGC1512	M81DwB	NGC3938	NGC4725	NGC5866
NGC0855	NGC2146	NGC3190	NGC4236	NGC4736	NGC6946
NGC0925	HolmbergII	NGC3184	NGC4254	DDO154	NGC7331
NGC1097	DDO053	NGC3198	NGC4321	NGC4826	NGC7793
NGC1266	NGC2798	IC2574	NGC4536	DDO165	
NGC1291	NGC2841	NGC3265	NGC4559	NGC5055	
NGC1316	NGC2915	NGC3351	NGC4569	NGC5398	
NGC1377	HolmbergI	NGC3521	NGC4579	NGC5408	
NGC1404	NGC2976	NGC3621	NGC4594	NGC5457	

The second delivery contains both PACS and SPIRE images in 3 bands each (70, 100, and 160 μm for PACS, and 250, 350, and 500 μm for SPIRE) for the galaxies in the sample. Summaries of the data products are given below, and details on the data processing are provided in sections 3 and 4.

2.2 PACS Maps

PACS maps for a total of 60 galaxies are delivered in DR2. The missing galaxy is NGC584, whose observations failed during the first attempt, the re-observations have been obtained a few months ago.

For each galaxy, 3 data cubes, one for each of the PACS bands, are delivered as FITS files. Each data cube contains four or five planes, with the plane index providing the third dimension: the signal map, the uncertainty map, the drifts subtracted during processing, the weight map, and (when present) the signal map built with each scan weighted by its inverse variance (see section 3.3). The Level 2 PACS maps were obtained through processing with *Scanamorphos* (Roussel, 2012, submitted, astroph/1205.2576) of the Level 1 products. The pixel scale of the PACS maps is wavelength-dependent: 1.4" at 70 μm, 1.7" at 100 μm, and 2.85" at 160 μm. The flux units are Jy/pix.

No residual background is removed from the maps. The final maps have orientation North up, East left. See section 3 for more details.

2.3 SPIRE Maps

For each of the 61 galaxies, two sets of maps, for a total of 18 maps per galaxy, are delivered as single-extension FITS files. The two sets differ in the mapping software used to produce the Level 2 products: one set is obtained with the HIPE processing pipeline and the other, which we recommend for use, with *Scanamorphos* (Roussel, 2012, submitted, astroph/1205.2576).

Within each set, there are three maps for each of the SPIRE bands: one each signal, uncertainty, and coverage maps. The pixel scale of the SPIRE maps is wavelength-dependent: 6" at 250 μm, 10" at 350 μm, and 14" at 500 μm. The flux units are MJy/sr, which were converted from Jy/beam (the output of the HIPE pipeline, see section 4.2). The HIPE maps have a median background removed, and all maps have orientation North up, East left. The uncertainty maps have the same pointing and calibration as the flux maps; the coverage maps have the same pointing as the flux maps. See section 4 for more details.

2.4 File Name Convention

For each galaxy, multiple datasets are delivered, with the following formats:

PACS imaging: 3 FITS data cubes, one for each PACS band, with name <name>_scanamorphos_v16.9_pacs< wavelength in μm>_0.fits. The content of each plane within the cube is described both in section 2.2 and section 3.3. The preferred name is the NGC, IC, Holmberg (designated 'Ho') or DDO designation followed by the catalog

number (with the exception of dwarf B in the M81 group, designated 'M81dwB', see Table 1). The wavelength is 70, 100, or 160 μm.

SPIRE imaging: 18 FITS files, 9 each for the two map processing methods (HIPE or *Scanamorphos*), and, for each processing method, three files for each SPIRE band, with name:
<name>_kingfish_spire<wavelength in μm>_v3-0_[hipe/scan][.unc, for uncertainty maps; .cov, for coverage maps].fits. The preferred name is the same as described for the PACS imaging, and the wavelength is 250, 350, or 500 μm.

3. PACS Imaging Data Products and Post-Level-1 Processing

3.1 Processing Summary

All targets were observed with the PACS bolometer arrays using the nominal large-scan mode, except IC342 that was observed in parallel mode. The raw data were processed with HIPE v. 6 to v. 8, mostly following the standard procedure and using the second-level deglitching method, up to Level 1 products. The non-uniform HIPE version has minor to negligible impact on the final products.

The level-1 data were then reformatted and processed with *Scanamorphos* v. 16.9 (closely preceding the public version 17). The steps performed for this release include the subtraction of the brightness drifts caused by the low-frequency noise (comprising both the thermal drifts of the telescope and detectors and the flicker noise of the bolometers), deglitching, and the masking of unstable bolometers and brightness discontinuities. The data are weighted by the inverse square high-frequency noise of each bolometer in each scan, and mapped using the gnomonic projection.

More details on the observations can be found in the KINGFISH reference paper by Kennicutt et al. and a full description of *Scanamorphos* is available in Roussel (2012, submitted, astroph/1205.2576) and at http://www2.iap.fr/users/roussel/herschel.

3.2 Known Features

Some maps show a very faint striped pattern in a portion of the field of view (see Figure 1). This is due to electrical interferences affecting the readout, that cannot be corrected at the moment. Their impact on the map quality is very minor.

The sky background around the galaxies shows faint structures that may not all be real, and are likely caused by drift residuals. Simulations have shown that these artifacts have brightness well below the 3 σ significance level computed from the error map.

Map edges covered in only one scan direction may be affected by strong drifts that cannot be corrected because there is not enough redundancy. Therefore, the user is advised to quantitatively use only the part of the map with nominal coverage.

3.3 Format of the Data Products

For each galaxy and each filter, four or five different planes are assembled into a data cube, the plane index corresponding to the third dimension (Keyword: NAXIS3). The first plane is the signal map, the second plane is the error map (unbiased weighted estimate of the error on the mean brightness), the third plane contains the drifts subtracted during the processing, and the fourth plane is the weight map. When a fifth plane is present, it contains the signal map built with each scan weighted by its inverse variance. It is provided to allow easy identification of residual artifacts (by comparison with the first plane), but in principle it should not be used for photometry.

Each cube is stored into a file conforming to the FITS standard (Wells et al. 1981, A&AS, 44, 363; Hanisch et al. 2001, A&A 376, 359), and can be separated into simple FITS files using an IDL routine (available upon request).

3.4 Flux Calibration

The pipeline was run with the V5 version of the PACS flux calibration set, but the maps have been rescaled by the appropriate correction factors to obtain the V6 flux calibration (as indicated in the fits headers by the FLUXCAL keyword).

3.5 Map Parameters

The maps are in the standard astronomical orientation (North up and East left). The adopted pixel scale is approximately one fourth of the point spread function full width at half maximum (FWHM), i.e.,1.4", 1.7", and 2.85" at 70, 100, and 160 μm, respectively.

The surface brightness unit is that of the processing output, Jy/pixel. The (small) sky background level has not been removed from the maps, and no adjustment to the pointing was made.

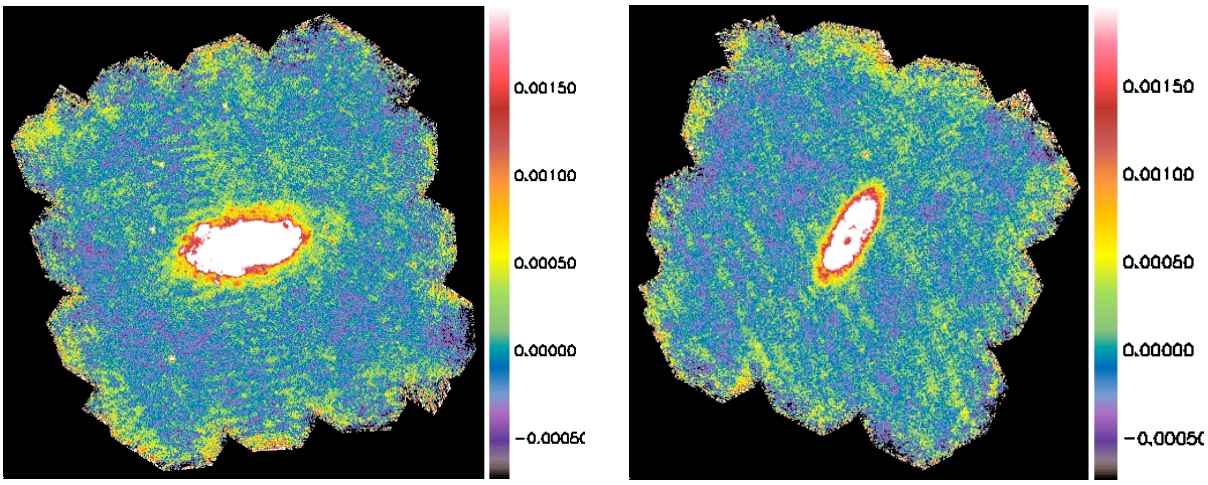

Figure 1: Known features: Two examples of electrical interference visible in the maps. The displayed brightness range emphasizes very faint structures (Jy/pixel). For NGC 5055 (left), the pattern is almost parallel to the galaxy major axis. For NGC 2841 (right), it makes an angle of roughly 45^{o} with the major axis.

4. SPIRE Imaging Data Products and Post-Level-1 Processing

4.1 Introduction

The KINGFISH SPIRE maps are created from multiple Herschel scans obtained in the SPIRE photometric mode (with the exception of IC342, which was measured in the SPIRE/PACS parallel mode), and fully processed with HIPE v. 8 up to Level 1 products. For the Level 2 products, both HIPE v. 8 and *Scanamorphos* v. 16.9 are used, and maps obtained with both types of processing software are delivered in DR2. Portions of the HIPE pipeline have been modified to mask out the galaxy when measuring the background, to increase the size of the map by adding the data taken while the spacecraft turns around after each scan leg, and to adjust the pointing.

The KINGFISH observing strategy is to map each galaxy with two scanning directions oriented at approximately right angles to each other, with 2 (for targets with S_{160} at R_{25} > 3 MJy/sr) or 4 (for targets with S_{160} at R_{25} <= 1 MJy/sr) repetitions (same pattern) for each, out to 1.5 times the optical radius.

4.2 Data Products

The output of our pipeline is 18 FITS files for each galaxy: 3 products (the calibrated image, the uncertainty, and the coverage map) for each of the 3 bands, processed twice: with HIPE and *Scanamorphos*.

4.3 Image Processing

The raw KINGFISH SPIRE data are processed through the early stages of HIPE to calibrate the data in physical units. For the data that will be processed further in HIPE, a line is fit to the data for each scan leg after masking out the galaxy, and this fit is subtracted from the data. Discrepant data (usually a rogue bolometer, of which there are <1 per map, on average) are also masked, and the data (plus the "turnaround" region, for the ~90% of the sample that didn't have visible streaks in that region) are mosaicked using the native mapper in HIPE. These steps are not required for the data processed with Scanamorphos, which automatically performs the matching or rejecting of data.

The map coordinates of both Scanamorphos and HIPE products are then adjusted so that the average position of the point sources (measured using StarFinder; Diolaiti et al. 2000, SPIE, 4007, 879) match those in the MIPS 24 μm images. This adjustment averaged 3" and had a Gaussian distribution characterized by a standard deviation of 3", which we take to be the pointing uncertainty. Finally, the images are converted to surface brightness units (MJy/sr), converted from Jy/beam (the output of both the HIPE pipeline and Scanamorphos) using the beam areas recorded in the image headers.

Photometric Uncertainties

Currently the estimated calibration uncertainties, from the SPIRE Observer's Manual 2010, are 7%. The uncertainty in the beam size is ~1%, and when added in quadrature

with the calibration uncertainty results in a total uncertainty still of ~7%.

4.4 Comparison with DR1 SPIRE Maps

The DR2 SPIRE maps look very similar to those of DR1, with the new products slightly (~2% at 250 and 350 μm) to moderately (~10% at 500 μm) fainter than those in the previous delivery. The backgrounds of the maps processed with *Scanamorphos* can be quite different from those of the maps processed with HIPE, since *Scanamorphos* does not force a background removal, which is instead implemented on the HIPE maps. The beam reconstructed by *Scanamorphos* is slightly (3%) larger than in DR1, as reflected in the 'BEAMSIZE' parameter in the image headers.