The DUNES archive

This document contains information on the DUNES archive in addition, and complementary to what is provided in the paper entitled “DUst around NEarby Stars. The survey observational results” (Eiroa et al. (2013).

In what follows, the contents of the several parts of the archive are described.

Any question on further details can be addressed to:

dunes-support@cab.inta-csic.es

Objects IDs

The prime identifier used by DUNES is the Hipparcos (HIP) number. When available, the HD (Henry Draper), HR (Harvard Revised)/BS (Bright Star) and other denomination of the type, e.g. 24 Cas, η Cas, EP Eri, are given.

Coordinates

The equatorial (IRCS, right ascension and declination), galactic (longitude and latitude), ecliptic (longitude and latitude) and proper motions are provided. All data are referred to the J2000.0 equinox.

Physical parameters

Stellar parallaxes and proper motions and errors are from the revision of the Hipparcos catalogue by van Leeuwen (2007), Vizier catalogue `I/311`. References for the remaining stellar parameters, namely, spectral type, effective temperature, gravity, metallicity, projected rotational velocity, bolometric luminosity and age can be found in Eiroa et al. (2013).

Photometry

Several magnitudes and colour indices have been used to build the spectral energy distribution (SED) for each star. Each item below describes the source of the data and gives the corresponding reference for the zero points (fluxes at zero magnitude) that have been used to compute the fluxes included in the files `hipxxxxxx_sed.dat` that can be found by clicking the option `Full SED`.

- Johnson *BV* and Cousins *I* magnitudes from the Hipparcos catalogue (`I/239` in Vizier). The calibration from magnitudes to fluxes is carried out using the zero points by Bessell (1979).

- Strömgren $b-y$, m_1 and c_1 is taken from Hauck & Mermilliod (1997), Vizier catalogue `II/215` (see also Hauck & Mermilliod, 1998). These indices were converted into *uvby* magnitudes, and then into fluxes using the zero points by Gray (1998).

- 2MASS JHK_s are from the 2MASS Point Source Catalogue (`II/246` in Vizier). Zero points for calibration from magnitudes to fluxes are from Cohen, Wheaton & Megeath (2003).

- Additional near-infrared $JHKLL'M$ photometry was collected from several sources. See Table 3b of Eiroa et al. (2013) for details and references. Averages of the available data for each band were used. Zero points for calibration were taken from Table 7.5 (p. 150) of “Allen’s Astrophysical Quantities (4th edition)”.

- IRAS 12, 25 and 60 µm fluxes (in Jy) and errors (percentage of the observed flux) are from the IRAS Faint Source Catalogue (`II/156a` in Vizier), when available, or from the IRAS catalogue of Point Sources (`II/125` in Vizier). Upper limits are not listed. Non-colour corrected fluxes are provided when clicking this option of the archive (see below the description of the files containing the SEDs for details on the colour corrections).

- Akari 9 and 18 µm fluxes and uncertainties (in Jy) are from the AKARI/IRC mid-IR all-sky Survey (ISAS/JAXA, 2010, `II/297` in Vizier). Non-colour corrected fluxes are provided when clicking this option of the archive (see the description of the files containing the SEDs for details on the colour corrections).

- WISE 3.4 (W1), 11.6 (W3) and 22.1 (W4) µm magnitudes and errors were extracted from the WISE All-Sky data Release Catalogue (`II/311` in Vizier) and converted into fluxes using the zero points for calibration from Wright et al. (2010). Fluxes and uncertainties are provided in Jy. Data from band W2 (4.6 µm) were not used and are not provided; a systematic bad behaviour of the fluxes in this band when compared with the remaining SED fluxes was apparent.

- *Spitzer*/MIPS fluxes at 24 and 70 µm are provided. The data analysis of the images to extract these fluxes is similar to that described in Bryden et al. (2009). At 24 µm, images were created from the raw data using software developed by the MIPS instrument team (Gordon et al. 2005), with image flats chosen as a function of scan mirror position to correct for dust spots and with individual frames normalized to remove large scale gradients (Engelbracht et al. 2007). At 70 µm, images were also processed with the MIPS instrument team pipeline, including added corrections for time-dependent transients (Gordon et al. 2007).

Aperture photometry was performed as in Beichman et al. (2005) with aperture radii of 15.3 arcsec and 14.8 arcsec, background annuli of 30.6–43.4 arcsec and 39.4–78.8 arcsec, and aperture corrections of 1.15 and 1.79 at 24 and 70 μm, respectively. The 24 μm centroid positions, which are consistent with the telescope pointing accuracy of <1 arcsec (Werner et al. 2004), were used as the target coordinates for both wavelengths.

As far as the flux uncertainties is concerned, the DUNES targets are observed at 24 μm with high S/N; the uncertainty at that wavelength being generally dominated by systematics at the level of ~2% for overall calibration and <1% for repeatability (Engelbracht et al. 2007). The 70 μm uncertainties are calculated from direct measurement of the background variation in each field, using the same apertures and corrections as for the photometry. A calibration uncertainty of 5% and a repeatability uncertainty of 4.5% (Gordon et al. 2007) are also included.

- PACS (70, 100 and 160 μm) and SPIRE (250, 350 and 500 μm) fluxes and uncertainties or 3-σ upper limits are provided. Units are mJy. Details on the image reduction, noise analysis and extraction of the photometry can be found in Eiroa et al. (2013).

Quick summary sheets

A summary sheet called `hipxxxxxx_summary_sheet.pdf` contains in a single page all the relevant information for each star. Hereafter, the string `xxxxxx` in the file names contains the Hipparcos identification of the star padded with zeros to the left when necessary (e.g. `hip000910` or `hip049908`). Identifications, equatorial coordinates, the parallax, proper motions, stellar parameters, plots of the PACS and SPIRE mosaics and the SED, and the PACS and SPIRE fluxes are provided.

Spectral Energy Distributions (SED)

By clicking this option, two files are provided for each star:

```
hipxxxxxx_sed.dat
hipxxxxxx_sed_plot.pdf
```

The first one contains the whole SED *including* the PACS and SPIRE fluxes; the second one is contains a plot of the full SED.

- Files `hipxxxxxx_sed.dat`

  The files look like this one:

```
HIP 101997
--------------------------------------------------------------------------
  Wv (mu)   F_nu (mJy)  Delta F_nu(mJy)   Band/comments
--------------------------------------------------------------------------
   0.440    6.272E+03    1.155E+02      | Johnson B
   0.550    1.040E+04    1.916E+02      | Johnson V
   0.790    1.495E+04    2.753E+02      | Cousins I
   0.349    1.979E+03    1.689E+02      | Stroemgren u
   0.411    4.895E+03    2.033E+02      | Stroemgren v
   0.466    8.137E+03    1.506E+02      | Stroemgren b
   0.546    1.058E+04    1.950E+02      | Stroemgren y
   1.235    1.214E+04    3.003E+03      | 2MASS J   [quality flag: D]
   1.662    1.220E+04    4.945E+02      | 2MASS H   [quality flag: A]
   2.159    9.665E+03    1.424E+02      | 2MASS K_s [quality flag: A]
   3.353    4.129E+03    3.160E+02      | WISE W1
  11.561    4.129E+02    5.705E+00      | WISE W3
  22.088    1.205E+02    3.219E+00      | WISE W4
   9.000    7.125E+02    4.246E+00      | Akari 9  [colour corrected]
  24.000    1.009E+02    2.058E+00      | MIPS 24
  70.000    7.400E+00    3.733E+00      | MIPS 70
  12.000    3.527E+02    2.822E+01      | IRAS 12  [colour corrected]
  70.000    10.41        1.66           | PACS  70
 100.000     5.59        0.95           | PACS 100
 160.000    <4.20                       | PACS 160  [3-sigma upper limit]
 250.000    <19.5                       | SPIRE 250 [3-sigma upper limit]
 350.000    <21.0                       | SPIRE 350 [3-sigma upper limit]
 500.000    <24.6                       | SPIRE 500 [3-sigma upper limit]
```

The data are organized in four columns: (1) wavelengths in µm, (2) fluxes and (3) uncertainties in mJy, and (4) descriptions of the bands (and any specific comment).

Details on the calibration from magnitudes to fluxes are given above in the paragrpah devoted to the photometry.

The Akari fluxes have been colour corrected using the data provided in Section 4.8 of the “Akari IRC Data User Manual. Version 1.4” (Lorente et al. 2008):

`http://www.sciops.esa.int/index.php?project=ASTROF&page=observers`

(look for the document in section “Instrument Data Users Manuals”).

The observed fluxes were divided by the corresponding constants, $K(9\ \mu\text{m})$, $K(18\ \mu\text{m})$. Values in Table 4.8.11 were taken and the effective temperature was used as independent variable. Typical values for the corrections at the temperatures of the DUNES stars are 1.18, 0.99 at 9 and 18 µm, respectively.

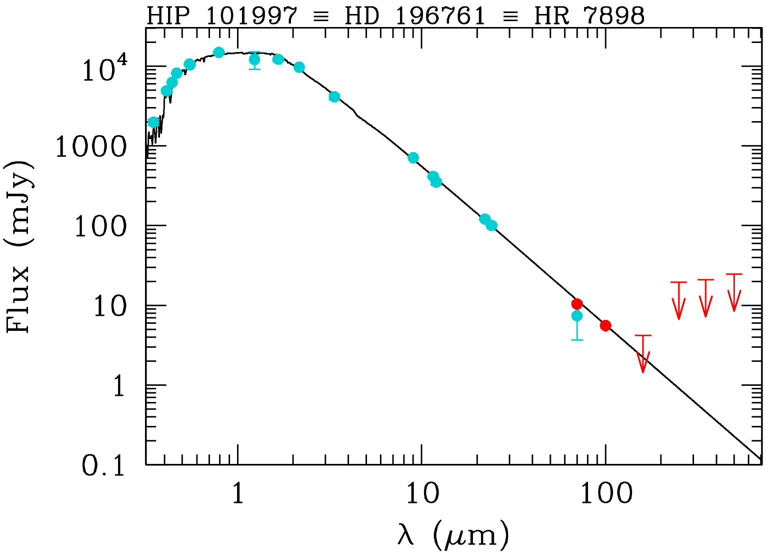
The IRAS fluxes have been colour corrected dividing the observed fluxes by the corresponding corrections $K(12\ \mu\text{m})$, $K(25\ \mu\text{m})$ and $K(60\ \mu\text{m})$. Their values are estimated by interpolation of the numbers given in the “IRAS Explanatory Supplement. VI. Flux Reconstruction and Calibration. C. Absolute Calibration. Table Suppl. VI.C.6 - Color Correction Factors, K”:

http://irsa.ipac.caltech.edu/IRASdocs/exp.sup/ch6/tabsupC6.html (see the last table of that web page) using the effective temperature as the independent variable. Typical values of the corrections are 1.43, 1.40 and 1.32 for 12, 25 and 60 μm, respectively.

The PACS –and SPIRE, when available– fluxes (or 3-σ upper limits) are given in the last lines of the table. The uncertainties in those fluxes contain only the statistical errors.

- Files `hipxxxxxx_sed_plot.pdf`

  A file containing a plot with the complete SED is provided. The plots look like this:



The photometry from the optical up to *Spitzer*/MIPS 70 μm is plotted as light-blue solid circles, the PACS and SPIRE fluxes are plotted as red circles; 3-σ upper limits are clearly indicated. The *Spitzer*/IRS spectra are plotted in magenta. The normalized photospheric model is plotted in black. Each graph shows the fluxes F_ν, in mJy, plotted against the wavelength in μm. These plot can be reproduced for a given star using the following set of files that can be found in this archive:

Full SED fluxes: `hipxxxxxx_sed.dat`
Spitzer/IRS spectrum: `hipxxxxxx_irs_spectrum.dat`
Model photosphere: `hipxxxxxx_model_photosphere.dat`

Note that SPIRE data and IRS spectra are not available for all the objects.

Photospheric models

By clicking this option, files called `hipxxxxxx_model_photosphere.dat` are provided for the stars selected. They have typically ~28000 lines, run from ~0.04 to 4000 µm and are organized in two columns: (1) wavelengths in µm and (2) fluxes in Jy. The files look like this:

```
-------------------------
 Wavelength     Flux_nu
  (micron)       (Jy)
-------------------------
3.760000E-02  7.447040E-37
3.819999E-02  2.606464E-36
3.880001E-02  1.117056E-35
............  ............
............  ............
3.999021E+03  6.474191E-06
3.999521E+03  6.472573E-06
4.000000E+03  6.471023E-06
```

They contain photospheric models normalized to the photometry that has been used to build the SED (see above). Details on the original models and the method used to normalize them to the photometry are given in Eiroa et al. (2013).

Several combinations of bands (BVI+ 2MASS JHK_s + auxiliar $JHKLM$ + WISE) were used to carry out normalizations of the original model; the one with the least reduced χ^2 was chosen. Only 2MASS photometry with quality A or B was used, and special care was taken not to include the WISE W4 band when the star showed an infrared excess starting at wavelengths around ~20 µm.

Spitzer/IRS spectra

The *Spitzer*/IRS (Houck et al. 2004) spectra provided in the archive are a combination of all low-resolution modules available from the *Spitzer* archive. For each module, data are taken with the star positioned at two locations along the slit, to allow for background subtraction. The resulting spectra are averages from the two slit positions, while the uncertainty at each wavelength is estimated from their difference. The slit for the long-wavelength mode (LL2: 14–21 µm and LL1: 20–40 µm) is much wider (11 arcsec) than the telescope pointing uncertainty (1 arcsec; Werner et al. 2004), such that flux loss outside of the slit is minimal and no scaling of individual modules is needed. The shorter wavelength modules (SL2: 5-8 µm and SL1: 8–14 µm), however, can suffer from slit loss and need to be normalized to match the longer wavelength spectra; the adjustement in flux is typically between 0 and 10% (see e.g. Lawler et al. 2009, who found a dispersion of 8% when they normalized short-wavelength data to an independent model photosphere).

The files, called `hipxxxxxx_irs.dat`, look like this:

```
----------------------------------------
 Wv (mu)     F_nu (Jy)    Delta F_nu (Jy)
----------------------------------------
 5.24749      1.89375      0.02007
 5.27773      1.86720      0.02676
 5.30797      1.84787      0.03531
........      .......      .......
........      .......      .......
34.64583      0.04550      0.00238
34.81519      0.04604      0.00417
34.98454      0.04606      0.00384
```

and the data are organized in three columns: (1) wavelengths in µm, (2) fluxes and (3) uncertainties in Jy.

Note: *All IRS the spectra but two were built by members of the DUNES team. The origin of the spectra for HIP 7978 and HIP 17439 can be found in the corresponding headers of the files; the original format of the data they contain has been kept unchanged in the archive.*

PACS mosaics and SPIRE small maps

A complete account of the *Herschel* PACS and SPIRE observations and data reduction can be found in Sect. 4 of Eiroa et al. (2013). After the reduction process, the two individual PACS scans were combined in a single mosaic to reduce sky noise and suppress $1/f$ stripping effects from the scanning. Final –standard– image scales were 1 arcsec per pixel at 70 and 100 µm and 2 arcsec per pixel at 160 µm compared to native instrument pixel sizes of 3.2 and 6.4 arcsec respectively. Both the native and standard image scale mosaics are provided by clicking this option in the archive. The files are called:

```
hipxxxxxx_PACS_Mosaic_lambda_std.fits
hipxxxxxx_PACS_Mosaic_lambda_ntv.fits
```

where `lambda` is a 2- or 3-character string specifying the corresponding wavelength, and `std/ntv` stand for "standard" or "native".

For the SPIRE observations, the small maps were created using the standard pipeline routine in HIPE, using the naive mapper option. Image scales of 6, 10 and 14 arcsec per pixel were used at 250, 350 and 500 µm, respectively. The files are called

```
hipxxxxxx_SPIRE_SmallMap_lambda.fits
```

where again `lambda` indicates the corresponding wavelength.

Important notes:

- *Three pairs of stars, namely*

  HIP 71681/HIP 71683
  HIP 73182/HIP 73184
  HIP 104214/HIP 104217

  are binaries and were observed on the same scan map, therefore the corresponding mosaics contain both stars. As an example, if you query for the PACS mosaics of HIP 71681, you will retrieve the following files:

  ```
  hip071681+hip071683_PACS_Mosaic_100_std.fits
  hip071681+hip071683_PACS_Mosaic_160_std.fits
  hip071681+hip071683_PACS_Mosaic_100_ntv.fits
  hip071681+hip071683_PACS_Mosaic_160_ntv.fits
  ```

  whereas if you query for HIP 71683, you will get:

  ```
  hip071683+hip071681_PACS_Mosaic_100_std.fits
  hip071683+hip071681_PACS_Mosaic_160_std.fits
  hip071683+hip071681_PACS_Mosaic_100_ntv.fits
  hip071683+hip071681_PACS_Mosaic_160_ntv.fits
  ```

  but the corresponing files are identical. The coordinates of each target must be explored in order to extract the right photometry.

- *During the Science Demonstration Phase (SDP), observations of two DUNES targets, namely:*

  HIP 7978 (70/160 and 100/160 combination; `OBS_IDs` *1342187141,-42)*
  HIP 113357 (100/160 combination; `OBS_ID` *1342187255)*

  were taken in point source photometry (chop-nod) mode. HIP 113357 (51 Peg) was only observed by the survey in chop-nod mode and thus that observation must suffice for analysis of that target. HIP 7978 (q1 Eri) was later observed in scan map mode by the calibration team with the 100/160 combination using non-standard map parameters (`OBS_IDs` *1342187138,-39) and by the DUNES survey with the 70/160 combination using the standard parameters as per the bulk of the survey (*`OBS_IDs` *1342212838,-39). Due to the scan map having a lower measured rms sky noise levels and a better characterized observing mode, we recommend the utilisation of the scan map data over the chop-nod data for analysis and interpretation of this target.*

References

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DUNES: Data reduction

This document serves as a summary of the data reduction process and parameter values adopted for the *Herschel* (Pilbratt et al., 2010) archive's PACS and SPIRE images made by the Open Time Key Programme DUNES (DUst around NEarby Stars) [1]. We refer the user to the DUNES survey paper, "DUst around NEarby Stars: The survey observational results" (Eiroa et al., 2013) wherein much of the information presented here is illustrated and many of the caveats explained.

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Observations

PACS (Poglitsch et al., 2010) scan map observations of all 133 DUNES targets in 130 fields (due to the doubling-up on several binary sources) were taken with the 100/160 channel combination. Some 70/160 observations were taken for a sub-set of these stars based on their expected 100 μm flux (in the case of faint sources) or the known presence of a bright disc. We note that additional PACS 70/160 observations for some DUNES resolved disc targets are available through the DEBRIS programme (e.g. HIP 22263, HIP 62207), with which DUNES shares 106 sources. Following the recommended parameters laid out in the scan map release note[2] each scan map consisted of 10 legs of 3′ length, with a 4″ separation between legs, scanning at the medium slew speed (20″ per second). Each target was observed at two array orientation angles (70°and 110°) to improve noise supression and assist in the removal instrumental artefacts and gl itches from the images after mosaicking.

SPIRE (Griffin et al., 2010) small map observations were taken of 20 DUNES targets based on the expected target brightness at sub-mm wavelengths. Each SPIRE observation was composed of either two or five repeats (equivalent on-source time of either 74 or 185 s) of the small scan map mode[3], producing a fully sampled map covering a region 4 ′ around the target.

Data reduction

All data reduction was carried out in HIPE *Herschel* Interactive Processing Environment (Ott et al., 2010) user release version 10.0.0, PACS calibration version 45 and SPIRE calibration version 10 for the images presented here. Although the HIPE version and calibration versions are different to those with which the results in the survey paper were derived, the PACS photometry calibration has been stable

[1] http://www.mpia-hd.mpg.de/DUNES/

[2] See PICC-ME-TN-036 for details.

[3] See herschel.esac.esa.int/Docs/SPIRE/html/spire_om.pdf for details.

since version 32 (used to create the images in the survey paper) and . This change should not affect the validity of either the material presented in the archive or the results presented in Eiroa et al., 2013.

The individual PACS scans were processed with a high pass filter to remove background structure, using high pass filter radii of 15 frames at 70 µm, 20 frames at 100 µm and 25 frames at 160 µm, suppressing structure larger than 62″, 82″ and 102″ in the final images, respectively. In the highpass filtering process, sources were identified from the level 2 pipeline product using SExtractor and masked during a second pass through the data reduction with a 10″ radius for all three wavebands. A region centered on the expected target position was masked automatically with a 15″ radius (if point-like) or 30″ (if extended), again invariant of wavelength. For comparison, the largest disc in the DUNES survey had a FWHM extent of 18″×10″ at 100 µm. Deglitching was carried out using the second level spatial deglitching task. At 70 and 100 µm the two individual PACS scans were mosaicked to reduce sky noise and suppre ss $1/f$ striping effects from the scanning. At 160 µm typically only the two longest exposure scans (100/160) were combined unless the 70/160 combination were of similar duration (e.g. in the case of HIP 17439). This is due to the large sky noise values at 160 µm for single repetitions typically observed in thhe 70/160 scans (~ 9 mJy) compared to the noise in the longer duration 100/160 scans (~ 2-4 mJy) along with the faintness of the sources (~ 5–10 mJy) resulting in the combination of all four available scans simply adding noise to the longer duration 100/160 mosaic. The final image scales of the mosaics used for analysis are 1″ per pixel at 70 and 100 µm and 2″ per pixel at 160 µm, compared to native instrument pixel sizes of 3.2″ at 70 and 100 µm and 6.4″ at 160 µm.

For the SPIRE observations, the small maps were created using the standard pipeline routine in HIPE, using the naive mapper option. Image scales of 6″, 10″ and 14″ per pixel were used at 250, 350 and 500 µm.

Script

The script used to produce the images submitted to the archive is presented in Appendix A. The script was based on the pipeline script included with HIPE 10, with some variations following discussion with the HSC and PACS data reduction experts regarding the particular science goals of DUNES:

- The script was a batch process working on all sources in a given input table.
- The revised pointing product for each observation were used to correct for the astrometry errors induced by the star tracker distortions.

- Sources were identified in the individual scans using SExtractor during the reduction process and masked accordingly.

- A drop size (pixfrac parameter) of 1.0 was used since the method of background measurement was insensitive to the presence of correlated noise.

- Highpass filter widths of 15, 20 and 25″ were used rather than the standard 15, 15 and 25″ for 70, 100 and 160 μm.

- Over-sampled pixel sizes of 1″ at 70 and 100 μm and 2″ at 160 μm are used for the mosaic image scales used to measure the results. Native scale images are also available.

Description

Keywords

A list of the keywords added to the mosaic metadata and their definitions is presented in Table 1. Many of the keywords in the scan and mosaic meta data provided are taken directly from the original observation and are therefore not listed here, being self explanatory (e.g. the HIPE and calibration versions, WCS information, position and roll angle of the telescope, observation ids, etc.).

Table 1: Header parameters added to the FITS image metadata.

Keyword	Meaning
"PROGRAMME"	OTKP_DUNES: data observed for the DUNES programme.
"OBSERVER"	ceiroa: All observations can be found in the Herschel Science Archive searching by observer.
"PID"	Programme ID: OTKP_ceiroa_1 (main programme) or SDP_ceiroa_3 (science demonstration phase observations).
"TYPE"	Type of image: Scan map or Mosaic.
"OBS_ID"	Observation ID (for scans).
"OBS00*x*"	Observation IDs (for mosaics, where x is the scan number).
"DESC"	Description of contents: typically image, error, coverage and mask frames.
"T_ONSRC"	On-source time, as calculated in HSpot.
"PIXFRAC"	Pixel fraction parameter for the drop size in image reconstruction.
"PIXSIZE"	Pixel size of the image.
"HPFWIDE"	High pass filter width parameter.
"LEG_LENG"	Leg length of the observation, in arcmin.
"LEG_SEPN"	Leg separation of the observation, in arcsec.
"SLEW_SPD"	Slew speed of the telescope, in arcsec/second.

Frames

The DUNES mosaics contain four separate frames, namely the ‘image’, ‘exposure’, ‘error’ and ‘flag’. The ‘image’ frame contains the final mosaic (or scan) product from the DUNES data reduction script. The ‘exposure’ frame contains the number of readout measurements taken by PACS at each point in the ‘image’ frame. The ‘error’ frame, derived from the ‘exposure’ frame using the *photCoverage2Noise* procedure is a measurement of the uncertainty in the ‘image’ mosaic. Finally, the ‘flag’ frame shows the regions of the ‘image’ frame that were actually observed (‘0’ values, c.f. off-image parts of the mosaic which are denoted by ‘1’).

Bibliography

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Griffin, M.J., et al., 2010, A&A, 518, L3
Ott, S., 2010, in Astronomical Data Analysis Software and Systems XIX, ASP Conference Series, Vol. 434., p. 139
Pilbratt, G.L., et al., 2010, A&A, 518, L1

Appendix A: The script

```
#IMPORT PACS CALIBRATION
from herschel.pacs.spg            import *
from herschel.pacs.spg.common     import *
from herschel.pacs.spg.phot       import *
from herschel.pacs.spg.pipeline   import *
from herschel.pacs.signal.context import *
from herschel.pacs.signal         import SlicedFrames
from herschel.pacs.cal            import GetPacsCalDataTask
from herschel.ia.dataset          import LongParameter
from herschel.pacs.spg.all        import *
from herschel.pacs.signal import MapIndex
from herschel.pacs.spg.phot import MapIndexTask
from herschel.pacs.spg.phot import IIndLevelDeglitchTask

import os
import commands
import herschel.store.auth

#HARD WIRED DIRECTORIES
root_dir = '/home/jmarshall/mydata/dunes/redux_4/'
pp_dir = '/home/jmarshall/mydata/dunes/pointing/revised_pointing_products/'
#READ IN TARGET ID AND OBSIDS TO ARRAYS FROM ASCII FILE
ascii=AsciiTableTool()
ascii.template=TableTemplate(6,names=["target","obs1","obs2","ot","od","rslv"],\
                             types=["String","Long","Long","Integer","Integer","Integer"])
table=ascii.load("~/dir/dunes_input_table.txt")
#NUMBER OF TARGETS (OR WAVELENGTH PAIRS) TO BE ANALYZED
ntgt = len(table["target"].data)
#BREAK DOWN DATA TABLE BY TARGET, BLUE_CHANNEL, OBS1, OBS2
target_names = table["target"].data
#SCAN AND CROSS-SCAN OBSIDS
```

```
scan_obsids = table["obs1"].data
xscan_obsids = table["obs2"].data
onsource_time = table["ot"].data
opday = table["od"].data
rsv = table["rslv"].data
#ACTUAL SOURCE POSITION IN EACH FIELD
#Empty array for roll angles - at most a mosaic will have 4 observations
rollangle=[0.0,0.0,0.0,0.0]
#USERNAME AND PASSWORD (user will need to add their own!)
your_user_name = "yourusername"
your_password = "yourpassword"
login_usr = "hcss.ia.pal.pool.hsa.haio.login_usr"
login_pwd = "hcss.ia.pal.pool.hsa.haio.login_pwd"
Configuration.setProperty(login_usr,your_user_name)
Configuration.setProperty(login_pwd,your_password)

#Drop size for pixels
pixfrac = 1.0

#Radius for high pass filter masking
radius = 15.0

#used by SEXTRACTOR to identify sources for masking from the level 2 image
#assumed FWHM are the mean of the major and minor axis for 20\arcsec/s scans
#at each wavelength [70,100,160]
fwhm = [5.61,6.79,11.36]

#LOOP OVER ALL OBSERVATION PAIRS IN THE LIST
for nn in range(0,len(target_names)):
    # Obsids to use in making the 70 or 100 micron mosaic
    n_obs_blue = [scan_obsids[nn],xscan_obsids[nn]]
    # Obsids to use in making the 160 micron mosaic
    n_obs_red = [scan_obsids[nn],xscan_obsids[nn]]
    #If both 70/160 and 100/160 observations available, you can combine all 4 160um maps
    #be careful of offsets between epochs and the different observing times of the 70/160
    #and 100/160 scans, though.
    #if(nn >= 1)and(target_names[nn-1] == target_names[nn]):
    #  n_obs_red = [scan_obsids[nn-1],xscan_obsids[nn-1],scan_obsids[nn],xscan_obsids[nn]]

    # Name of the HIPE pool you saved the data to (same as target name)
    targetid = target_names[nn]
    # Is the disc resolved?
    resolved = rsv[nn]
    # Location of the HIPE pools on your computer
    pooldir = "˜/.hcss/lstore/"
    #on source time
    tos = onsource_time[nn]
    od = opday[nn]
    # set some blank arrays
    map_wcs_red = []
    map_wcs_blue= []
    # define the channels to be processed
    channel  = ["blue","red"]
    bandfwhm = [0,fwhm[2]]
    # set blue channel names and creat directory for files
    bluobs=getObservation(scan_obsids[nn],verbose=True,useHsa=True,instrument=’PACS’)
    pacs_blue = bluobs.meta["blue"].value
    del(bluobs)
    if(pacs_blue == ’blue1’):
      blueid = "pacs70"
      channel[0] = "blue"
      bandfwhm[0] = fwhm[0]
```

```
if(pacs_blue == ’blue2’):
  channel[0] = "green"
  blueid = "pacs100"
  bandfwhm[0] = fwhm[1]
bandnames= [blueid,"pacs160"]
### ADD IN DIRECTORIES FOR DATA FILES TO GO IN ###
# output directory, attempt to make directories
os.system(’mkdir ’+root_dir+targetid+"/")
os.system(’mkdir ’+root_dir+targetid+"/"+blueid+"/")
direc = root_dir+targetid+"/"+blueid+"/"

### ACTUAL DATA REDUCTION STARTS HERE ###

for i in range(0,len(channel)):

  color = channel[i]

  if color==’red’:
    n_obs = n_obs_red
  elif color==’green’:
    n_obs = n_obs_blue
  elif color==’blue’:
    n_obs = n_obs_blue

#BLANK ARRAYS FOR VARIOUS THINGS
  scanlist = []
#RESET MAPS TO AVOID PIXEL SIZE PROBLEMS
  map_wcs = []

  for j in range(len(n_obs)):
    obsid = n_obs[j]
  # observation id :
  #  get observation context from HSA:
    obs = -1
  #proprietary files
    if targetid == ’hip7978’ and pacs_blue_channel[nn]==2:
      obs=getObservation(obsid,poolName=targetid, poolLocation=pooldir,verbose=True,\
                         useHsa=False,instrument=’PACS’)
    if obs == -1:
      obs=getObservation(obsid,verbose=True,useHsa=True,instrument=’PACS’)
  #TARGET LOCATION FROM META DATA
    tgt_pmra = obs.meta["pmRA"].value
    tgt_pmdec = obs.meta["pmDEC"].value
    rasource=obs.meta["raNominal"].value
    decsource=obs.meta["decNominal"].value
    cosdec=COS(decsource*Math.PI/180.)

    rollangle[j] = obs.meta["posAngle"].value
    if color==’red’:
      rad1=150
      rad2=150
      outpixsz=2.0
      hpfrad1=100
      hpfrad2=25
      bandid = bandnames[1]
      wavelength = ’160 microns’
      map_wcs_red=Wcs(cunit1="Degrees",cunit2="Degrees",cdelt1=-1.0*outpixsz/3600.,\
        cdelt2=outpixsz/3600.,crota2=0.,crpix1=rad1,crpix2=rad2,\
        crval1=rasource,crval2=decsource,ctype1="RA---TAN",ctype2="DEC--TAN",\
        equinox=2000.0)
      map_wcs_red.setParameter("naxis1",2*rad1,"naxis1")
      map_wcs_red.setParameter("naxis2",2*rad2,"naxis2")
```

```
        elif color==’green’:
          rad1=300
          rad2=300
          outpixsz=1.0
          hpfrad1=100
          hpfrad2=20
          n_obs = n_obs_blue
          bandid = bandnames[0]
          wavelength = ’100 microns’
          map_wcs_blue=Wcs(cunit1="Degrees",cunit2="Degrees",cdelt1=-1.0*outpixsz/3600.,\
            cdelt2=outpixsz/3600.,crota2=0.,crpix1=rad1,crpix2=rad2,\
            crval1=rasource,crval2=decsource,ctype1="RA---TAN",ctype2="DEC--TAN",\
            equinox=2000.0)
          map_wcs_blue.setParameter("naxis1",2*rad1,"naxis1")
          map_wcs_blue.setParameter("naxis2",2*rad2,"naxis2")
        elif color==’blue’:
          rad1=300
          rad2=300
          outpixsz=1.0
          hpfrad1=100
          hpfrad2=15
          n_obs = n_obs_blue
          bandid = bandnames[0]
          wavelength = ’70 microns’
          map_wcs_blue=Wcs(cunit1="Degrees",cunit2="Degrees",cdelt1=-1.0*outpixsz/3600.,\
            cdelt2=outpixsz/3600.,crota2=0.,crpix1=rad1,crpix2=rad2,\
            crval1=rasource,crval2=decsource,ctype1="RA---TAN",ctype2="DEC--TAN",\
            equinox=2000.0)
          map_wcs_blue.setParameter("naxis1",2*rad1,"naxis1")
          map_wcs_blue.setParameter("naxis2",2*rad2,"naxis2")

        print ""
        print "Reducing OBSID:", obsid, " (", i+1, "/", len(n_obs), ")"

      ############ SETTINGS ##########################################################
      #extract the frames from the observation context "obs"
        if color==’blue’ or color==’green’:
          frames=obs.level0.refs["HPPAVGB"].product.refs[0].product
          map_wcs = map_wcs_blue
        elif color==’red’:
          frames=obs.level0.refs["HPPAVGR"].product.refs[0].product
          map_wcs = map_wcs_red

# -------------------------------------------------------------------------------------
# Extract the PointingProduct
        pp = obs.auxiliary.pointing
# correct pointing product according to revised pps from ESAC
# this is no longer required after v9.1.0 - the revised pointing is automatically included
#        if(od >= 320) and (od <= 761):
#          pp = fitsReader(pp_dir+’/pointing_od_0’+str(od)+’.fits’)
# Extract the calibration tree
        calTree = getCalTree(version=45)
# set the calibration tree as default
        GetPacsCalDataTask.setDefaultCalTree(calTree)
# Extract Housekeeping parameters
        photHk = obs.refs["level0"].product.refs["HPPHK"].product.refs[0].product["HPPHKS"]
# Extract OrbitEphemeries
        orbitEphem = obs.auxiliary.orbitEphemeris

#######################
# LEVEL 0 -> LEVEL 0.5
#######################
```

```
        frames = filterSlew(frames)
        frames = findBlocks(frames,calTree=calTree)
        frames = detectCalibrationBlock(frames)
        frames = removeCalBlocks(frames,useBbid=1)
        frames = photFlagBadPixels(frames,calTree=calTree,scical="sci",keepall=False)
        frames = photFlagSaturation(frames, calTree=calTree, hkdata=photHk)
        frames = photConvDigit2Volts(frames, calTree=calTree)
        frames = convertChopper2Angle(frames, calTree=calTree)
        frames = photAddInstantPointing(frames, pp, orbitEphem = orbitEphem,calTree = calTree)
# DELETE UNNECESSARY VARIABLES
        del(pp,photHk,orbitEphem)
# Save the level 0.5 data as a frames file
        savefile = direc+"frame_"+"_" + str(obsid) + "_" + bandid + "_" + "Level_0.5.fits"
        simpleFitsWriter(frames,savefile)
#######################
# LEVEL 0.5 -> LEVEL 1
#######################
        frames = photRespFlatfieldCorrection(frames, calTree = calTree)
# Save the level 1 data as a frames file
        savefile = direc+"frame_"+"_" + str(obsid) + "_" + bandid + "_" + "Level_1.fits"
        simpleFitsWriter(frames,savefile)
#####################
# LEVEL 1 -> LEVEL 2
#####################
# Mask the central region
        ralist = Double1d(1)
        ralist[0] = rasource
        declist = Double1d(1)
        declist[0] = decsource
        rad = Double1d(1)
        rad[0] = 15.0

# Use bigger rad size for large discs in the sample
        if resolved == 1:
          rad[0] = 30.0
# Create a list of sources in the field based on the level2 image from the obs
        if(color == 'red'):
          map=obs.refs["level2"].product.refs["HPPPMAPB"].product
        if(color == 'blue' or color=='green'):
          map=obs.refs["level2"].product.refs["HPPPMAPR"].product
        sourceList = sourceExtractor(image=map, algorithm="sussextractor", detThreshold=10.0,\
            fwhm=bandfwhm[i], pixelRegion=1.5,fluxPriorsLambda=0.0, fitBackground=True,\
            useSignalToNoise=False, fluxPriorsMin=1.0E-4, fluxPriorsMax=1.0E8,getFilteredMap=False,\
            getPrf=False, doApertureCorrection=True)
        ralist = ralist.append(sourceList["sources"]["ra"].data)
        declist = declist.append(sourceList["sources"]["dec"].data)
        radlist = [10.0]*(len(ralist)-1)
        radlist = Double1d([float(s) for s in radlist])
        rad = rad.append(radlist)

        from herschel.pacs.spg.phot import MaskFromCatalogueTask
        mfc = MaskFromCatalogueTask()
        mask = mfc(map, ralist, declist, rad, copy = 1)
        frames  = photReadMaskFromImage(frames, si=mask, extendedMasking=True,\
            maskname="HighpassMask")

# Project hpfmask into an image
        frames_masked = frames.copy()
        objectMask = frames_masked.getMask('HighpassMask').copy()
        frames_masked.setSignal(Double3d(objectMask))
        frames_masked = deactivateMasks(frames_masked,String1d(["HighpassMask"]))
        hpfmask = photProject(frames_masked,calTree=calTree,outputPixelsize=outpixsz,\
             pixfrac=pixfrac,wcs=map_wcs)
        Display(hpfmask)
        hpfmask.image[hpfmask.image.where(hpfmask.image > 0.0)] = 1.0
        hpfmask.image[hpfmask.image.where(hpfmask.coverage < 0.1)] = -1.0
        # Save the hpfmask image for later use (add to Mosaic product)
        outfile = direc+ "hpfmask_Scan_"+targetid+"_" + str(obsid) +"_"+ bandid +"_hpf"+\
             str(hpfrad2)+".fits"
        simpleFitsWriter(hpfmask,outfile)

# Delete unneccesary parameters
        del(ralist,declist,rad,map,frames_masked,objectMask)

# Run the high pass filter on a frames class, where the sources are masked (using HighpassMask)
        frames  = maskedHighpassFilter(frames,hpfrad2,maskname="HighpassMask",\
                  interpolateMaskedValues=True)

        frames  = filterOnScanSpeed(frames,limit=10)

# spatial deglitching - define properties
        from herschel.pacs.spg.phot.deglitching.map import MapDeglitchTask
        s = Sigclip(nsigma=30,behavior="clip",outliers="both",mode=Sigclip.MEDIAN)
# deglitch map
        mdt = MapDeglitchTask()
        deg = mdt(frames,deglitchvector='timeordered',maskname='2nd level glitchmask',algo=s)
#        frames_masked = frames.copy()
#        objectMask = frames_masked.getMask('2nd level glitchmask').copy()
#        frames_masked.setSignal(Double3d(objectMask))
#        frames_masked = deactivateMasks(frames_masked,String1d(["2nd level glitchmask"]))
# Project the glitch mask into an image
#        glitchmask = photProject(frames_masked,calTree=calTree,outputPixelsize=outpixsz,\
#                pixfrac=pixfrac,wcs=map_wcs)
#        glitchmask.image[glitchmask.image.where(glitchmask.image > 0.0)] = 1.0
#        glitchmask.image[glitchmask.image.where(glitchmask.coverage < 0.1)] = -1.0
#        Display(glitchmask)
# Save the glitchmask image for later use (add to Mosaic product)
#        outfile = direc+ "glitchmask_Scan_"+targetid+"_" + str(obsid) +"_"+ bandid +"_hpf"+\
#             str(hpfrad2)+".fits"
#        simpleFitsWriter(glitchmask,outfile)
# Delete unneccesary parameters
#        del(frames_masked,objectMask)

#################
# Make the image
#################
        image = photProject(frames,calTree=calTree,outputPixelsize=outpixsz,pixfrac=pixfrac,\
           wcs=map_wcs)
        Display(image)
# Create error map
        photCoverage2Noise(image, hp = hpfrad2, pixfrac = 1.0)
# Add metadata to image
        image["hpfmask"] = hpfmask["image"]
#        image["glitchmask"] = glitchmask["image"]
        image.meta["PROGRAMME"] = StringParameter("OTKP_DUNES")
        image.meta["OBSERVER"] = StringParameter("ceiroa")
# Exact observing programme for the obsid
        obs_programme = "OTKP_ceiroa_1"
        if(obsid == 1342195666 or obsid == 1342187328 \
           or obsid == 1342187142 or obsid == 1342187141):
           obs_programme = "SDP_ceiroa_3"
        image.meta["PID"] = StringParameter(obs_programme)
        image.meta["INSTRUMENT"] = StringParameter("PACS")
        image.meta["TYPE"] = StringParameter("SCAN IMAGE")
        image.meta["DESC"] = StringParameter("IMAGE COVERAGE AND UNCERTAINTY MAPS")
        image.meta["WAVELENG"] = StringParameter(wavelength)
        image.meta["TARGET"] = StringParameter(targetid)
        image.meta["PM_RA"] = StringParameter(str(tgt_pmra))
        image.meta["PM_DEC"] = StringParameter(str(tgt_pmdec))
        image.meta["REFFRAME"] = StringParameter("ICRS")
        image.meta["EQUINOX"] = StringParameter("2000.0")
        image.meta["RIGHTASC"] = StringParameter(str(rasource))
        image.meta["DECLINAT"] = StringParameter(str(decsource))
        image.meta["T_ONSRC"] = StringParameter(str(tos))
        image.meta["vHIPE"] = StringParameter("10.0.0")
        image.meta["vPACScal"] = StringParameter("45")
        image.meta["PIXFRAC"] = StringParameter("1.0")
        image.meta["PIXSIZE"] = StringParameter(str(outpixsz))
        image.meta["HPFWIDE"] = StringParameter(str(hpfrad2))
        image.meta["SCAN_ID"] = StringParameter(str(obsid))
        image.meta["posAngle"] = StringParameter(str(rollangle[j]))
        image.meta["arrAngle"] = StringParameter(str(obs.meta["mapScanAngle"].value)+" "+"deg")
        image.meta["leg_leng"] = StringParameter(str(obs.meta["mapScanLegLength"].value)+" "+"arcmin")
        image.meta["leg_sepn"] = StringParameter(str(obs.meta["mapScanCrossScan"].value)+" "+"arcsec")
        image.meta["slew_spd"] = StringParameter(str(obs.meta["mapScanSpeed"].value))
# Save image to fits file
        outfile = direc+ "Scan_"+targetid+"_" + str(obsid) +"_"+ bandid +"_hpf"+str(hpfrad2)+".fits"
        print "Saving file: " + outfile
        simpleFitsWriter(image,outfile)

# Delete unneccesary variables
        del(frames,obs,hpfmask)
        System.gc()

##############
# MOSAICKING
##############
    from java.util import ArrayList
    from herschel.ia.toolbox.image import MosaicTask

    for nc in range(len(channel)):
      print channel[nc]
# camera :
      camera = channel[nc]
      bandid = bandnames[nc]

      if camera=='red':
        outpixsz=2.0
        hpfwidth=25
        n_obs = n_obs_red
        bandid = bandnames[1]
        map_wcs = map_wcs_red
        wavelength = '160 microns'
      elif camera=='green':
        outpixsz=1.0
        hpfwidth=20
        n_obs = n_obs_blue
        bandid = bandnames[0]
        map_wcs = map_wcs_blue
        wavelength = '100 microns'
      elif camera=='blue':
        outpixsz=1.0
        hpfwidth=15
        n_obs = n_obs_blue
        bandid = bandnames[0]
        map_wcs = map_wcs_blue
        wavelength = '70 microns'

#Create a list of images to be mosaicked
      images = ArrayList()
#      glmap = ArrayList()
      hpmap = ArrayList()
      for nb in range(len(n_obs)):
        obsid=n_obs[nb]
        map_file = direc+ "Scan_"+targetid+"_" + str(obsid) + "_" + bandid + "_hpf"+\
              str(hpfwidth)+".fits"
#        gl2_file = direc+ "glitchmask_Scan_"+targetid+"_" + str(obsid) +"_"+ bandid +\
              "_hpf"+str(hpfwidth)+".fits"
        hpf_file = direc+ "hpfmask_Scan_"+targetid+"_" + str(obsid) +"_"+ bandid +"_hpf"+\
              str(hpfwidth)+".fits"
        map = simpleFitsReader(map_file)
#        gl2map = simpleFitsReader(gl2_file)
        hpfmap = simpleFitsReader(hpf_file)
        map.exposure = map.coverage
#        glmap.add(gl2map)
        hpmap.add(hpfmap)
        images.add(map)
# Mosaic the selected scans
      mosaic = MosaicTask()(images=images,oversample=0)
      hp_msc = MosaicTask()(images=hpmap,oversample=0)
#      gl_msc = MosaicTask()(images=glmap,oversample=0)

      for n in xrange(len(mosaic.image)):
        if mosaic["flag"].data[n]==1: mosaic["image"].data[n]=0

# Add mosaics of the masks used in the processing
      mosaic["hpfmask"] = hp_msc["image"]
#      mosaic["glitchmask"] = gl_msc["image"]
      Display(mosaic)
# Add metadata to mosaic image
      mosaic.meta["CREATOR"] = StringParameter("OTKP_DUNES")
      mosaic.meta["OBSERVER"] = StringParameter("ceiroa")
# Main programme = KPOT_ceiroa_1, SDP phase = SDP_ceiroa_3
      mosaic.meta["PROGRAMS"] = StringParameter("KPOT_ceiroa_1")
      mosaic.meta["INSTRUME"] = StringParameter("PACS")
      mosaic.meta["TYPE"] = StringParameter("MOSAIC IMAGE")
      mosaic.meta["DESC"] = StringParameter("IMAGE COVERAGE AND UNCERTAINTY MAPS")
      mosaic.meta["WAVELENG"] = StringParameter(wavelength)
      mosaic.meta["TARGET"] = StringParameter(targetid)
      mosaic.meta["PM_RA"] = StringParameter(str(tgt_pmra))
      mosaic.meta["PM_DEC"] = StringParameter(str(tgt_pmdec))
      mosaic.meta["REFFRAME"] = StringParameter("ICRS")
      mosaic.meta["EQUINOX"] = StringParameter("2000.0")
      mosaic.meta["RIGHTASC"] = StringParameter(str(rasource))
      mosaic.meta["DECLINAT"] = StringParameter(str(decsource))
      mosaic.meta["T_ONSRC"] = StringParameter(str(2*tos))
      mosaic.meta["vHIPE"] = StringParameter("10.0.0")
      mosaic.meta["vPACScal"] = StringParameter("45")
      mosaic.meta["PIXFRAC"] = StringParameter("1.0")
      mosaic.meta["PIXSIZE"] = StringParameter(str(outpixsz))
      mosaic.meta["HPFWIDE"] = StringParameter(str(hpfwidth))
# Loop over obsids to add details for each scan
      for ns in range(n_obs):
        mosaic.meta["SCAN_ID"+str(ns+1)] = StringParameter(str(n_obs[ns]))
        mosaic.meta["posAngle_"+str(ns+1)] = StringParameter(str(rollangle[ns]))
# Save image to fits file
      outfile = direc+ "Mosaic_"+targetid+"_" + camera +"_"+ bandid +"_hpf"+str(hpfwidth)+\
           "_pix"+str(outpixsz)+".fits"
      print "Saving file: " + outfile
      simpleFitsWriter(mosaic,outfile)

#DELETE LEVEL 1 .SAV FILES FROM DIRECTORY TO SAVE SPACE
    os.system('rm -rf '+root_dir+targetid+"/"+blueid+"/frame*.fits")
#DELETE MAP FILES FROM DIRECTORY TO SAVE SPACE (ONLY NEED SCANS AND MOSAICS)
    os.system('rm -rf '+root_dir+targetid+"/"+blueid+"/map*.fits")
#DELETE .HCSS POOL TO SAVE SPACE (THIS IS PROBABLY NOT WISE...)
    if targetid != 'hip7978':
      os.system('rm -rf '+pooldir+targetid)

    print "INFO: Finished reducing "+targetid+" "+blueid+"/160, target number "+str(nn+1)+" of "+str(ntgt)

    System.gc()
```