The Herschel-SPIRE Point Source Catalog (SPSC) Feasibility Study

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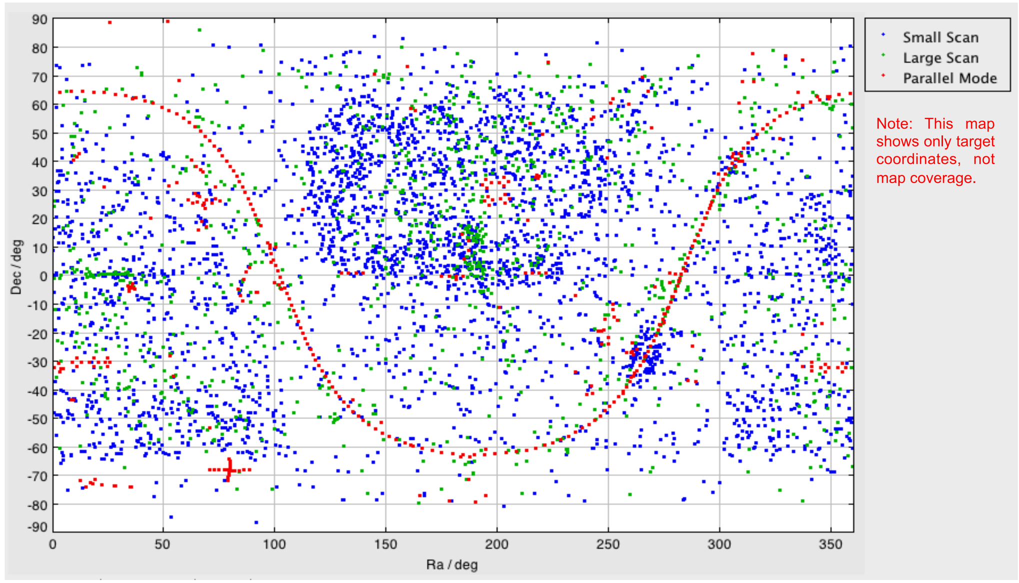
The extraordinary stability and sensitivity of SPIRE, one of the three scientific instruments on-board of the Herschel Space Observatory, resulted in an excellent photometric and spectroscopic dataset. Specifically the 6917 scan map observations of the photometer, each coming in three filter bands centred at 250, 350, and 500 microns, cover about 11% of the sky. Although some source catalogs have already been produced by individual observing programs, there are many observations of small programs that would never be analysed for their full source content. We aim to build a homogeneous SPIRE Point Source Catalog (SPSC) from all SPIRE scan map observations with an estimated total of 3 Million reliable sources, that can serve as a pathfinder for ALMA and other Submm and Far-IR facilities for many years to come. Such a catalog will provide the best possible photometry derived by instrument experts with optimized extraction algorithms. The extraction will be performed in a homogeneous way out of well characterized celestial environments with associated figures for reliability, completeness, photometric, and positional accuracies. The availability of the planned catalog will fill in SED photometry of astronomer's favorite objects without the need for them to invest significant time into establishing their own Herschel data reduction processing and the associated learning curve. The homogeneous source extraction enables a systematic and unbiased comparison of sensitivity across the different SPIRE fields that single programs will generally not be able to provide. This large dataset will enable better studies of surface density, clustering and star formation history of galaxies. Catalog homogeneity is further helped by the fact that SPIRE scan maps are already confusion limited after the first two repetitions. Further benefits of such a catalog include statistical studies of galaxy dust mass and emissivity, diffuse dust emission along the Hubble sequence, sub-millimeter galaxy counts, and luminosity functions when combined with already existing databases. This poster presents the findings of a recently concluded feasibility study to produce such a catalog.

SPIRE Sky Coverage

All scan maps	squ. deg	fraction	of all sky
Total	4723		11.4%
SpirePacsParallel	2515	53%	6.1%
SpirePhotoLargeScan	2001	42%	4.8%
SpirePhotoSmallScan	208	4%	0.5%

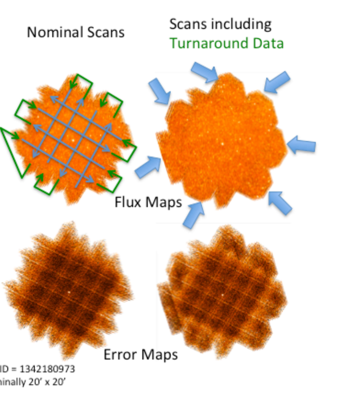
- There are three relevant SPIRE scan map observing modes:
  - *Parallel Mode:* SPIRE and PACS observing larger portions of the sky simultaneously.
  - *Large Scan Mode:* SPIRE scanning the sky in several scan legs, normally followed by scans in a perpendicular direction.
  - *Small Scan Mode:* SPIRE scanning across a single coordinate in two perpendicular directions.



- SPIRE observed a total area of 4723 deg^2 equivalent to ~11.4% of the sky.
- Depending on the detection threshold we can expect a total of about 3 Million sources in all three bands for a 30 mJy threshold.

Scan Maps and Coverage

- SPIRE scans the sky with its 4' x 8' detector arrays at an angle close to 45 deg in almost perpendicular directions.
- Very few observations exist without a cross-scan direction.
- Parallel Mode observations normally are linked to another observation in cross-scan direction.
- Turnaround data exist but are currently not part of the standard products in the archive.



The "turnaround" portion of the SPIRE scan maps comprises an estimated 4% of the covered sky area. The quality of this dataset has been found good in spite of being taken in non-standard conditions and will be included in the next version of HIPE. We will perform an early re-processing of this dataset to include the full sky coverage into the SPSC.

Tested Extraction Procedures

	Impl.	Source Detection	Photom.	Detection Performance	Photom. Rating
Sussextractor	HIPE	yes	yes	very good	2
Simultaneous Extractor	HIPE	no	yes	N/A	3
Daophot	HIPE	yes	yes	not tested	4
Timeline Fitter	HIPE	no	yes	N/A	1 (best)
Starfinder	IDL	yes	yes	very good	5
Getsources	Fortran	yes	yes	very good	4

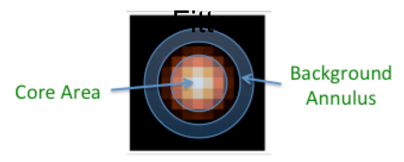
Performance results are based on artificial source injection trials performed with SPIRE data of the GOODS-N field.

A number of source extraction algorithms has been tested for source detection and photometric accuracy.

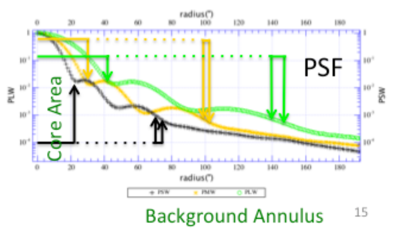
The exercise further improved our understanding of the system and led to improvements of the extraction algorithms.

The timeline fitter led to the best results extracting artificial sources injected into real SPIRE maps. The radii for core aperture and background annulus were optimized in the course of the exercise.

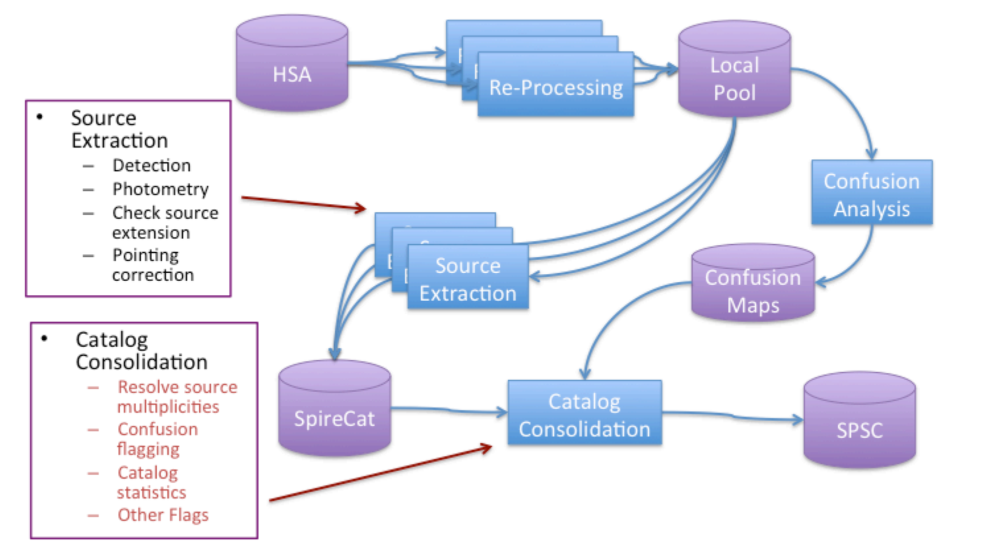
Improved Operating Parameters for Timeline Fitter



	PSW	PMW	PLW
Core radius ["]	22	30	42
Inner radius ["]	70	98	140
Outer radius ["]	74	103	147



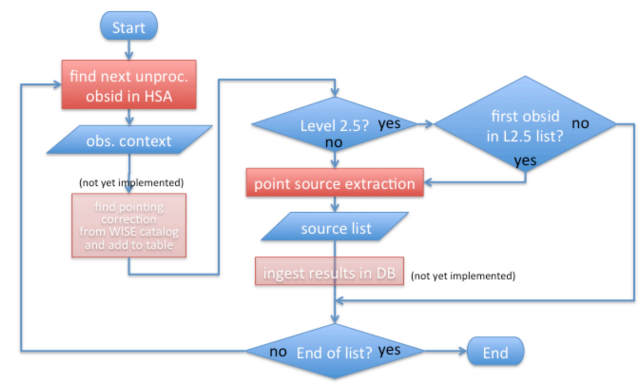
Building the SPSC



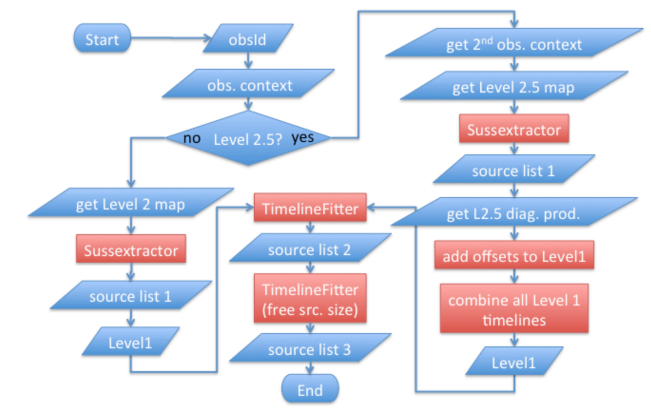
The SPSC will be produced in several major phases:

1. All SPIRE scan map data are re-processed, starting from Level 0 archival products. The newest two-pass pipeline developed by the SPIRE-ICC is being used. This phase is currently on-going.
2. Structure noise maps are derived from the reduced maps to assess the local confusion noise from background galaxies and Galactic Cirrus.
3. The baseline source extraction algorithm is run and point source data is ingested into a relational database (Postgres).
4. To each database source, a quality flag based on the structure noise maps is assigned.
5. Coordinate corrections (RA, DEC offsets) are derived from comparisons with the WISE point source catalog at 25μm where extragalactic sources have a high correlation, and are fed into the database.
6. In a consolidation-phase, multiple detections of the same source are recorded in a Group Table. The database is statistically analysed to establish thresholds for object inclusion, extended object flags, confusion noise flags etc. After extensive quality control this phase yields the final catalog.

Point Source Extraction I



Point Source Extraction II



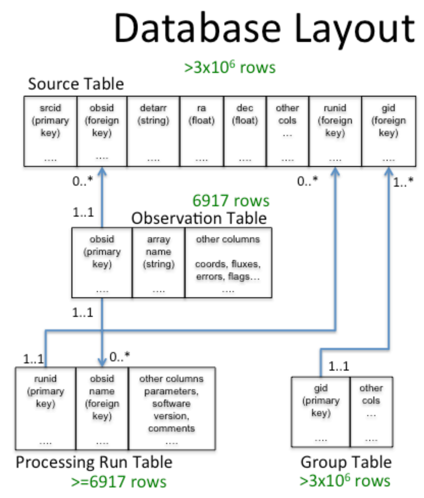
We decided on the combination of Sussextractor and Timeline Fitter to be the baseline.

- Both did very well in the tests with simulated sources.
- Both are available in HIPE avoiding additional interfacing difficulties with the archive and data reduction.
- Timeline Fitter provides options to discriminate extended emission.

Special Issues

- The Timeline Fitter requires the Level 1 timeline data rather than Level 2 maps.
- For parallel mode data the timelines of two perpendicular observations must be combined to extract photometry with the Timeline Fitter.
- To discriminate slightly extended sources, Timeline Fitter is run twice, once with a fixed circular Gaussian model, and another time with a free elliptical Gaussian that also allows for a tilted background.
- Processing run-times were assessed and were found substantial but acceptable.
- We plan to use the WISE point source catalog at 25μm to obtain coordinate corrections.

Database Layout (SpireCat)



- Relational database (Postgres)
- Point Source Table contains point sources found in maps.
- Observation Table contains all mapping observations of SPIRE.
- Group Table associates multiple detections of the same source in the same filter. Future extension to band merging possible.
- Processing Run Table contains history records of each source extraction run on a given observation.
- Use Q3C 2 dim. indexing to match up multiple extractions of the same object in the point source table.

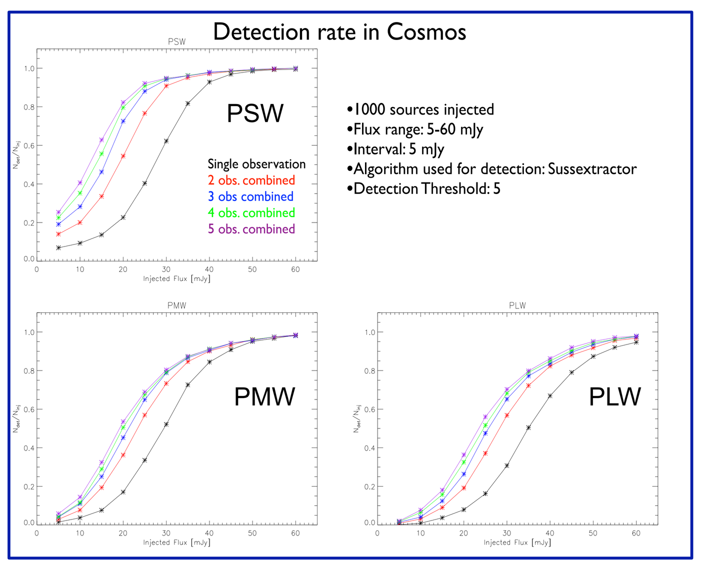
Completeness and Reliability

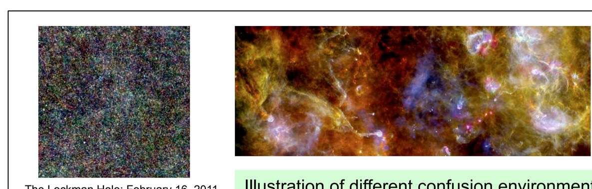
Completeness will be derived by injecting and recovering artificial sources into real maps. This will be done for different areas with degrees of confusion in a statistically meaningful sample.

In the example on the right 1000 sources were injected into the timelines of maps of the Cosmos field. To show the dependence on the number of repetitions in the observation, several of these single-pass maps were combined into one. The diagrams show the fraction of recovered sources versus flux.

Reliability is very high for SPIRE and less of a concern since instrument noise is much smaller than the confusion noise from the extragalactic background. We will follow the method by Smith et al. 2012 for this purpose, where point sources are extracted from the difference of two separate maps of the same sky region.

Detection rate in Cosmos





The Lockman Hole: February 16, 2011, Credit: ESA/Herschel/SPIRE/HerMES

Cygnus X, May 10, 2012, Credit: ESA/PACS/SPIRE/Martin Hennemann & Frdrique Motte, Laboratoire AIM Paris-Saclay, CEA/Irfu CNRS/INSU Univ. Paris Diderot, France

Illustration of different confusion environments in the Herschel sky.

Conclusions

- We have investigated the ingredients needed to make a Herschel-SPIRE Point Source Catalog.
- The catalog will cover up to 11% of the sky and contain approx. 3 Million sources including all three filter bands with a cutoff at 5 times the confusion noise.
- Tests of completeness and photometric accuracy were conducted with three detection and 5 extraction algorithms.
- A baseline point source extraction algorithm was selected and a prototype built and tested, resulting in further improvements to parameters and procedure.
- A database schema was developed that supports an approach consisting of an extraction and a consolidation phase.
- Background confusion will be characterized by appropriate flags derived from structure noise maps.
- The benefits to the astronomical community lie not only in an expert derived, homogeneous, and well characterized catalog of SPIRE point sources, but also in additional knowledge that will benefit standard pipeline processing and the SPIRE products in the Herschel archive.

References

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