

The Herschel Legacy Data Products

D. Teyssier, on behalf of the Calibration Scientists at the HSC, NHSC and the Instrument Control Centres (past and present)

Instrument and Calibration Scientists Team lead

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- 1. Products from the Standard Product Generation (SPG)
- 2. User-Provided Data Products (*UPDPs*)
- 3. Highly-Processed Data Products (*HPDPs*)
- 4. Ancillary Data Products (*ADPs*)
- 5. Conclusions and Remaining Work in the POP



Standard Product Generation (SPG – aka pipeline data products)

- > Data Products generated by the respective instrument pipeline software
 - Automatic product generation no fine tuning
 - State of the art output as of applicable HCSS release
 - Best-ever pipeline products will be achieved by HIPE 14.1 for HIFI and SPIRE, and HIPE 14.2 for PACS
- Their data quality, but also limitations and caveats from a science-readiness perspective, are described in the Legacy Calibration presentation
- > Served exclusively through the HSA
 - All processing levels are made available, allowing *ad hoc* reprocessing by interested users (only possible within HIPE)
- See also the Legacy Archive presentation for further details



User-Provided Data Products (UPDPs)

- > Data Products essentially stemming from Key Project consortia
 - Formal commitment from KP teams was to at least provide all their data from the Science Demonstration Phase (SDP)
 - Rest of their core programme to be delivered on best effort basis, linked to accepted publications – several catalogues came with those
 - In additional, welcoming any initiative from other non-KP (guaranteed or open time) projects
- > To date, UPDPs from 22 programs/consortia have been ingested into the HSA
 - first deliveries started as early as 2010 and HIPE 6/7 processing, implying data quality inferior to most recent HSA pipeline products, or in the worse-case scenario (rare) erroneous calibration (<u>http://www.cosmos.esa.int/web/herschel/user-provided-data-products</u>)
- Although contemplated in HSC POP plan, in practice no systematic quality check was performed by instrument experts on the deliveries (only one, very recent, exception on a PACS-S somewhat controversial delivery) – there is no plan to revisit this in the remainder of POPs (no resources)



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Beyond SPG: Highly-Processed Data Products (HPDPs)

- As explained in the Legacy Calibration presentation, part of the pipeline products are not science-ready for some of the instruments – overall ~>10% of all observations (~20% of spectroscopy data) could fall into that category
- Numerous dedicated software tasks and "useful scripts" exist in HIPE in order to circumvent those caveats and allow archive users to improve the products quality to full science-ready level
- Early 2015, the SGS took the initiative to look into sub-sets of unruly products that could be systematically improved using some of the above tools, and provide them to the archive as additional or alternative products
 - Concept of Highly-Processed Data Products (HPDPs) introduced formally coordinated by dedicated WG since mid-2015 – see also <u>http://herschel.esac.esa.int/twiki/bin/view/Public/HPDPDefinitionPage</u>
 - About 20+ HPDP Work-Packages presently identified, mostly under custody of HSC personnel
 - HSC POP plan did not contemplate those to be curated in-house



Beyond SPG: Highly-Processed Data Products (HPDPs)

> Main targets of the HPDP effort:

- Correction of remaining instrument artifacts (e.g. HIFI or PACS-S unchopped baseline correction)
- Semi-extended source and pointing-offset correction for SPIRE-S and PACS-S products
- Other added-value HPDPs considered by this Working Group:
 - Optimised product merging in spatial or spectral domain, maximising Signal to Noise Ratio
 - Catalogues (PACS and SPIRE Point Source Catalogues, spectral line feature catalogues for each spectrometer)



Highly-Processed Data Products HIFI examples



Baseline distortion correction in Spectral Scans



Highly-Processed Data Products esa **PACS-P** examples Galactic Plane (±115 Merge of overlapping fields degree of Gal. Centre) **North Galactic Pole** LMC at 100 µm -64°00′ -66°00′ Declination (J2000) 68°00′ **Pipeline Level 2** -70°00 -72°00′ 05h30m 05h00m 04h30m 06h30m 06h00m Right Ascension (J2000) **Unimap HPDP** SMC at 100 µm HERITAGE UPDP (Meixner+ 2013) **Unimap HPDP** Courtesy of J. Graciá-Carpio, MPE

Highly-Processed Data Products SPIRE-S examples

Various calibration corrections in SPIRE-S



Highly-Processed Data Products PACS-S example

Continuum subtraction in un-chopped PACS-S observations



Highly-Processed Data Products PACS/SPIRE Point source catalogues

- Project started in late 2013 in order to extract point sources from the PACS and SPIRE photometer maps in all 6 available bands (~10% of whole sky)
 - Working group formed essentially by HSC, NHSC and Konkoly obs. staff
- Homogeneous source extraction allowing unbiased sensitivity comparison significant effort dedicated to simulation for spurious detection characterisation
- Status as of April 2016:
 - Source candidate extraction completed for both instruments
 - SPIRE reported ~6.5M candidates, expect ~2M unique sources/band.
 Most likely separated into high/low flux reliability catalogues
 - PACS reported ~8M candidates, however high level of spurious detection (~85%) expect ~1M unique sources (all bands)
 - First public delivery expected in Sep 2016 (SPIRE) and Oct 2016 (PACS) – intermediate internal deliveries expected to e.g. validate interfaces with archive
 - 2nd Generation catalogue envisaged on best effort basis only
 - No band merging planned (considered within an EXPRO though)



Highly-Processed Data Products Line catalogues

SPIRE-S: spectral feature catalogue

HIFI: line list catalogue Orion S: 479.501 - 489.563 GHz (20 lines)

482

484

frequency

486

488

A-CH3OH CS-34, v=0,1 E-CH3OH

H2CS SO2, v=0



HIFI: line transition assignment table

Index	name	position [GHz]	peakPosition [GHz]	stdPosition [GHz]	width [km/s]	stdWidth [km/s]	flux [K·km/s]	transition	species	snr
0	Orion_S	483.46070149886225	483.461906662317	3.194957778718721E-4	4.858838927881935	0.4680779130065521	0.3344807591011659	(10 5 - 0 _ 9 5 - 0)	A-CH3OH	6.004747177
1	Orion_S	491.92214068166226	491.922209110964	2.1386581211427016E-4	6.5423122652042505	0.30691906219315435	0.8032514261399534	(7 4 4 _ 6 3 3)	SO2, v=0	6.721427348
2	Orion_S	492.77369611613466	492.778189123498	6.411436645653314E-4	6.581385334499013	0.9185264738264693	0.37094279187291934	(9635_8545)	CH3OCH3, v=0	6.952213992
3	Orion_S	496.9123994663574	496.91109261859305	6.010871935874076E-4	7.319394330544363	0.9594779011096383	0.24813735315653346	(14 0 0 13 1 0)	E-CH3OH	7.472849510
4	Orion_S	503.0040647646153	503.001950394695	3.526621706383171E-4	4.876228590832814	0.49495725820146114	0.2813615059621468	(28 0 28 5 _ 27 1 27 5)	CH3OCH3, v=0	5.917433068
5	Orion_S	508.52331157982053	508.524821433508	3.574465735551674E-4	4.406689048416189	0.49622359332487465	0.4013273752380872	(11 0 _ 10 0)	C-13-S, v=0,1	7.399215769
6	Orion_S	510.89789021754035	510.89776602432903	4.295811758753937E-4	4.772168828661211	0.5935942384103788	0.3686901896467418	(6 _ 5)	HCO-18+	6.905474389
7	Orion_S	511.4902191765085	511.489752201221	4.098814247795359E-4	6.312963845488728	0.5984857857731055	0.19178020883015975	(28 1 27 _ 27 2 26)	SO2, v=0	7.169412363
8	Orion_S	511.706990677327	511.70724712263	3.2572005812334657E-4	6.027146720425251	0.4494053960952625	0.4214003729382122	(10643_9543)	CH3OCH3, v=0	8.473593971
9	Orion_S	512.0663406808367	512.0662387400359	1.4104480376698708E-4	1.6727567906162244	0.19445063901598456	0.16681167381760537	(27 2 26 _ 26 1 25)	SO2, v=0	5.625871815
10	Orion_S	514.3391186723669	514.3401856424921	6.596613611462668E-4	4.864127729799529	0.906900079732284	0.14174268117116318	(12 0 _ 11 0)	Si-29-0, v=0-3	5.184414064
11	Orion_S	519.180072629248	519.180072629248	5.819698624708677E-4	8.429634353278221	0.9052029580280835	0.2195047434979636	(29 1 29 _ 28 0 28)	SO2, v=0	7.207062097
12	Orion_S	520.7166650027104	520.717036740538	3.6311859364570714E-4	7.306842829398893	0.4927948411200071	0.4601824210790318	(13 2 - 0 13 1 + 0)	A-CH3OH	8.687146112
13	Orion_S	520.8685057534005	520.872033121312	6.71706781889706E-4	11.88680568090375	0.9104341460839886	0.8471852790187123	(12 0 _ 11 0)	SiO, v=0-6	8.789596084
14	Orion_S	524.257954058741	524.257954058741	6.253738225505365E-4	8.215185423508293	0.9129216939084477	0.27266848767228935	(13 -4 0 13 -3 0)	E-CH3OH	6.878124040
15	Orion_S	524.3721974127524	524.371951396859	3.0730411146125716E-4	5.101105350404839	0.4140257437097178	0.30998658661034284	(12 -4 0 12 -3 0)	E-CH3OH	7.537435189
16	Orion_S	524.5717658008894	524.5729467035401	4.5293554266660193E-4	8.253885666691877	0.6154154926480565	0.4518934631398485	(10 -4 0 10 -3 0)	E-CH3OH	9.051644767
17	Orion_S	525.0449708601637	525.044935682414	4.714740172805977E-4	7.357483306053501	0.641816390836841	0.30632990440666646	(4 -3 0 5 -2 0)	E-CH3OH	7.120214378
18	Orion S	526.5115042472135	526.510901451543	4.629609591321723E-4	7.988199123787431	0.7039430558772343	0.3427812206402932	(142=0 141±0)	A_CH30H	6 780499661

Summary: the legacy science



Instrument	Non science-ready pipeline products	Fraction recovered by HPDPs, or added-value HPDPs		
HIFI	20% (distorted baselines)	Half of those, leaving ~10% of total observations as non strictly science-ready (mostly single-point observations)		
PACS-S	> 15 % (not counting	All but semi-extended source cases.		
	ext. source cases)	Added-value HPDPs for ~ 30% of observations (un-chopped and/or featuring red leak range data)		
SPIRE-S	 55% (semi-extended source and background contamination) 	3/4 of those, leaving just 15% of all sparse mode observations un-corrected		
PACS-P	All science ready	Added-value HPDPs for 75% of parallel mode and 4% of PACS-P maps		
		(being only 7% of total PACS-P observations but ~30% of the total observing time)		
	All science ready	Isolated artefacts not dealt with by pipeline fixed for ~4% of obsids (ICC- curated – possible manpower issue)		

Ancillary Data Products (ADPs)

- Ancillary Data Products (ADPs) correspond to products not necessarily associated to any observation performed by the Observatory
- Used as Herschel's long-term preservation storage of items that may be needed for users of the archive, but also as source of information for future missions – as such a lot of engineering-oriented items are contemplated there
- The bulk of the instrument ADPs is provided through the ICCs, or the corresponding HSC experts after ICC hand-over formally performed Observatory ADPs are provided by the HSC
- > The ADP deliverables can be summarised as:
 - Calibration: calibrator models, instrument PSFs, photometer filters
 - Software: on-board SW images and release notes
 - Observatory: all uplink-related products (CUS, MIBs, MTL files, etc)
 - Engineering: trend-analysis data from instrument HouseKeeping
 - Historical: Telemetry and Science data from pre-launch test campaigns
- http://herschel.esac.esa.int/twiki/bin/view/Public/AncillaryDataProductsPage provides the list of currently contemplated ADPs



Ancillary Data Products: going back in time

Unique dataset collected pre-launch: HIFI spectrum of CH₃OH

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Ancillary Data Products: going back in time

Unique dataset collected pre-launch: HIFI spectrum of CH₃OH

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Conclusions (1)

- > A plethora of products will be served by the HSA on top of the pipeline outputs
- A key component of those deliverables are Highly-Processed Data Products, exquisitely curated by instrument experts – note that the provision of HPDPs was not originally considered to be an in-house effort in the HSC POP plan
 - Those dedicated to artefact or sub-optimal calibration correction will allow recovery of ~2/3 of the pipeline products identified as non science-ready (the vast majority being spectrometer observations)
 - Those providing added-value legacy products typically in the form of optimised (large) spatial merging will cover ~75% of the parallel mode obs., and 4% of all PACS-P prime observations (30% of PACS-P time)
 - Line catalogues will apply to up to ~75% of spectral data, and point source catalogues to the whole sky area mapped by the photometers
- The long-term preservation of other unique mission-related products will be ensured by the storage of Ancillary Data Products. Noticeable component of this archive subset are the Herschel Calibrator models, or the instrument PSFs



Conclusions (2) Status of Legacy Data Product deliverables

Deliverable Status		Where				
User-Provided Data Products						
3 rd -party deliveries 22 deliveries - more expected		HSA + HELL				
Highly-Processed Data Products						
HIFI/SPIRE	First respective HPDP deliveries expected at the end of this month	HSA + HELL (Release Notes)				
PACS-P	Most of added-value HPDPs delivered in prototype form in April 2016	ESA VOSpace				
PACS-S	Will only start after HIPE 14.2 release	N/A				
Ancillary Data Products						
HIFI	Trend Monitoring Data Product archive delivered in April 2016	HSA + HELL (Release Notes)				
SPIRE/PACS	No delivery made yet – expected from July 2016 onwards	N/A				
Observatory	Uplink File archive delivered in April 2016	FTP				



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Conclusions (3) Remaining Data Products work in POPs



Priority 1: Mandatory, Priority 2: Highly-desirable, Priority 3: Nice to have

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Conclusions (3) Remaining Data Products work in POPs (cont)

Workpackage	When	Priority	Where/Remarks				
HPDPs dedicated to artefact fixes and calibration improvements							
HIFI	Up to June 17	1					
SPIRE	Up to Feb 17	1	HSA + HELL (Release Notes)				
PACS	Up to June 17	1					
Added-value HPDPs							
HIFI	Dec 2016	2					
SPIRE	Dec 2016	2	HSA + HELL (Release Notes)				
PACS	Oct 2016	2					
Point Source Catalogues (PSC)							
SPIRE PSC	Sep 2016	2	HSA + HELL (Release Notes) + IRSA + VizieR + ESASky				
PACS PSC	Oct 2016	2					

Priority 1: Mandatory, Priority 2: Highly-desirable, Priority 3: Nice to have

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Acknowledgments: present Legacy Product Task Force contributors

HSC (past and present staff)

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- Bruno Altieri (Euclid)
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- > SPIRE ICC
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