

The SPIRE Destriper

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The Naïve Map Maker and Detector Offsets

- Establishes a regular, rectangular grid of skybins that covers the area scanned by all detectors of a given SPIRE array.
- Default bin sizes are 6", 10", 14" for PSW, PMW, PLW respectively, while the SPIRE beam sizes are 17.6", 23.9", 35.1".
- Excludes all masked L1 readouts and all readouts below a certain scan speed (default 5"/sec)
- Distributes remainder into skybins depending on sky position and calculates average, error-, and coverage maps.
- Two methods exist, one treats all readouts equal, the other weights the readouts by the white noise levels of individual detectors.
- The Naïve Map Maker doesn't work well without an offset removal.
- Three options exist:
 - Median baseline removal
 - Polynomial baseline removal
 - Destriper
- Median baseline removal subtracts medians from each scan, assuming that most of the readouts see the same background level on the sky.
- Polynomial baseline removal subtracts fitted polynomial, assuming that there is a low frequency drift in the signal and that most of the readouts see the same background level on the sky.
- The destriper covers those cases where the assumption about the background statistics breaks down.

Detector Offsets and Constraints

Signal Offsets

- Each SPIRE bolometer is at a different arbitrary offset level
- Dark sky measurements were used as a reference during signal linearization and flux calibration, but...
- Thermal drifts of telescope and instrument will still create offsets that vary with time and that are typically larger than astronomical signals and can not be cast into a static calibration table.

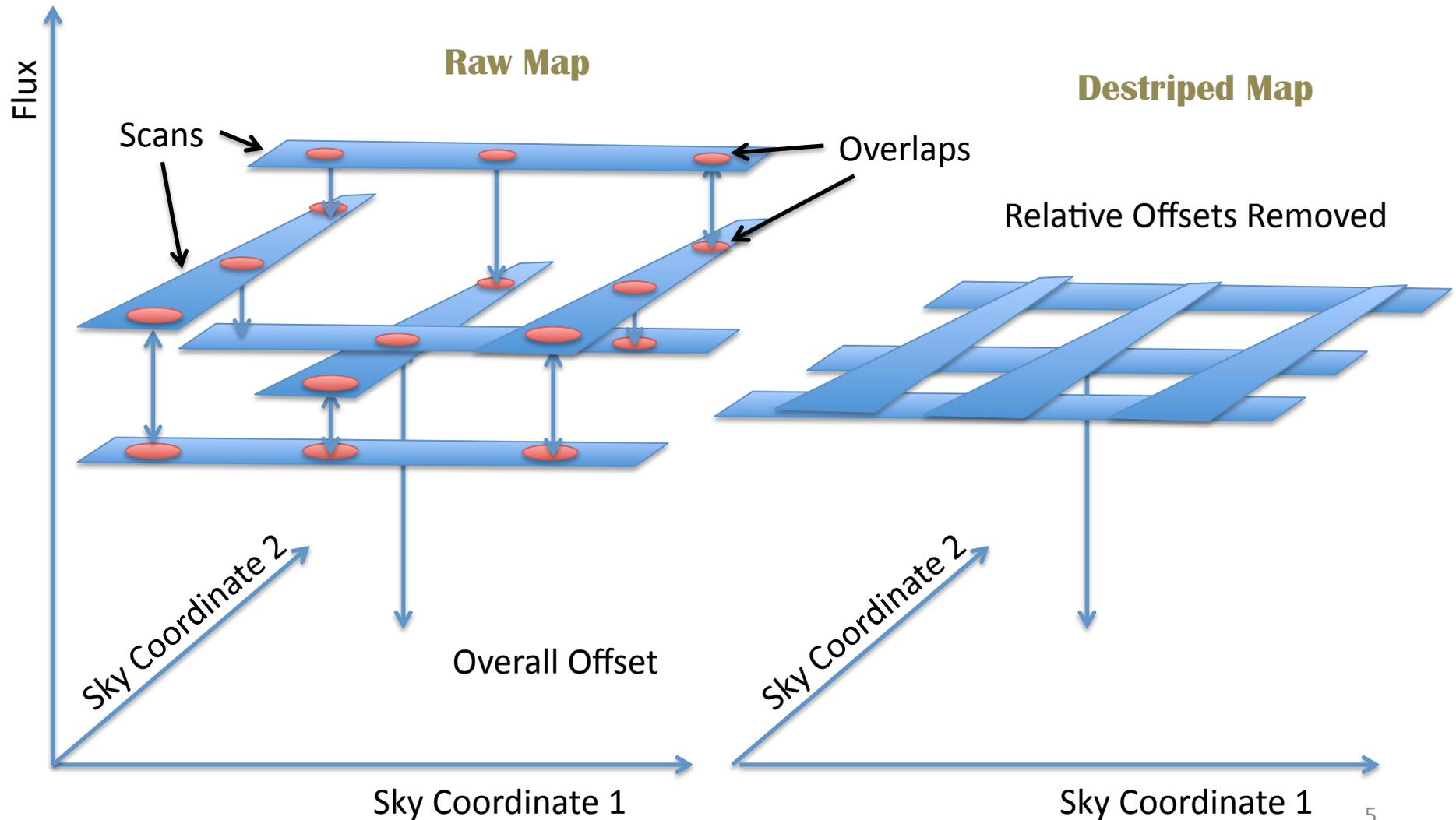
A Mathematical Problem

- The scans of different bolometers across the sky typically overlap in some positions.
- Each readout in a signal timeline $S(t)$ is associated with a specific position on the sky.
- Positions in the sky where timelines of different detectors and scan directions cross, constrain the solution for the offsets sufficiently.

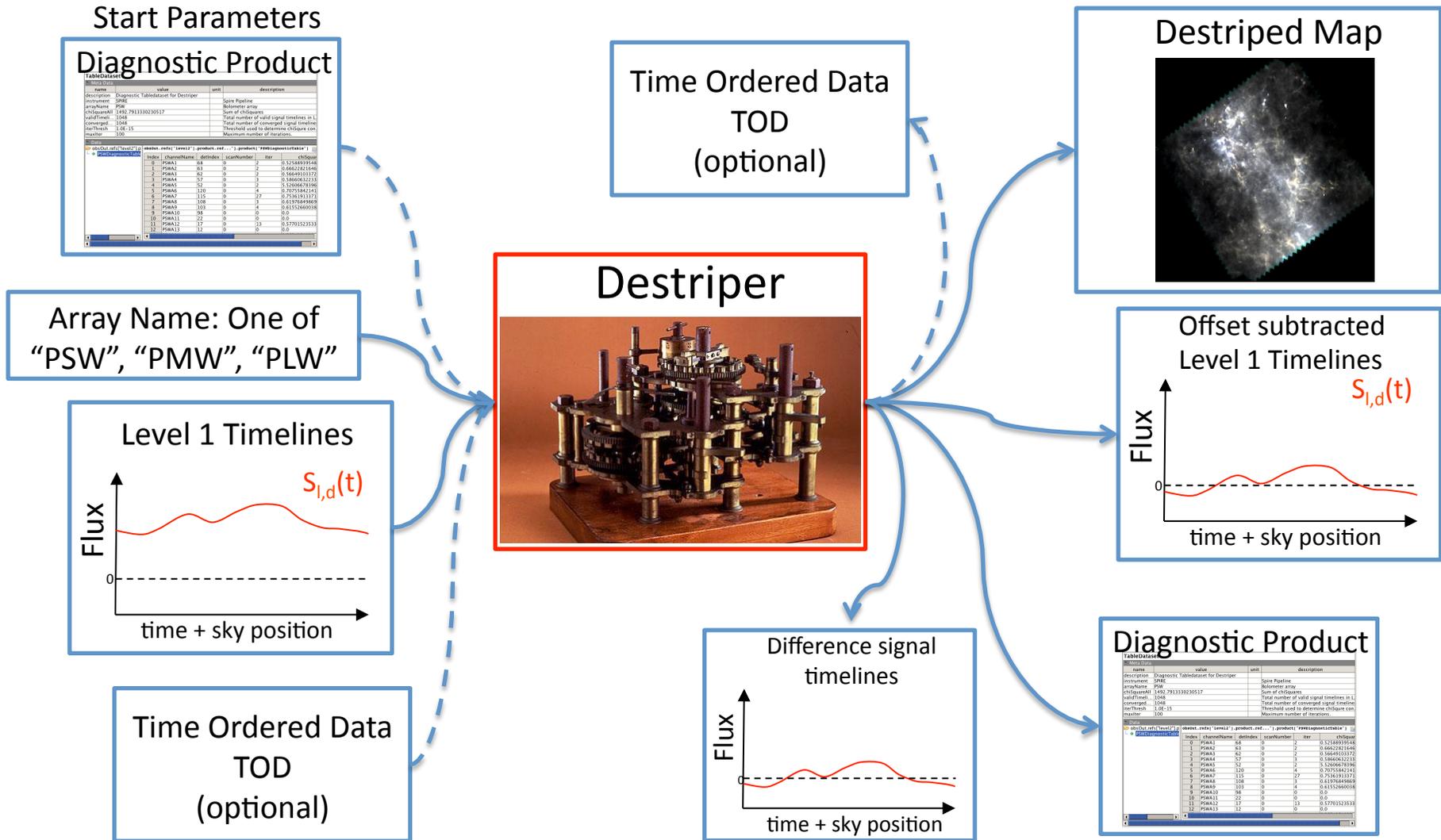
Basic Algorithm

- Make first naïve map.
 - Optionally start with median offsets
- Re-sample readouts within map.
- Compare each re-sampled signal timeline with the corresponding original timeline.
- For each timeline: Fit offset function to difference.
 - simplest case is zero order polynomial, i.e. an offset (default)
- Subtract fitted offset function from original timeline and make another map.
- Calculate χ^2 and continue with re-sampling step while difference between consecutive χ^2 s is above threshold.
- These iterations actually converge by themselves.

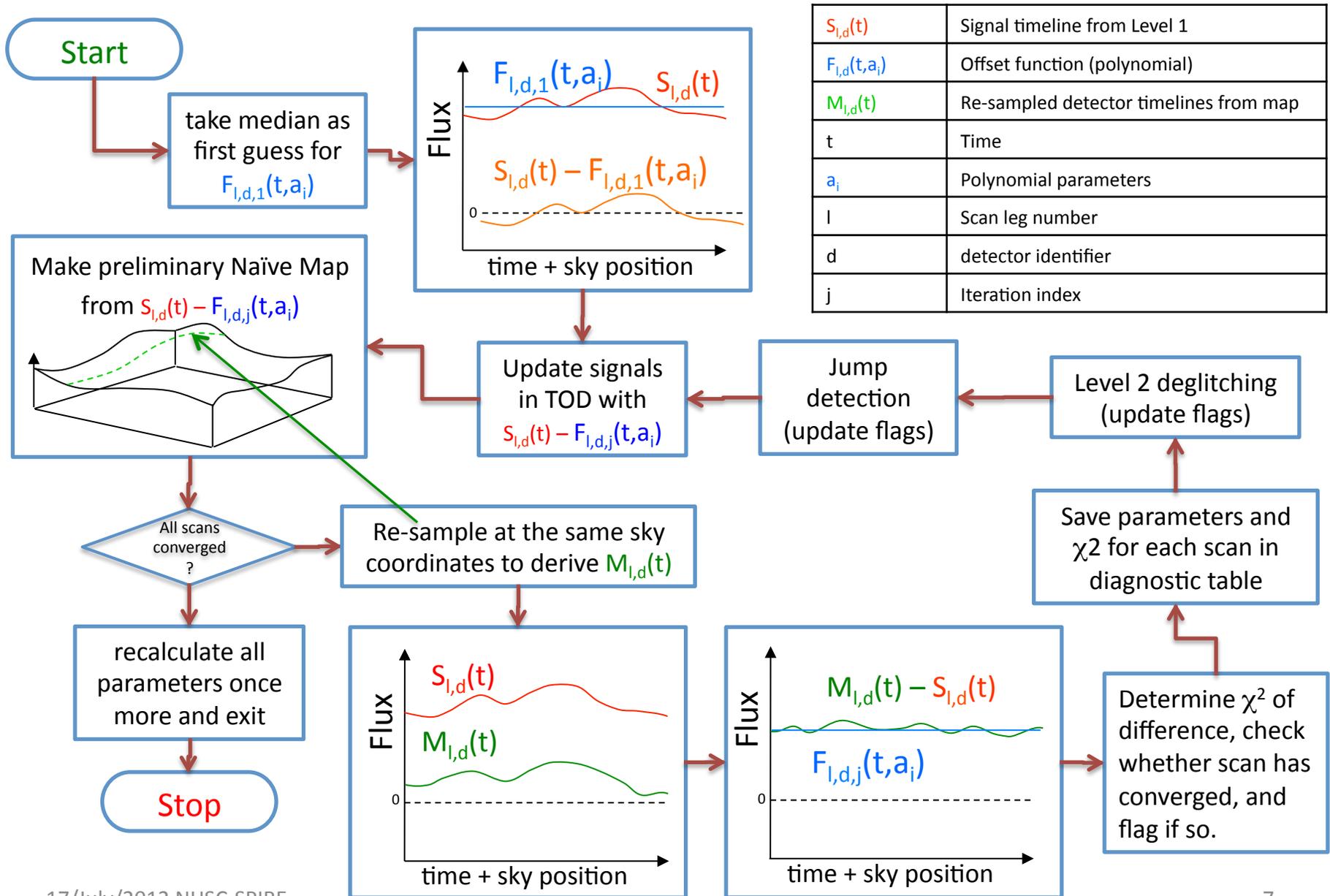
Overlaps Constrain Offsets



Destriper Input Output



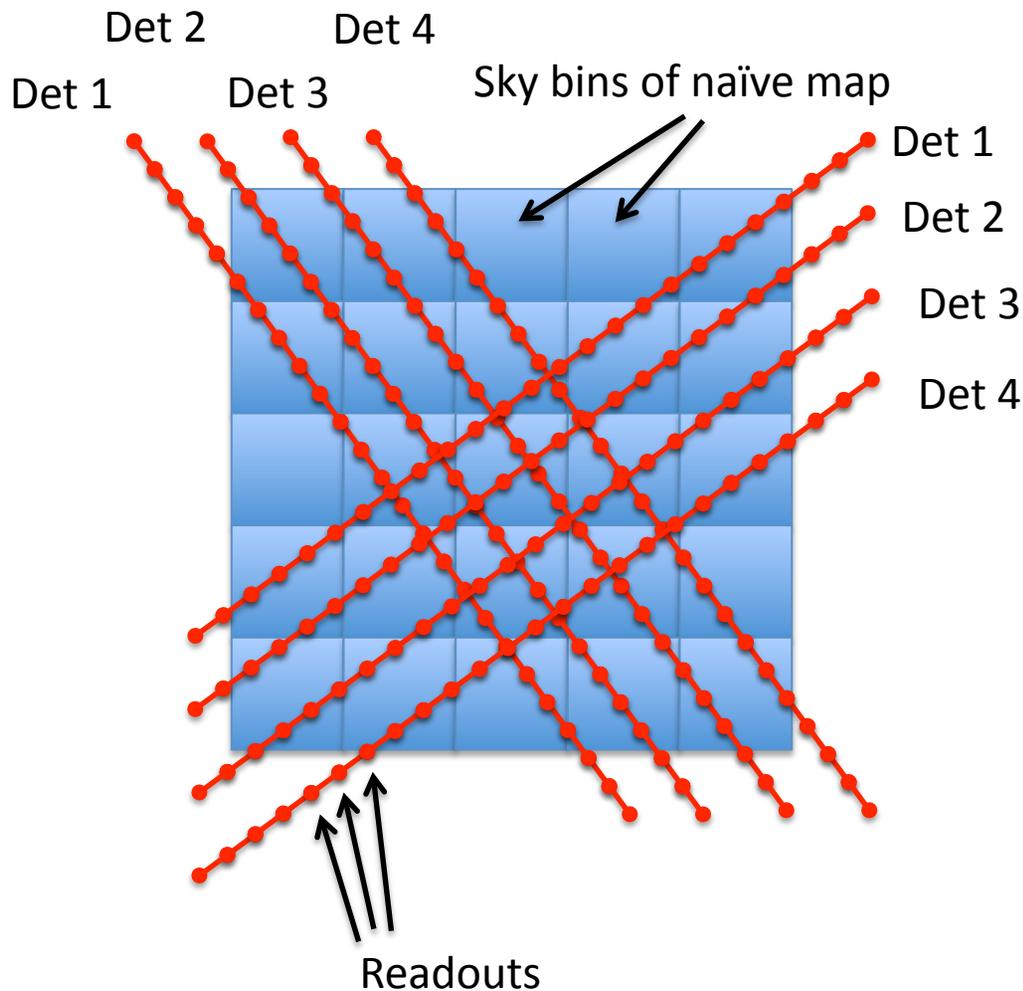
Destriper Flow Diagram



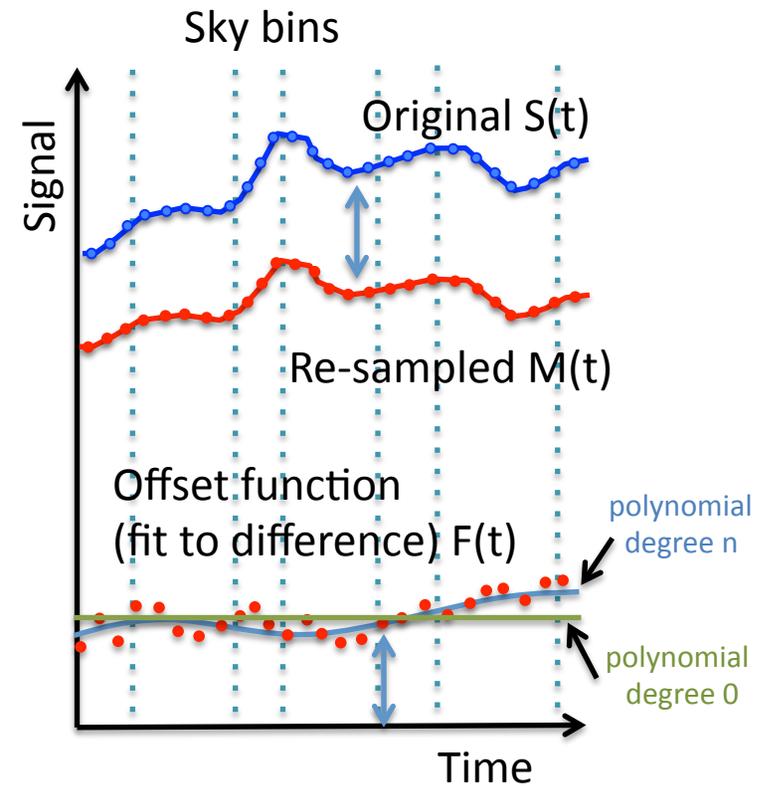
$S_{l,d}(t)$	Signal timeline from Level 1
$F_{l,d}(t,a_i)$	Offset function (polynomial)
$M_{l,d}(t)$	Re-sampled detector timelines from map
t	Time
a_i	Polynomial parameters
l	Scan leg number
d	detector identifier
j	Iteration index

Re-Sampling and Offset-Function

Scans projected on sky



Scans as signal timeline



Destriper Features

Input

- Polynomial offset function selection
- Iteration limit by number and χ^2 threshold
- Choice between per-scan and full-observation timelines
- Option to start with median offsets
- Level 2 deglitcher with repeat control, iteration control and choice of two different methods
- Bright source exclusion
- Sky bin size control
- Weighted fitting (under development)

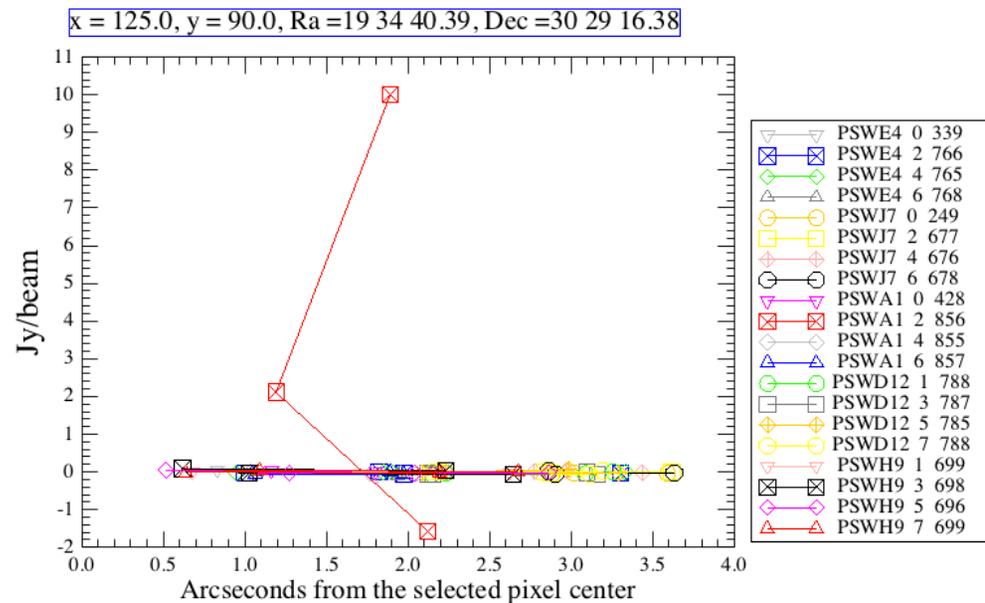
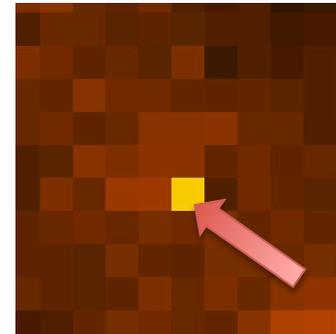
- TOD output control
- Start parameter feedback from diagnostic product
- Temporary pool control
- Thread control

Output

- Offset subtracted Level 1
- Reconstructed map
- Diagnostic product
- TOD (if requested)
- Difference timelines

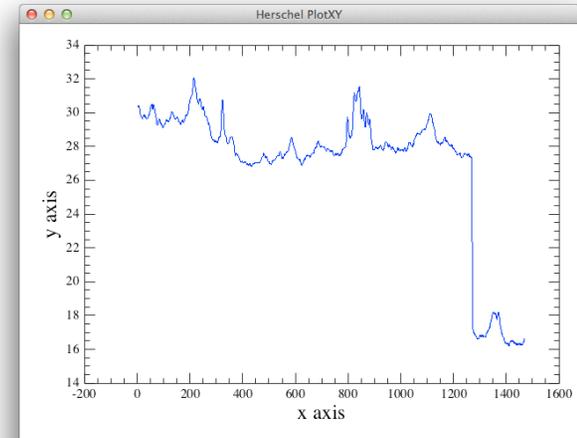
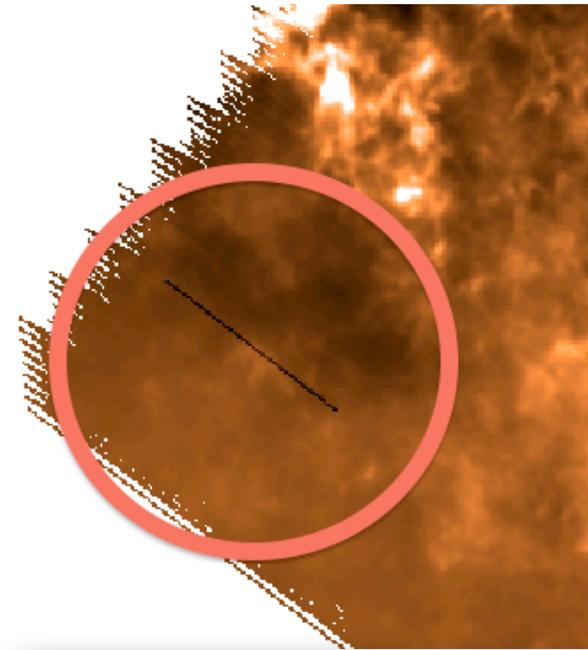
Level 2 Deglitching

- Glitches not caught by Level 1 deglitching can be identified in a map based on better redundancy.
- The Level 2 deglitching identifies outliers within a skybin.
- Two methods are available that can be iterated:
 - **sigmaKappa**
 - Rejects all readouts more than $\kappa \cdot \sigma$ away from the skybin average, where σ is the error calculated for a given skybin.
 - **twoSigmas**
 - Readouts are rejected only if in addition, the readout is more than κ times the average error map away from the average.



Jump Detection

- Wavelet analysis of residual signal (difference between re-sampled signal and original signal-offset function).
- Perform wavelet transformation with modified Haar wavelet.
- Jump is considered detected when wavelet transformation function above a threshold and the
- Advantage: This method is less susceptible to misdetections due to variations in the sky flux.



The Diagnostic Product

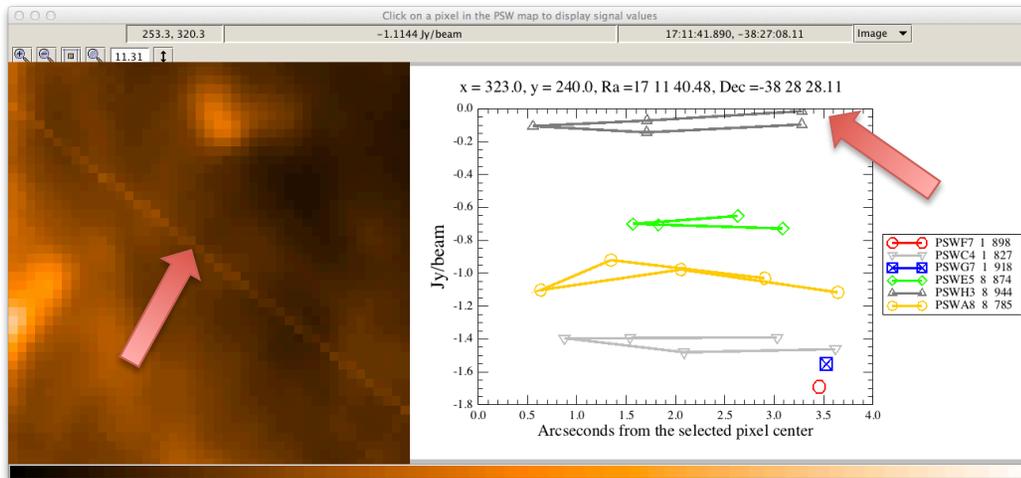
Diagnostic Tabledataset for Destriper

Meta Data			
name	value	unit	description
description	Diagnostic Tabledataset for Destriper		
instrument	SPIRE		Spire Pipeline
arrayName	PSW		Bolometer array
chiSquareAll	96795.149474963		Sum of chiSquares
validTimelines	1310		Total number of valid signal timelines in Level1.
convergedTimelines	1300		Total number of converged signal timelines.
iterThresh	1.0E-15		Threshold used to determine chiSquare convergence.
maxIter	100		Maximum number of iterations.

Data										
obsid_1342183678_1_obsid_1342183678_1_refs["level2"].product.refs["psrcPSWdiag"].product["PSWDiagnosticTable"]										
Index	channelName	detIndex	scanNumber	iter	chiSquare	convergence	numberL2Flags	a0	a1	deselected
1255	PSWG11	77	8	0	0.0	0.0	0	0.0	0.0	1
1256	PSWG12	77	8	16	15.90735466238692	true	0	-829.65...	0	0
1257	PSWG13	82	8	73	25.19977222179214	true	0	-879.18...	0	0
1258	PSWG14	87	8	71	41.83204994355209	true	0	-992.43...	0	0
1259	PSWG15	92	8	38	47.331246363544	true	0	-927.75...	0	0
1260	PSWH1	28	8	11	16.359033912799287	true	0	-739.16...	0	0
1261	PSWH2	31	8	13	13.051937331445929	true	0	-727.53...	0	0
1262	PSWH3	35	8	2	611.924874301273	true	0	-729.55...	0	0
1263	PSWH4	40	8	13	11.66151671746164	true	0	-700.16...	0	0
1264	PSWH5	45	8	12	12.697930198518089	true	0	-684.32...	0	0
1265	PSWH6	122	8	30	16.245584179811814	true	0	-657.39...	0	0
1266	PSWH7	126	8	13	12.489114733365833	true	0	-662.25...	0	0
1267	PSWH8	130	8	29	16.56636693347251	true	0	-719.22...	0	0
1268	PSWH9	135	8	37	22.07490087265246	true	0	-725.58...	0	0
1269	PSWH10	139	8	22	11.835772512471706	true	0	-716.44...	0	0
1270	PSWH11	143	8	38	11.924577436701712	true	0	-749.21...	0	0
1271	PSWH12	76	8	72	22.664628232564225	true	0	-802.81...	0	0

- Provides a record for each scan whether it converged, how the fit process turned out, and the final value found (a0,a1...).
- Indicators for each scan are 1) number of iterations (iter), 2) degree of convergence (chiSquare), 3) flag whether converged (convergence), 4) number of Level2 glitches found (numberL2flags).
- The last column contains flags that can be set to deselect the corresponding scan in a second destriper run.
- This offers more options of automatic iterative processing of maps in scripts.

Parameter Feedback



- Sometimes scans don't converge well for various reasons.
- The bolometer finder script and the diagnostic product help to identify the scan.
- In this case it is PSWH3 in scan number 8 showing a high chiSquare value.
- It can be deselected by setting the respective flag to 1 and feeding the modified diagnostic product back as "startParameters" to the destriper for another run.
- This run converges faster as most parameters are already close to optimal.
- A future development may allow higher polynomial degrees for selected scans, initiated through parameter feedback.

Diagnostic Tabledataset for Destriper

Meta Data

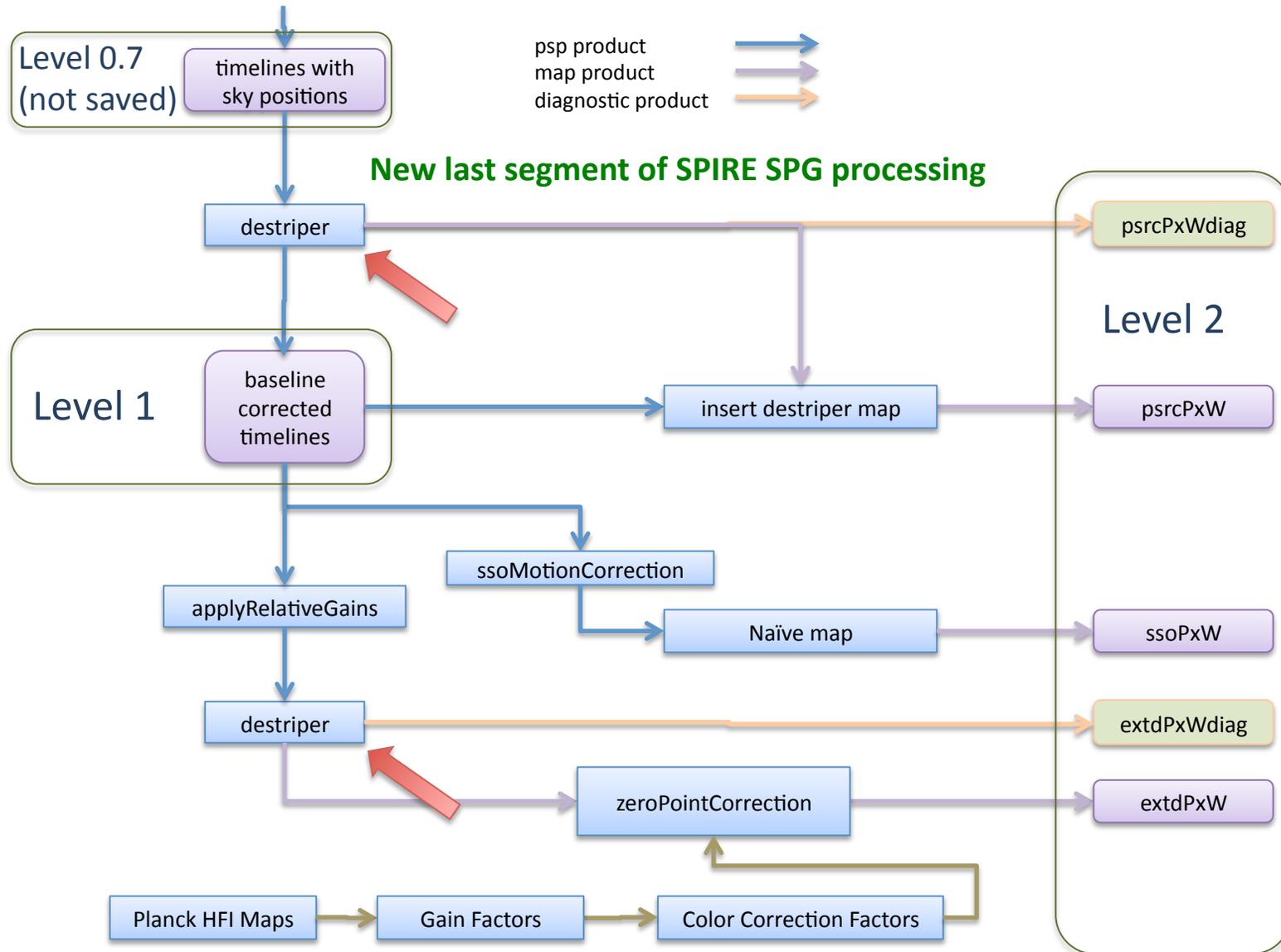
name	value	unit	description
description	Diagnostic Tabledataset for Destriper		
instrument	SPIRE		Spire Pipeline
arrayName	PSW		Bolometer array
chiSquareAll	96795.149474963		Sum of chiSquares
validTimelines	1310		Total number of valid signal timelines in Level1.
convergedTimelines	1300		Total number of converged signal timelines.
iterThresh	1.0E-15		Threshold used to determine chiSquare convergence.
maxIter	100		Maximum number of iterations.

Data

obsid_1342183678_1.ref["level2"].product.ref["psrcPSWdiag"].product["PSWDiagnosticTable"]

Index	channelName	detIndex	scanNumber	iter	chiSquare	convergence	numberL2Flags	a0	deselected
1256	PSWG12	77	8	16	15.90735466238692	true	0	-829.65...	0
1257	PSWG13	82	8	73	25.19977222179214	true	0	-879.18...	0
1258	PSWG14	87	8	71	41.83204994355209	true	0	-992.43...	0
1259	PSWG15	92	8	38	47.331246363544	true	0	-927.75...	0
1260	PSWH1	28	8	11	16.359033912799287	true	0	-739.16...	0
1261	PSWH2	31	8	13	13.051937331445929	true	0	-727.53...	0
1262	PSWH3	35	8	2	611.924874301273	true	0	-729.55...	0
1263	PSWH4	40	8	13	11.66151671746164	true	0	-700.16...	0
1264	PSWH5	45	8	12	12.697930198518089	true	0	-684.32...	0
1265	PSWH6	122	8	30	16.245584179811814	true	0	-657.39...	0
1266	PSWH7	126	8	13	12.4489114733365833	true	0	-662.25...	0
1267	PSWH8	130	8	29	16.56636693347251	true	0	-719.22...	0
1268	PSWH9	135	8	37	22.07490087265246	true	0	-725.58...	0
1269	PSWH10	139	8	22	11.835772512471706	true	0	-716.44...	0
1270	PSWH11	143	8	38	11.924577436701712	true	0	-749.21...	0

SPG processing in HIPE 10

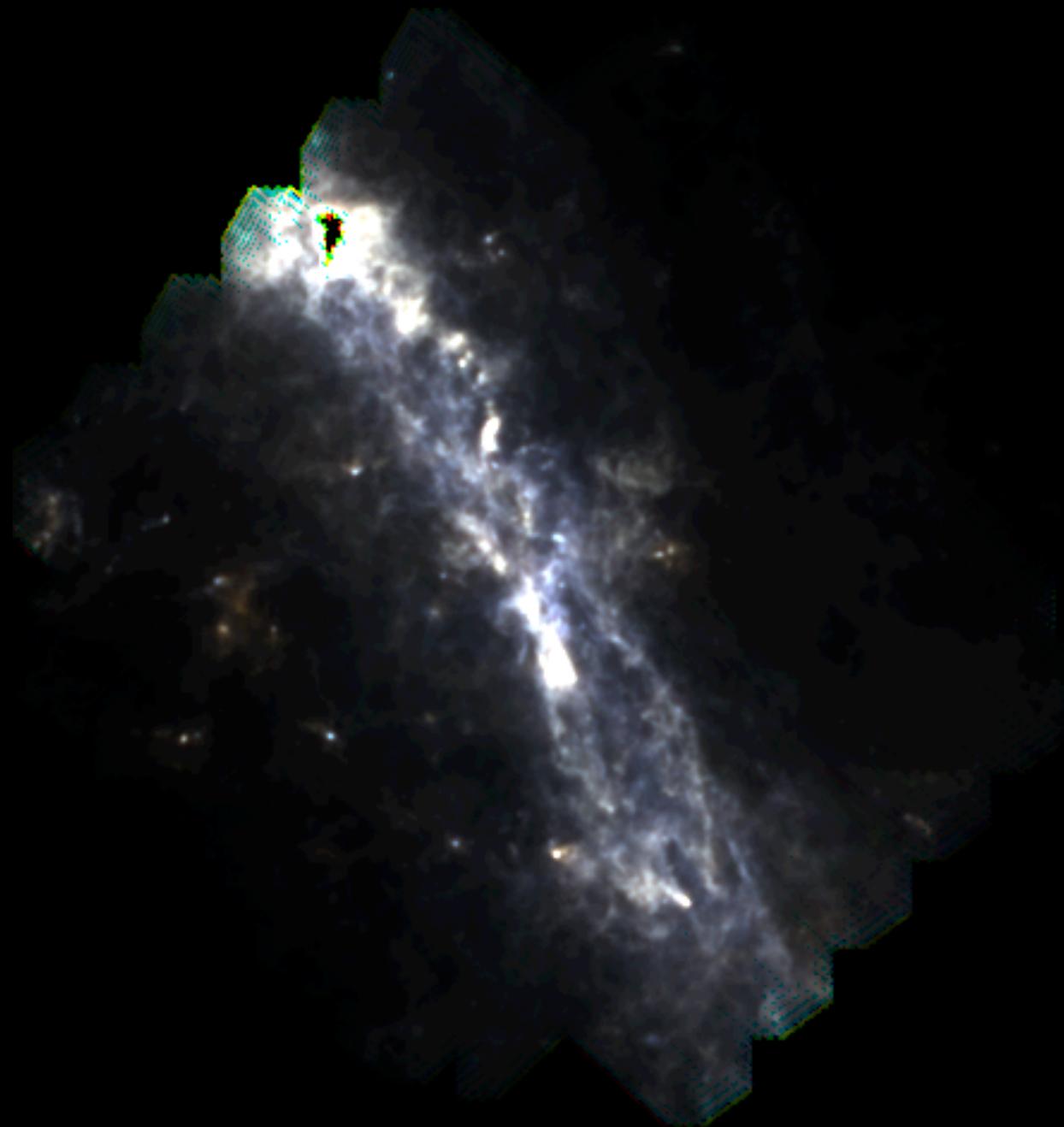


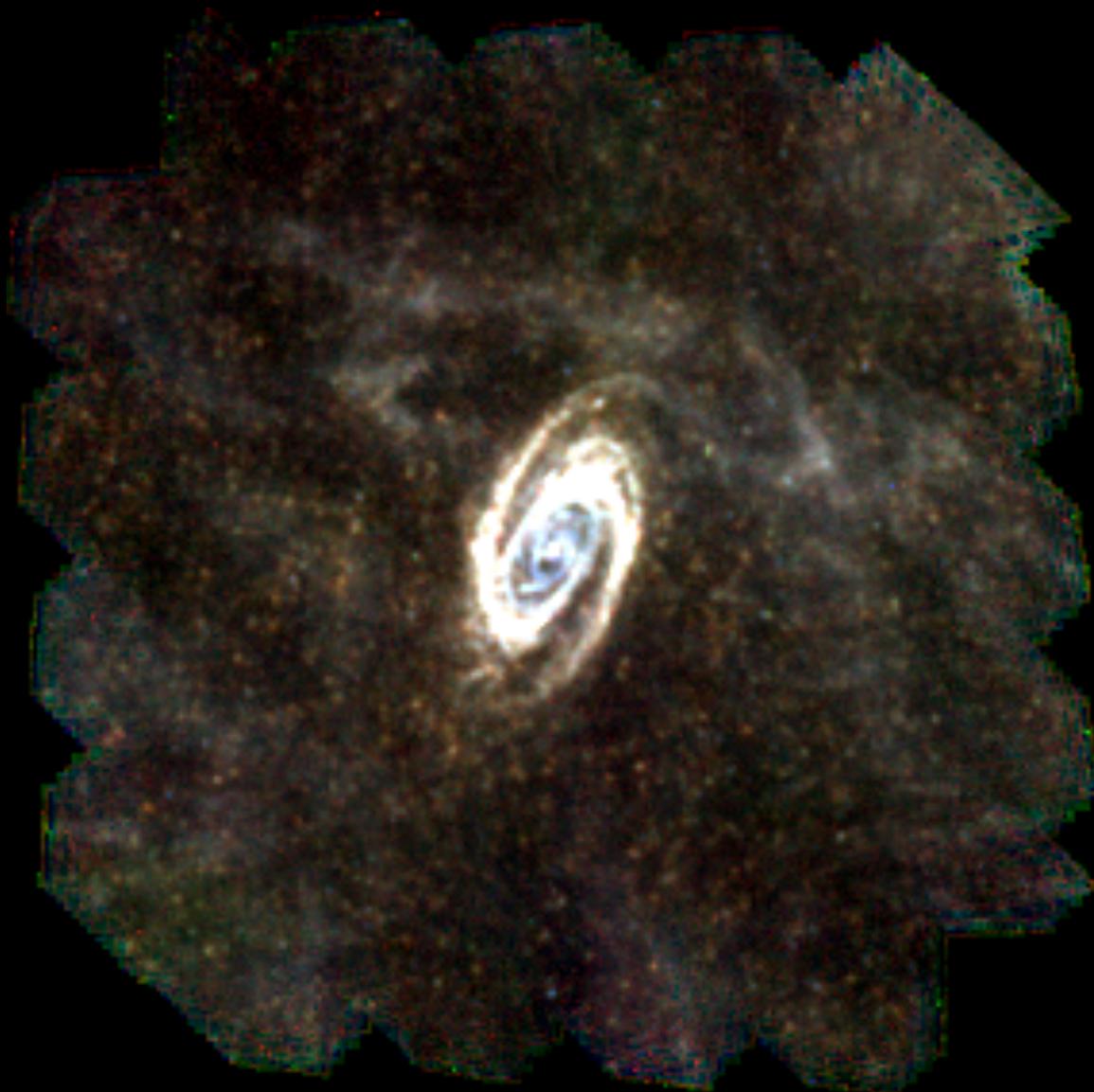
Remarks

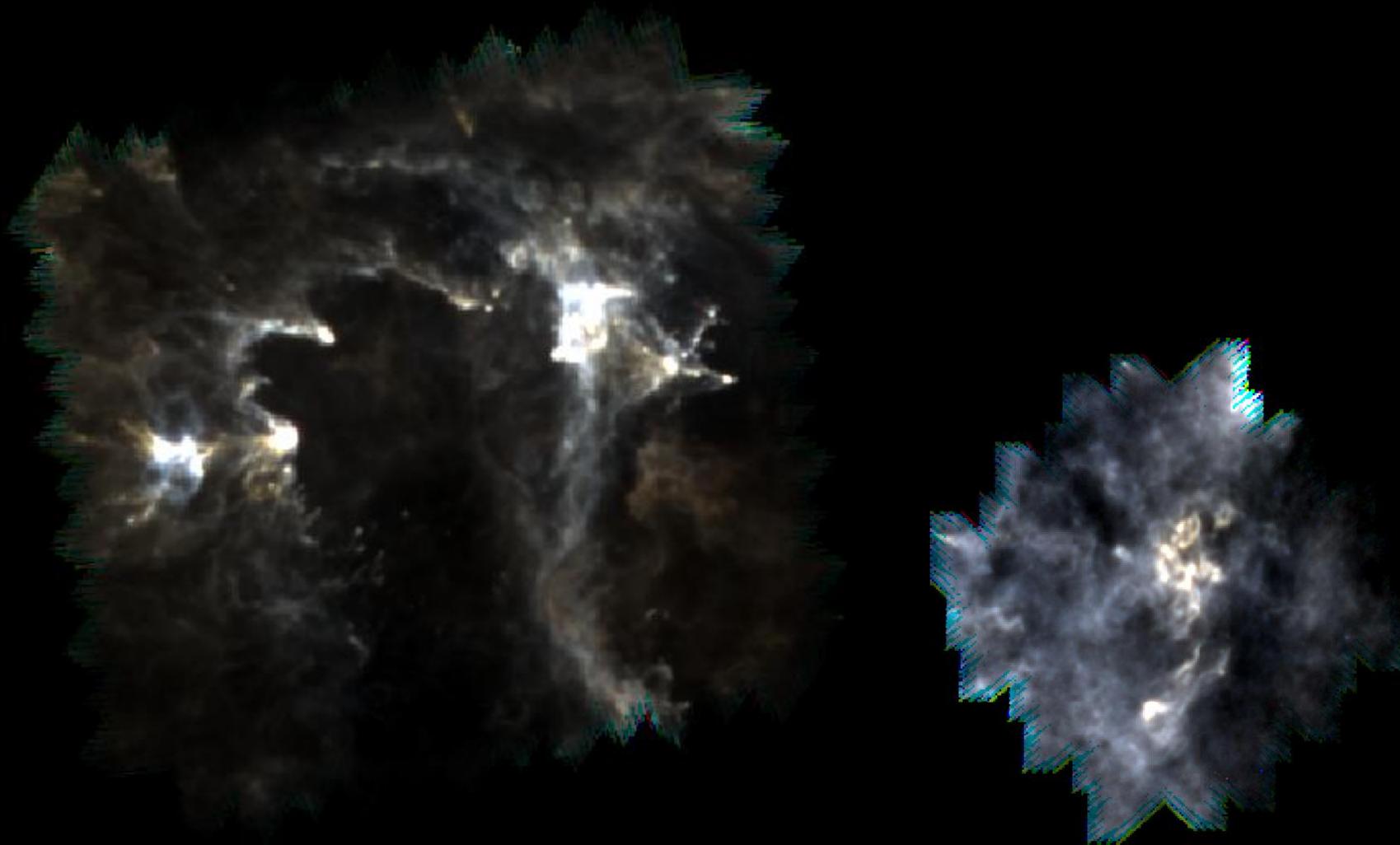
- The destriper is very stable with zero degree polynomials and this is the default SPG mode.
- The signal timelines are kept in their original form. Only constants are subtracted.
- Allowing higher polynomial degrees makes the result less stable but deals better with residual drifts and cooler burps.
- Higher polynomial degrees will remove real celestial flux if insufficiently constrained, in particular a tilted background.
- Future improvements include
 - Validate fullTimeline mode.
 - Allow higher order polynomials for select scans while keeping polynomial order lower for all others. This will provide cooler burp correction with better constraints.
 - Provide weighted fitting of polynomials.

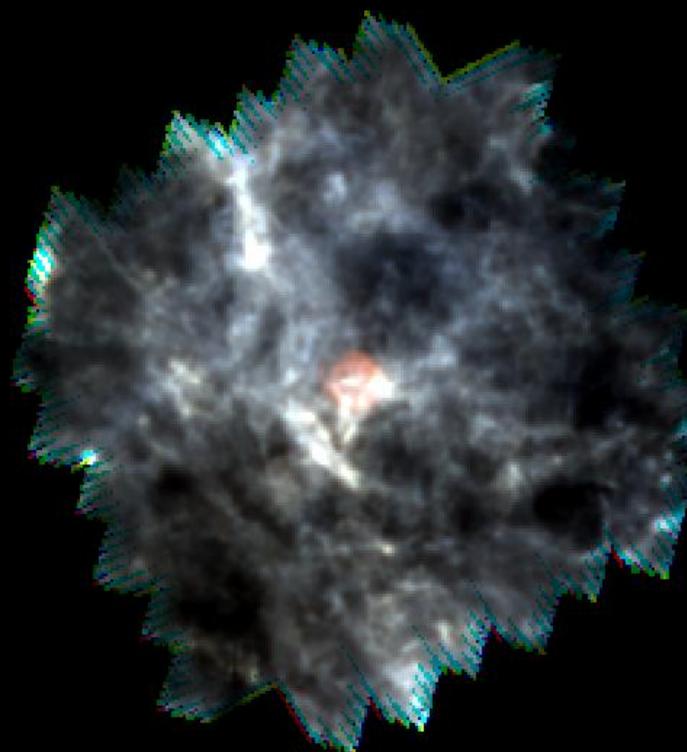
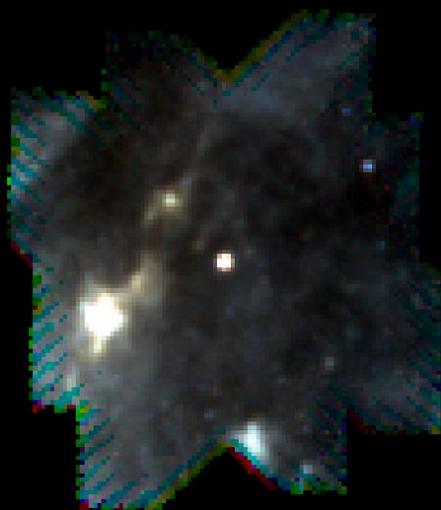
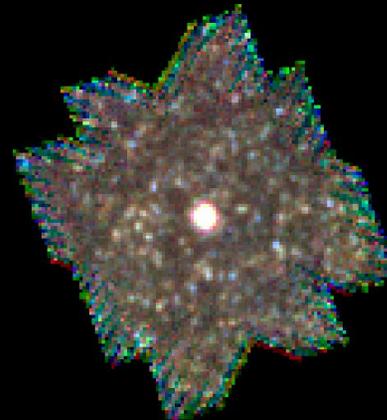
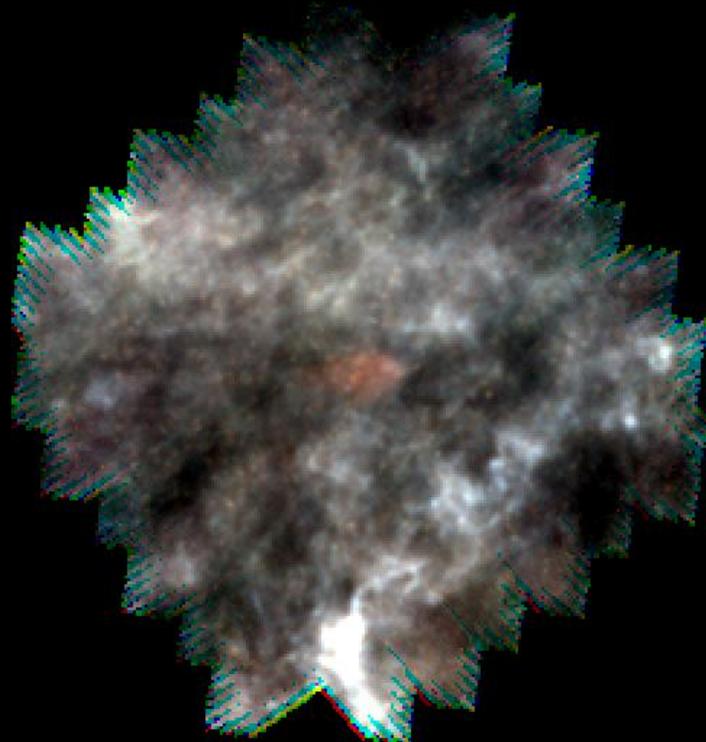
Further Reading

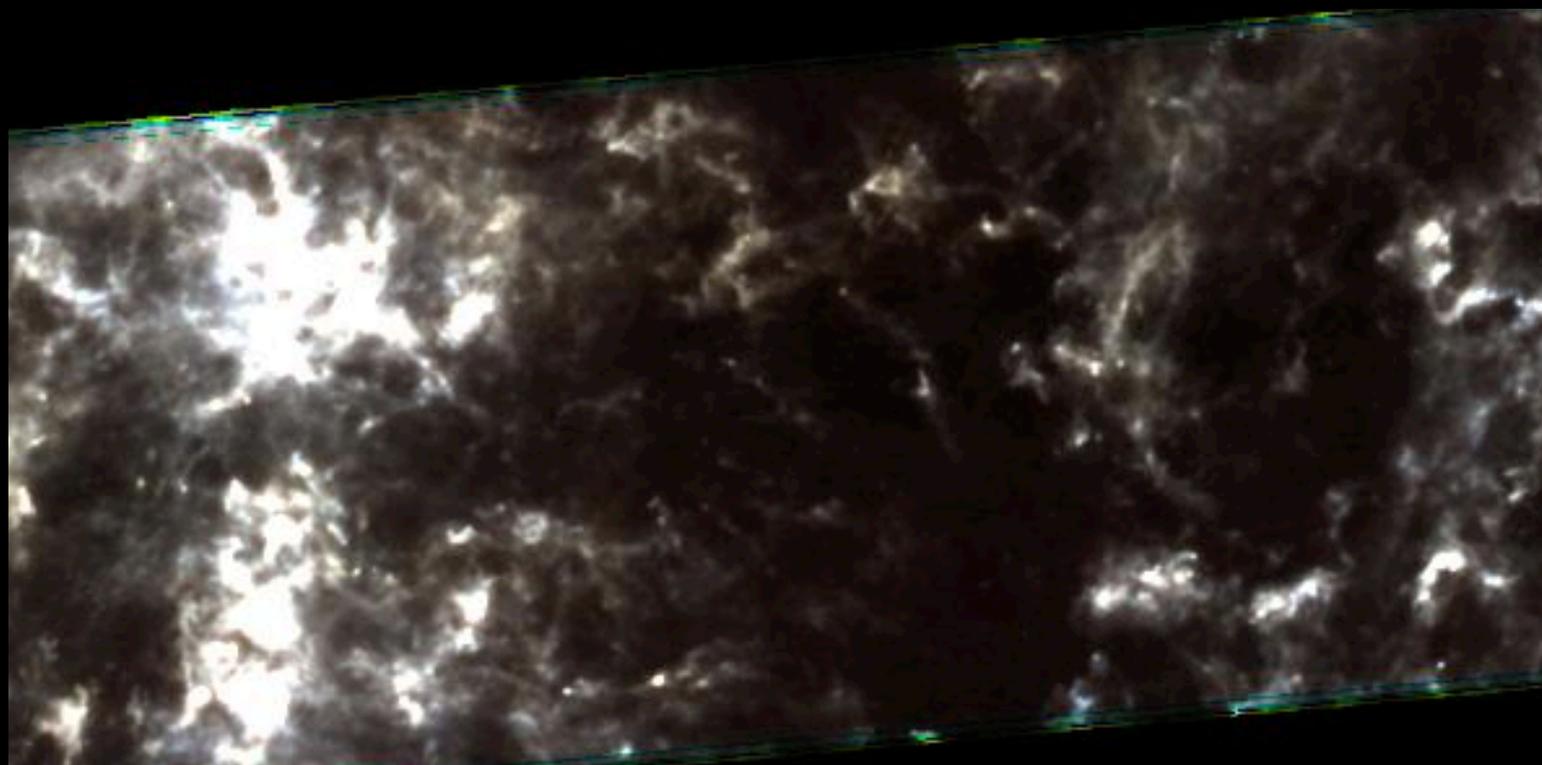
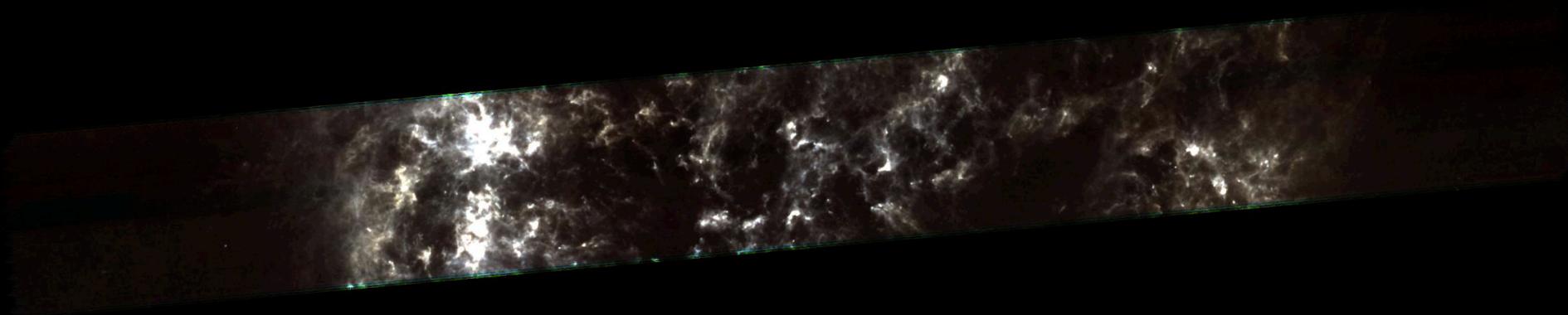
- Destriper Homepage
 - <https://nhscsci.ipac.caltech.edu/sc/index.php/Spire/PhotScanMapDestriper>
- SPIRE Data Reduction Guide
 - http://herschel.esac.esa.int/hcss-doc-8.0/load/spire_drg/html/spire_drg.html
- SPIRE instrument and calibration web pages
 - <http://herschel.esac.esa.int/twiki/bin/view/Public/SpireCalibrationWeb?template=viewprint>
- SPIA Homepage
 - <https://nhscsci.ipac.caltech.edu/sc/index.php/Spire/SPIA>













Appendix

Main Destriper Parameters I

- Mandatory Input Data
 - Level1
 - Level 1 context with all signal timelines
 - array
 - string indicating detector array

- Optional Input Data
 - tod
 - To save time if TOD was already generated
 - startParameters
 - Diagnostic product from prior destriper run with modified column

- Destriper Specific Input
 - offsetFunction
 - Fit polynomial to scans across map individually (“perScan”) or as a whole for each detector (“fullTimeline”)
 - default: “perScan”
 - polyDegree
 - degree of polynomial
 - default: 0
 - iterThresh
 - χ^2 threshold to stop iterations
 - default : 1E-10
 - iterMax
 - Maximum number of iterations
 - default: 100
 - withMedianCorrected
 - Subtract medians before start
 - default: selected
 - brightSource
 - Exclude bright sources from fit
 - default: selected
 - fitWithWeight
 - Fit polynomial to readouts weighted by their uncertainties in the error map. (doesn’t work yet)
 - default: off

Main Destriper Parameters II

- System Control Input Data
 - nThreads
 - Number of threads to use in processing
 - Default: 2
 - useSink
 - Use temporary pool on disk to handle larger datasets at the cost of speed
 - Default: off
 - storeTod
 - Request TOD after destripping is complete.
 - Default: off
- Mapmaker Parameters
 - pixelSize
 - Pixel size in arcseconds.
 - Default: Depending on detector array: 6", 10", 14" for PSW, PMW, PLW respectively.
 - minVel
 - Minimum scan speed accepted in "/sec.
 - Default: 5"/sec
 - maxVel
 - Maximum scan speed accepted in "/sec
 - Default: none
 - method
 - Choice of method. Options are:
"BinaryWeightStrategy" Average readouts within a skybin.
 - "WhiteNoiseWeight" Weight the contributing readouts by the white noise of their respective detectors.
 - Default: "BinaryWeightStrategy"
 - chanNoise
 - Calibration file needed for second method.
 - useOnlyMasks
 - Mask defining data that are to be accepted by the mapmaker.
 - ignoreDefaultMasks
 - Mask that overrides mapmaker defaults.

Main Destriper Parameters III

- Level2 Deglitcher Input
 - kappa
 - Acceptable range expressed in number of standard deviations
 - Default: 5
 - l2DeglitchRepeat
 - Iteration number where the deglitcher is to be used first.
 - 0 turns the deglitcher off, otherwise it is executed at least at the end.
 - Default: 100
 - l2DeglitchAlgorithm
 - Choice between methods “sigmaKappa” and “twoSigmas”
 - Default: “sigmaKappa”
- l2IterMax
 - Maximum number of iterations for Level 2 deglitching
 - Default: 5
- Level 2 Jump Detector Input
 - jumpThresh
 - Detection threshold for Level 2 jump detector
 - Default: -1.0
 - jumplter
 - Iteration number where the jump detector is to be used first.
 - 0 turns the deglitcher off, otherwise it is executed at least at the end.
 - Default: 100

Full Destriper Input Parameter List

Parameter	Type	Description
Level1	SpireListContext	spireListContext: Level1Context or SpireListContext of pointed photometer detector timelines.
tod	Object	tod: time ordered data, Tod, or TodBuffer
array	String	Array: the bolometer type, PSW, PMW or PLW. It is a mandatory input.
pixelSize	Double	pixelSize: size of the skybin in map. If not given, the default size is used, depending on the detector array, i.e. 6", 10", 14" for PSW, PMW, PLW respectively.
offsetFunction	String	offsetFunctions: perScan or fullTimeline to calculate offset. The default is perScan.
polyDegree	Integer	polyDegree: the polynomial degree of the offset function.
kappa	Double	Kappa: the kappa value to perform iterative level2 sigma-kappa deglitching. The default is 5.0.
iterThresh	Double	iterThreshold: the threshold to determine if the fitting convergence is achieved.
l2DeglitchRepeat	Integer	l2DeglitchRepeat: the number of iterations to start the first Level 2 deglitching. By default, the level2 deglitching only happens once right before the final output is created.
l2DeglitchAlgorithm	String	L2DEGLITCH_ALGORITHMS: sigamKapp: sigma-kappa algorithm; twoSigmas: two sigmas algorithm
iterMax	Integer	iterMax: maximum number of iterations.
l2IterMax	Integer	l2IterMax: the maximum number of iterations for level2 deglitchers.
nThreads	Integer	nThreads: the number of threads to be started. The default is 1.
jumpThresh	Double	jumpThresh: This parameter define the threshold for jump de- tection.

jumplter	Integer	jumplter: This parameter define the number of destriper it- eration after than perform the jump detection
minVel	Double	minVel: Minimum acceptable scan speed (arcsec/sec).
maxVel	Double	maxVel: Maximum acceptable scan speed (arcsec/sec).
method	Object	method: Java class implementing Naive mapper algorithms.
startParameters	Product	startParameters: a TableDataset which contains the start parameters.
chanNoise	Object	Calibration table of the detector noise power spectrum.
useOnlyMasks	SpireMask	Bolometer masking - data values flagged with any of these mask values will be ignored
ignoreDefaultMasks	SpireMask	Bolometer masking - modify the 'useOnlyMasks' value (normally used to modify the default)
withMedianCorrected	Boolean	subtractMedian: set to True if the median should be subtracted when make the first naive map.
brightSource	Boolean	brightSource: set to True if the observation has bright sources.
fitWithWeight	Boolean	vfitWithWeight: set to True if the fitting of the offset function should be performed using weights.
useSink	Boolean	ProductSink: set to True if use ProductSink to save the final output Level1 data, the default is false.
storeTod	Boolean	storeTod: set to True to store the Tod data files in temporary directory, the default is false.