Overview of SPIRE Photometer Data Reduction Pipeline

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on behalf of the SPIRE ICC,
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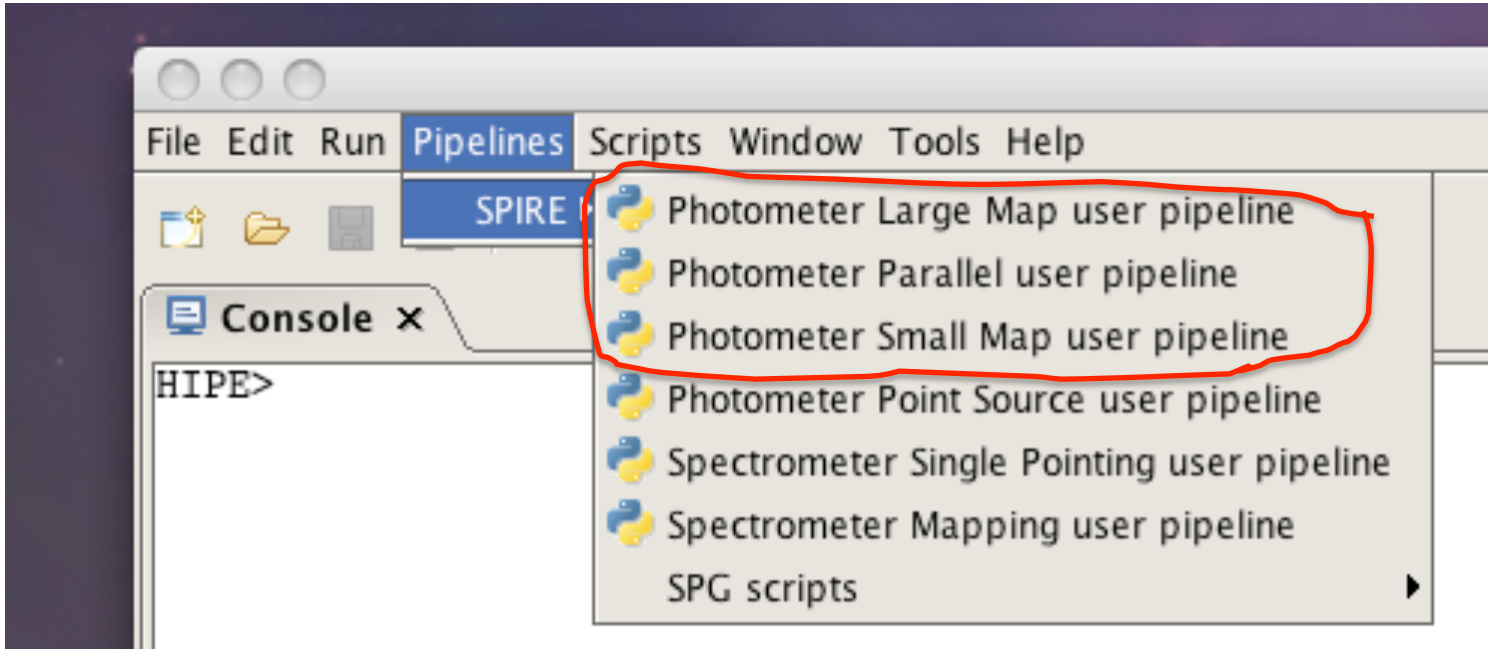
The Goal

- Show how SPIRE Photometer pipeline works (functionalities of major modules).
- Will concentrate on scan map "user pipelines" (covering small map, large map, SPIRE/PACS parallel modes).

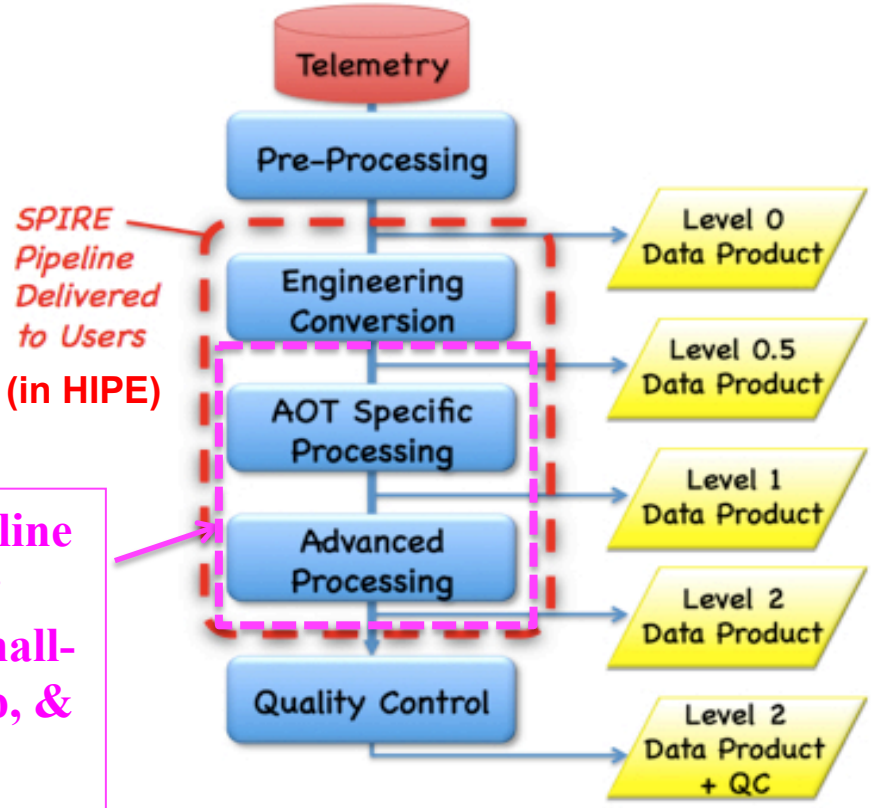
Reference: "*SPIRE Data Reduction Guide*" in HIPE (under "Help") or in:
http://herschel.esac.esa.int/hcss-doc-12.0/load/spire_drg/html/spire_drg.html

User Pipelines

- User pipelines: simplified version of Standard Product Generation (SPG) pipelines.
- They are Jython scripts for data re-processing.
- Can be found in HIPE:



Pipeline & Data Products



Scan-Map Pipeline (shared by user pipelines for small-map, large-map, & SPIRE/PACS parallel modes).

Since HIPE 11 (only in archive data from HSA) →

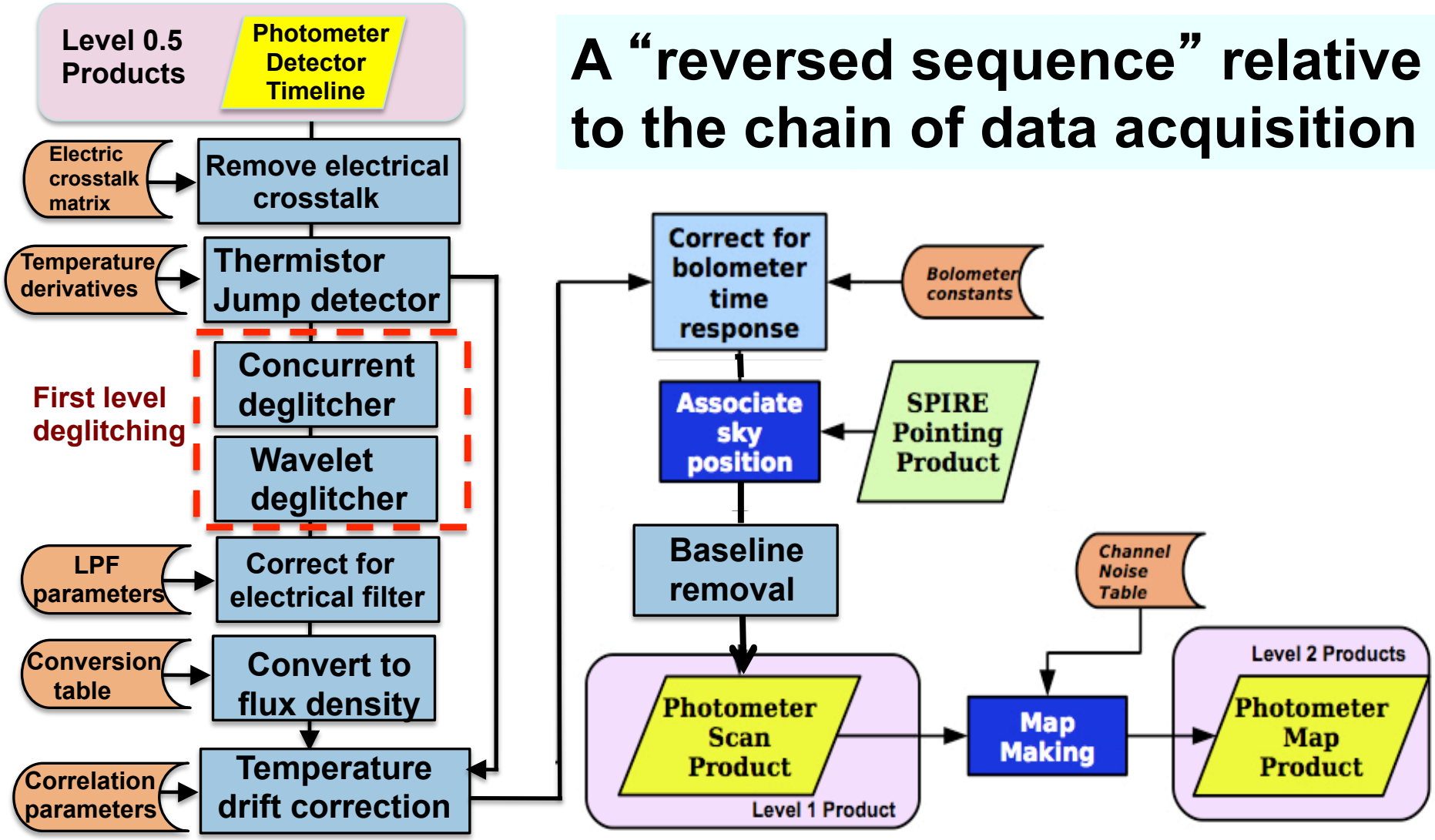
Level 2.5 Data Product

- **Maps of combined parallel observations with cross-scans**

Level 3 Data Product

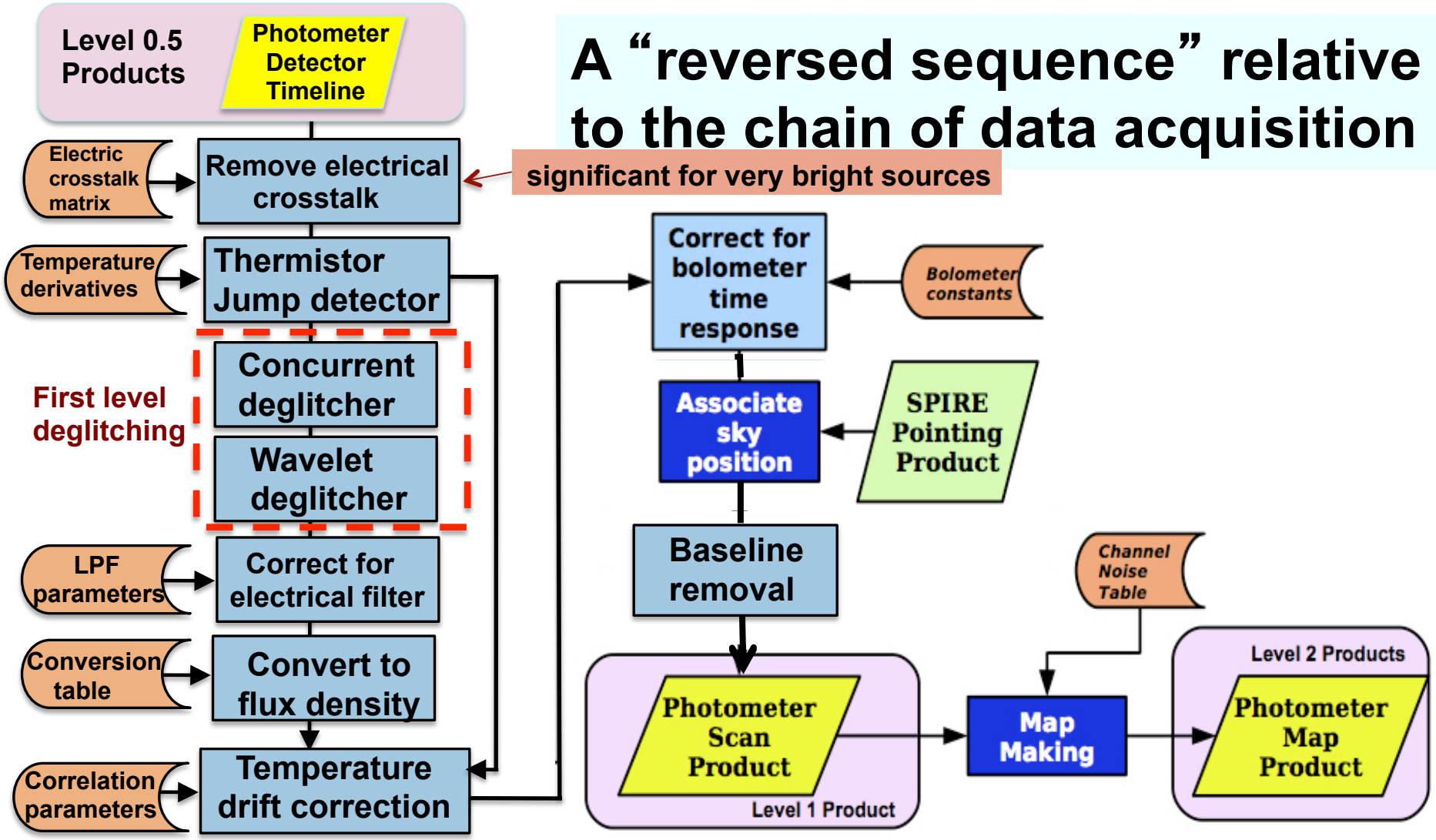
- **Maps of overlap observations belonging to the same proposal**

Scan Map Pipeline Flow Chart

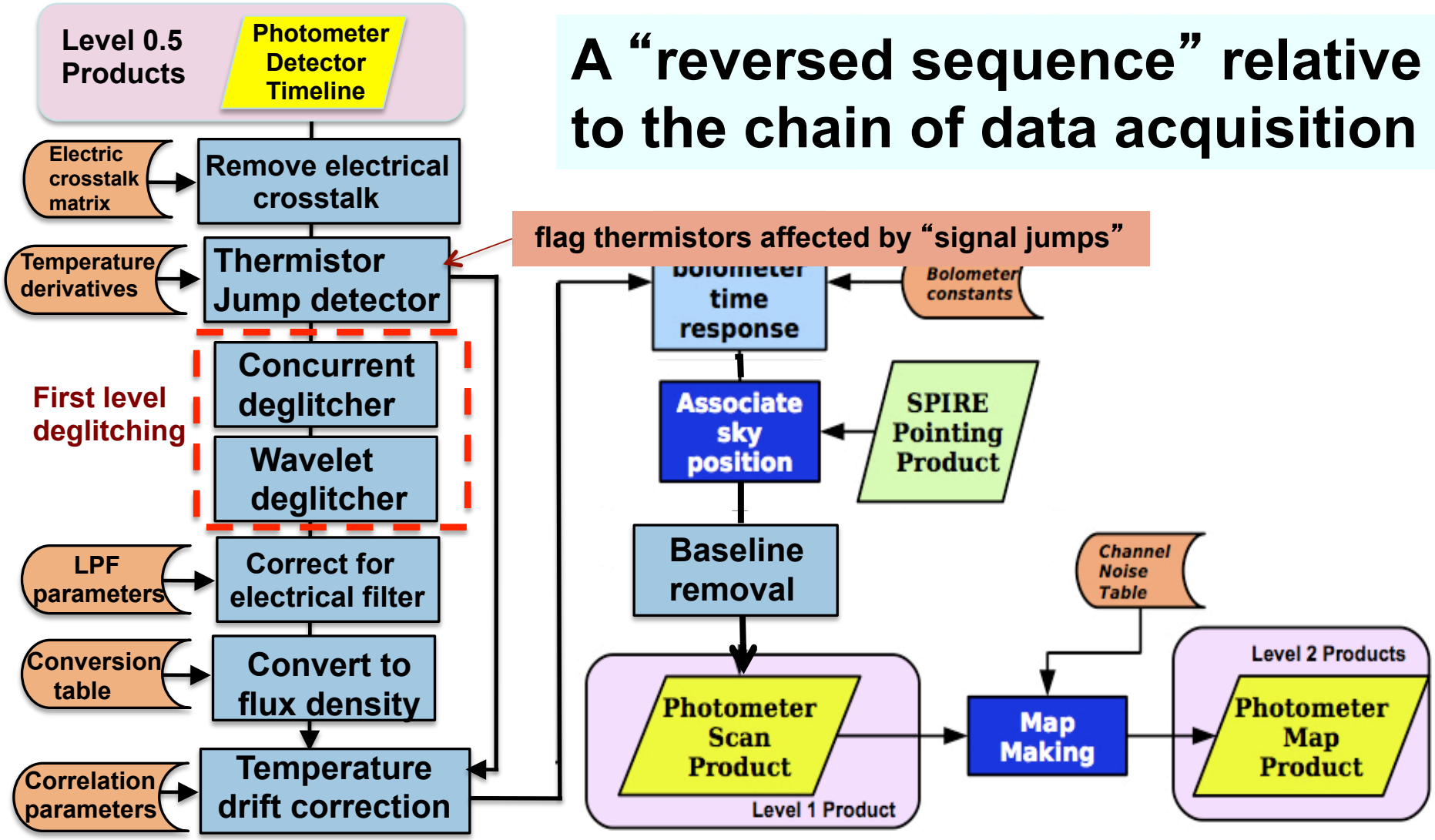


A "reversed sequence" relative to the chain of data acquisition

Scan Map Pipeline Flow Chart



Scan Map Pipeline Flow Chart



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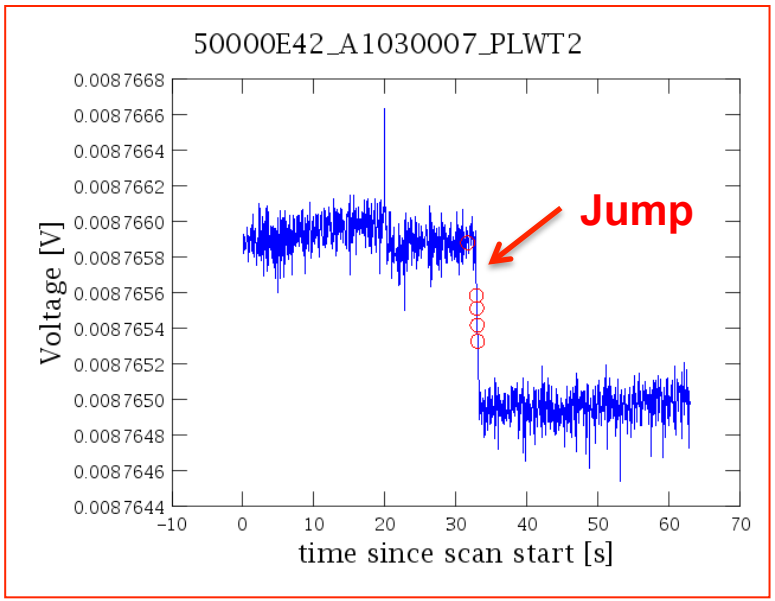
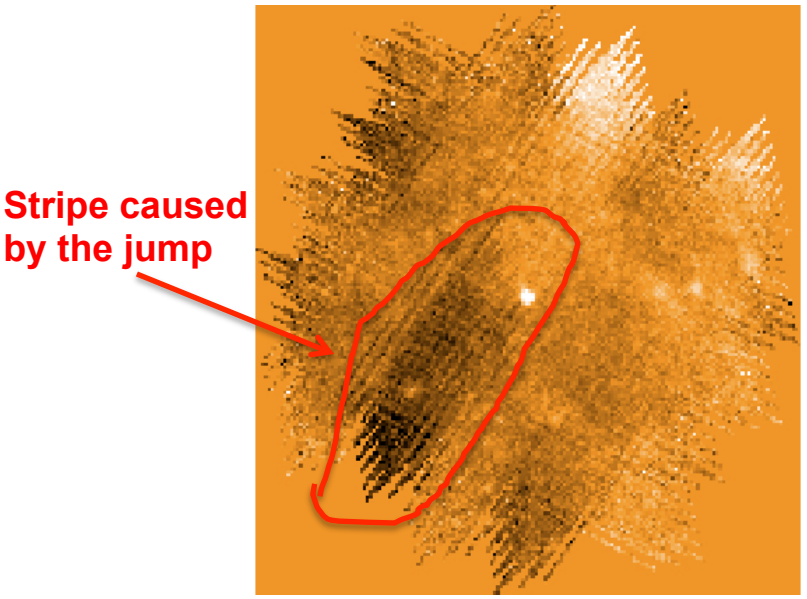
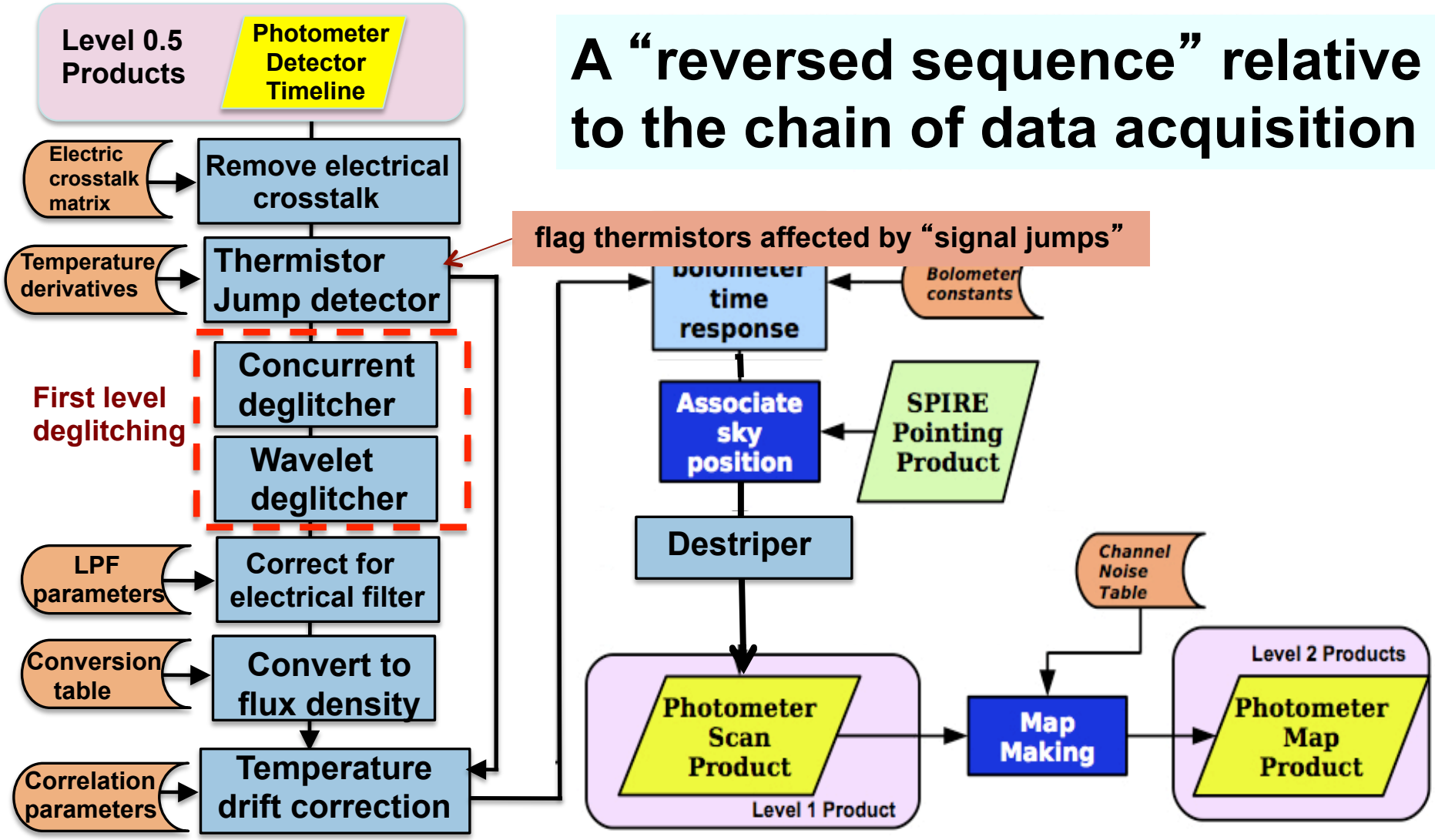
Thermistor Signal Jump

- Sudden spontaneous jump in a thermistor timeline.
- The average frequency is ~ 1/day.
- Effect: The pipeline uses thermistor timelines in the correction for detector signal drift due to temperature drift. A thermistor "jump" affects this correction, introducing artificial stripes in the final map.





Scan Map Pipeline Flow Chart



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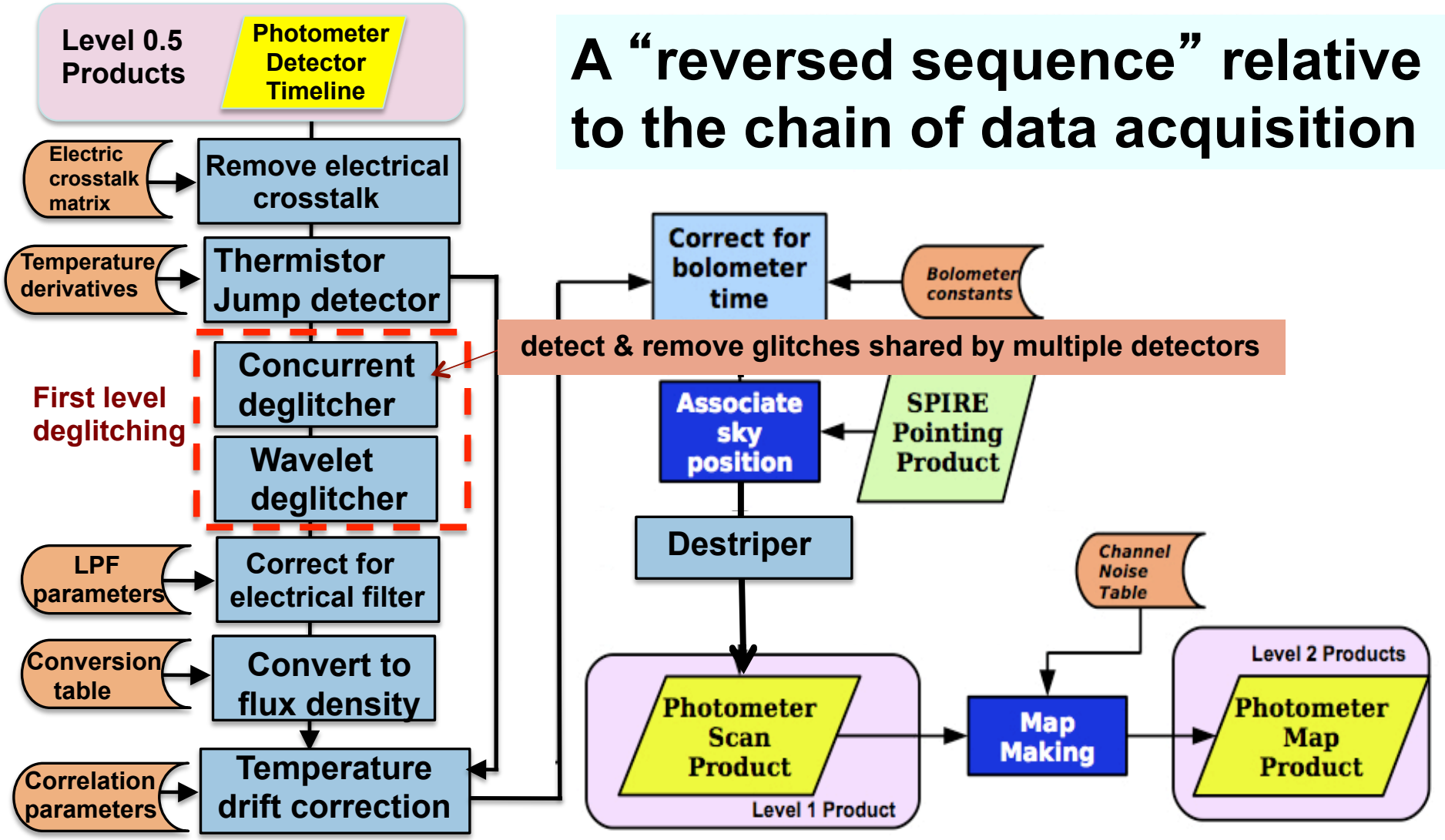

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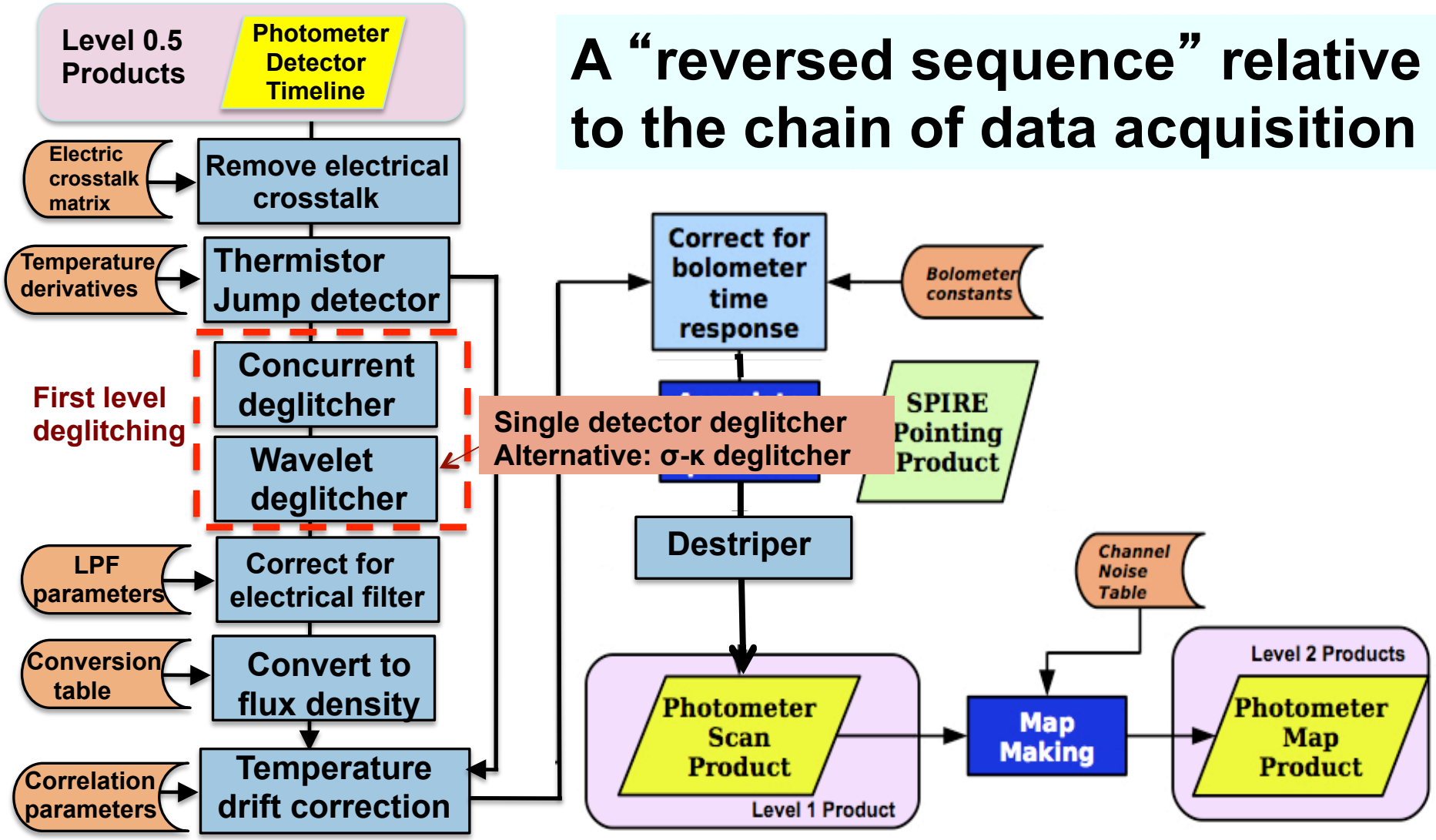

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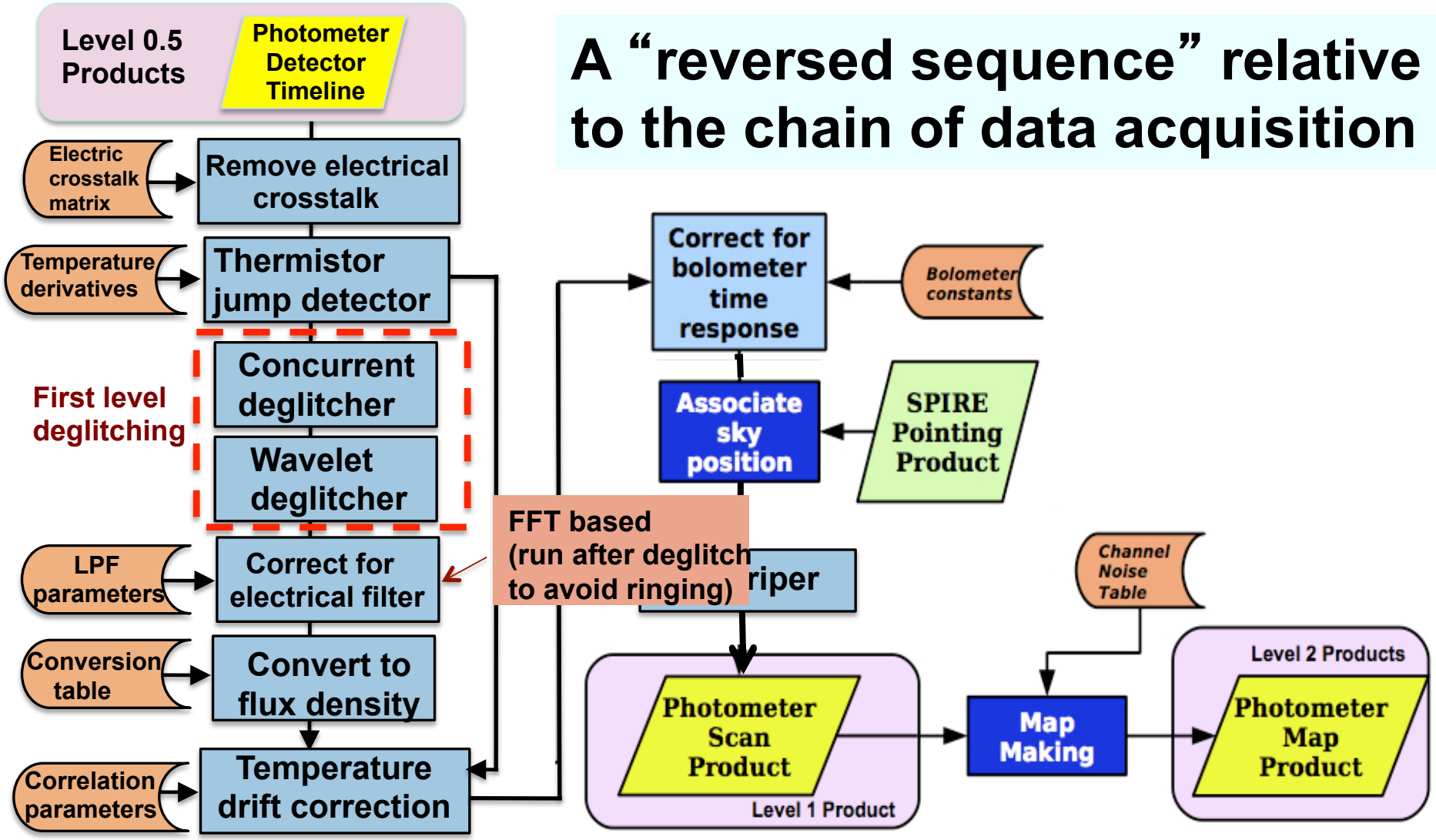
Scan Map Pipeline Flow Chart



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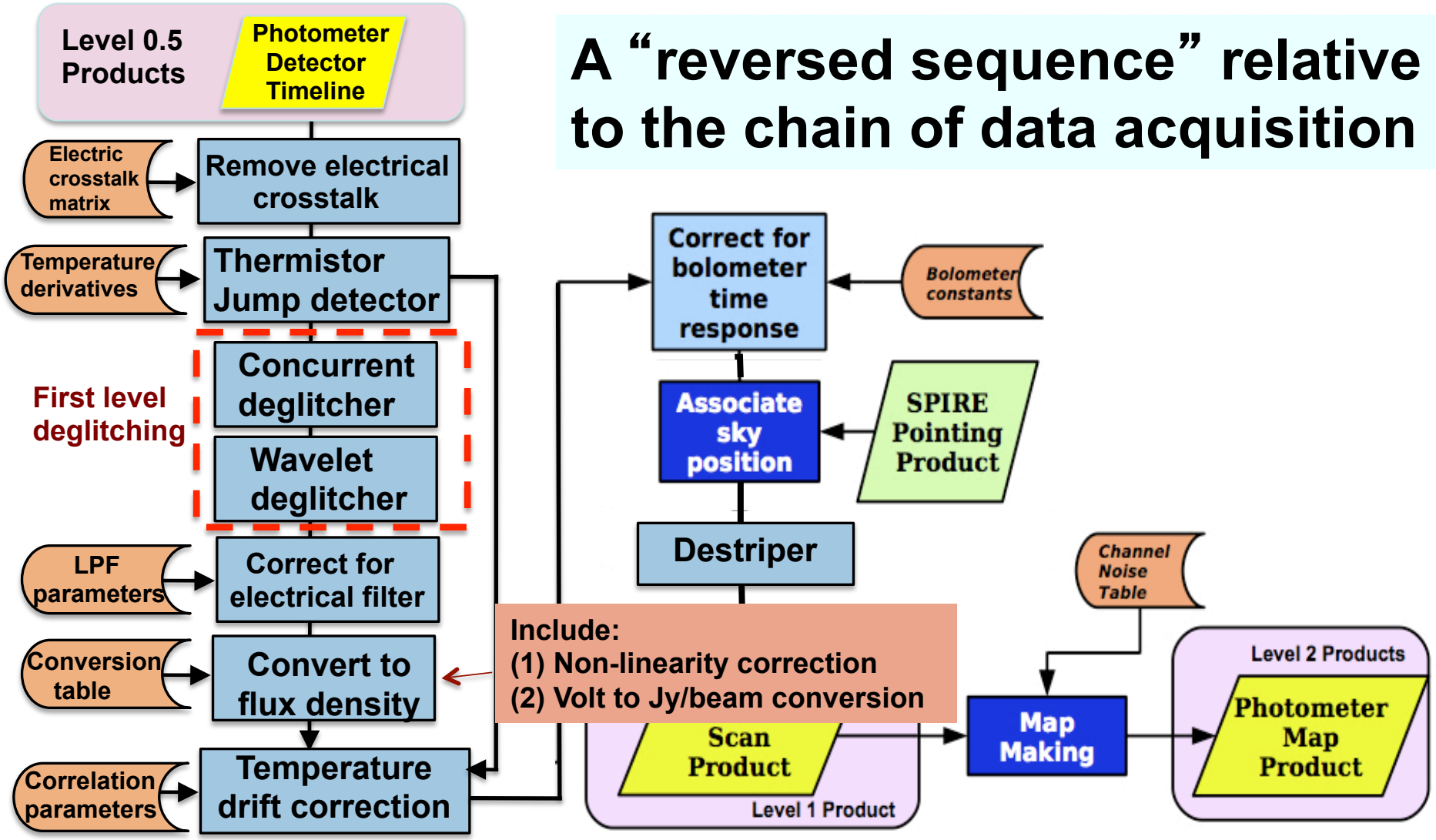

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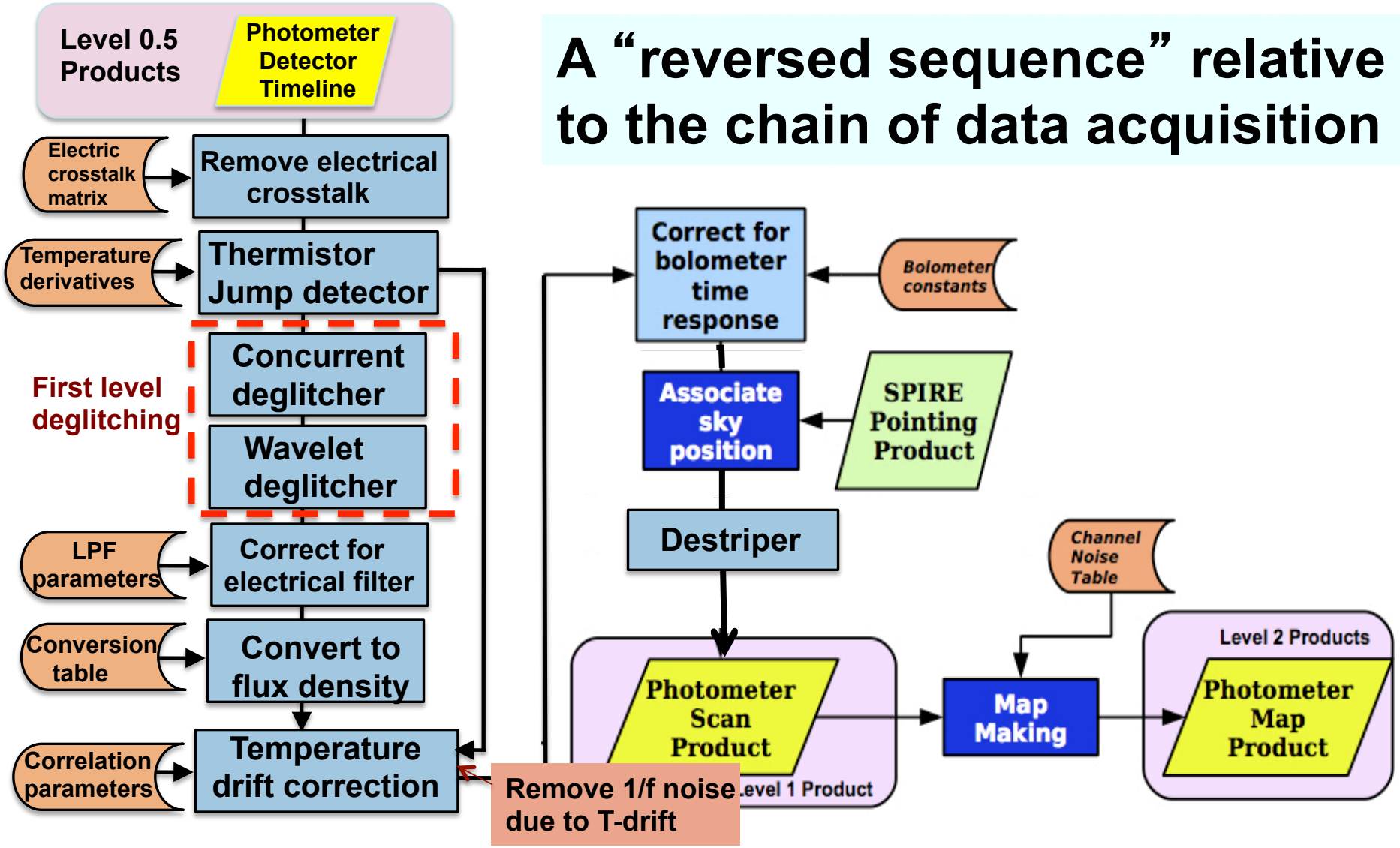

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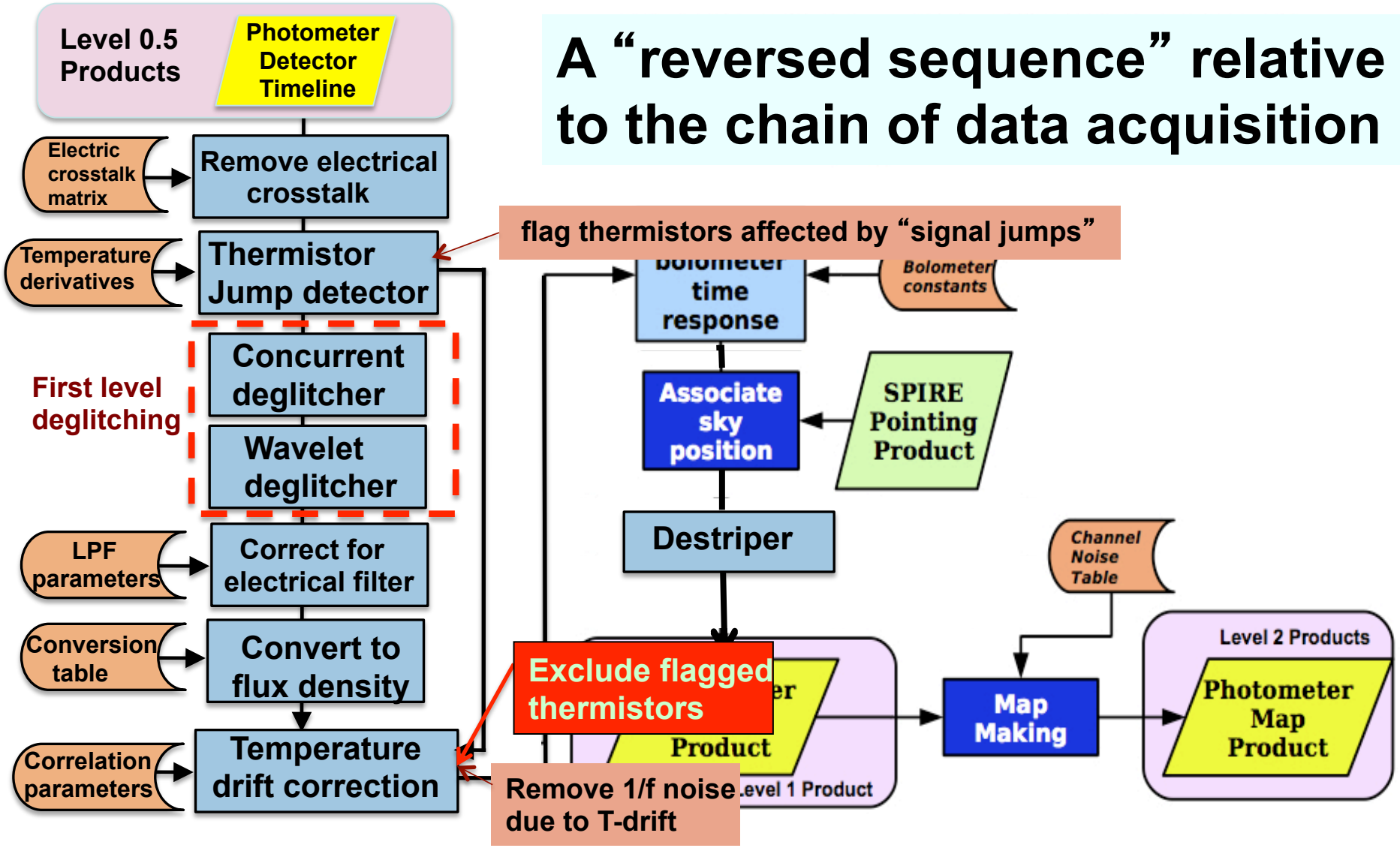

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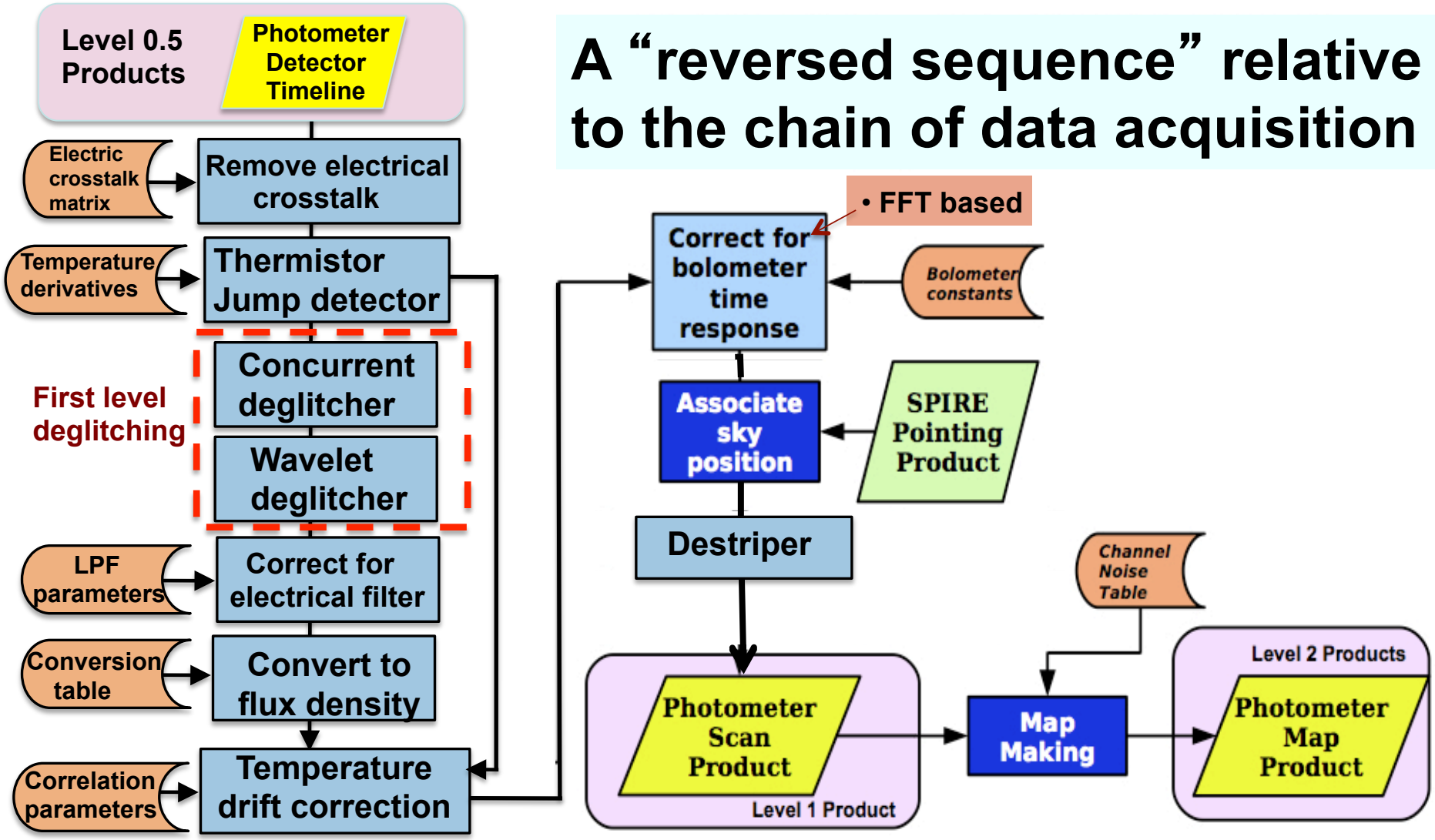

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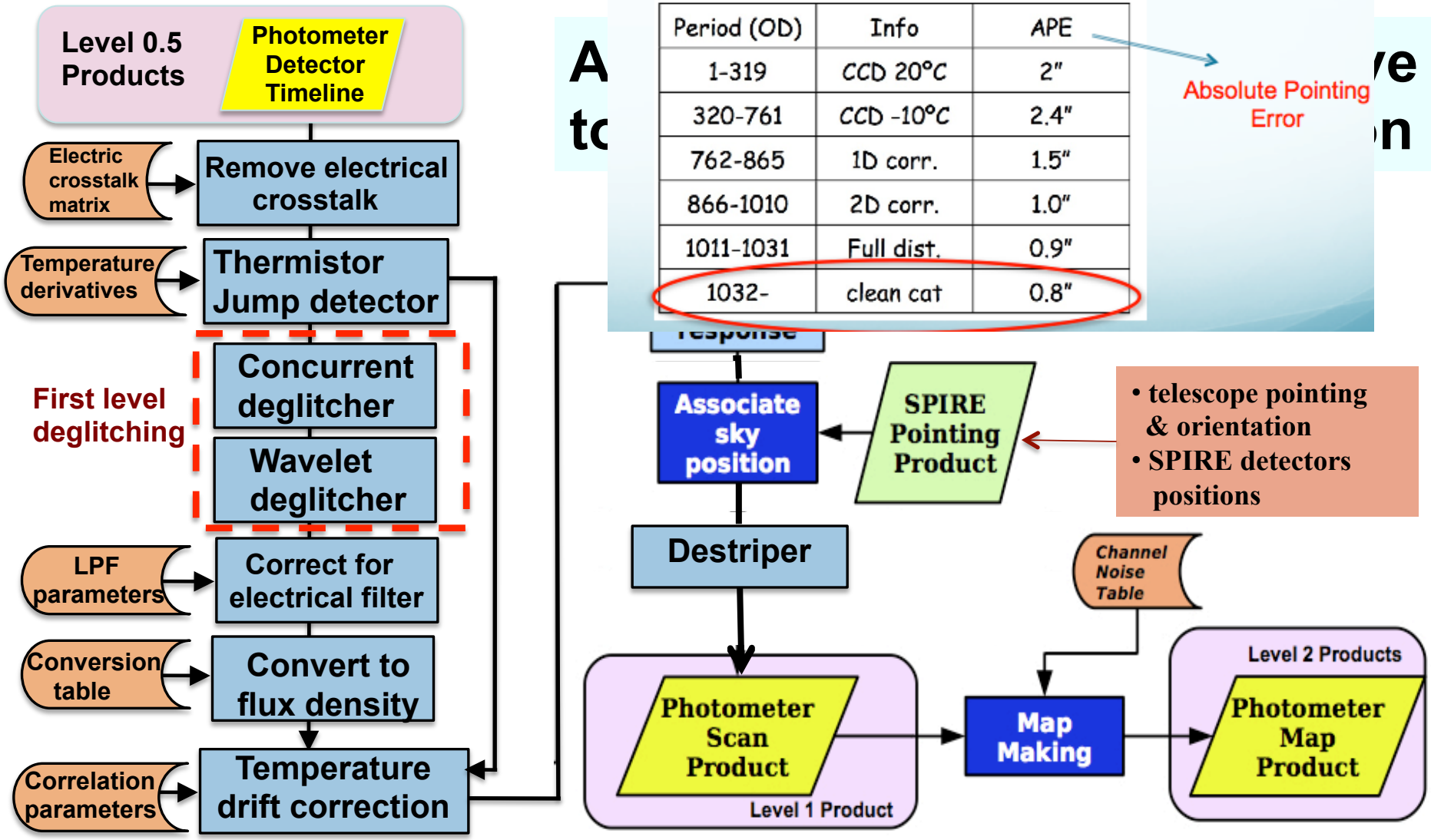
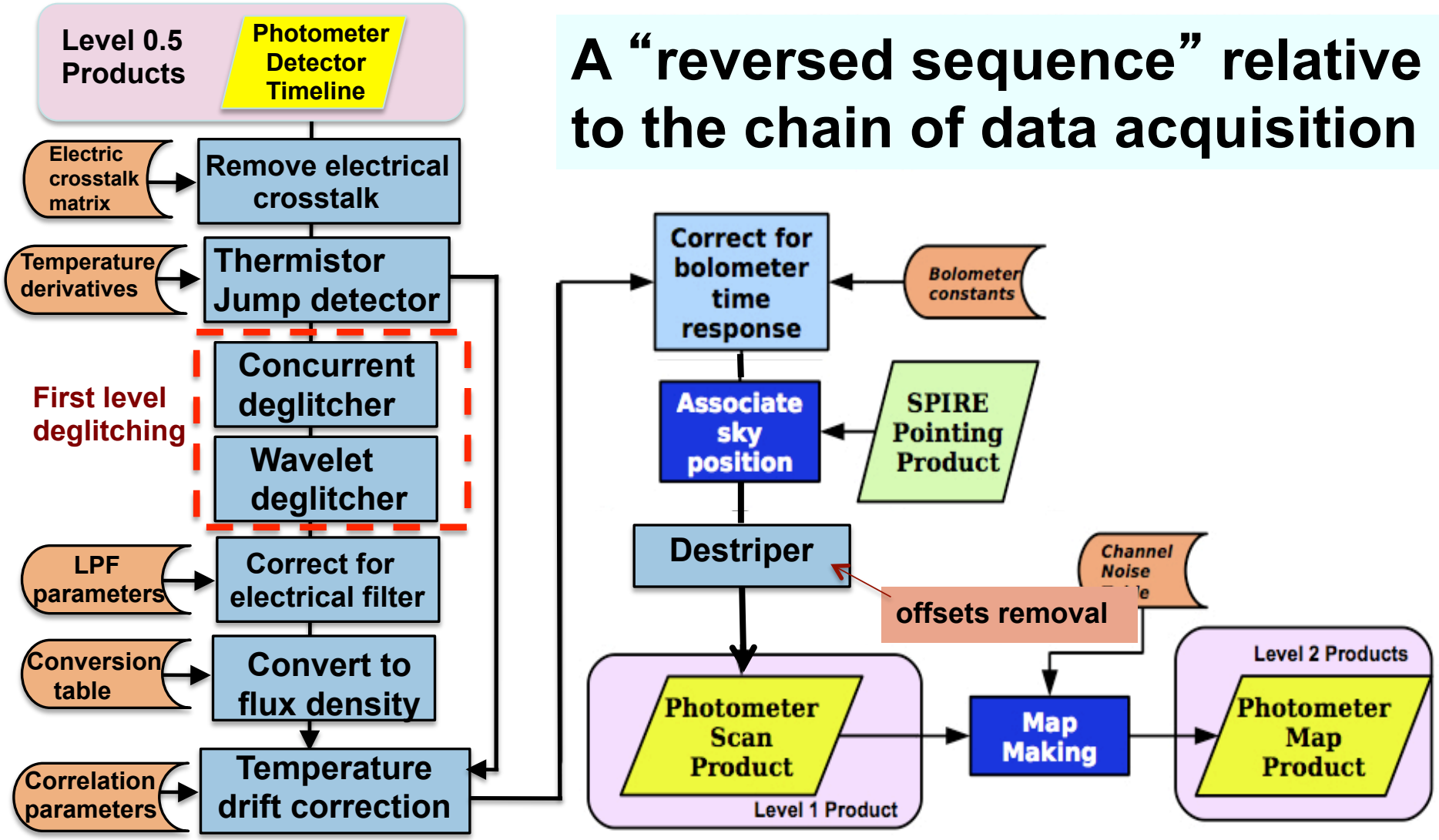


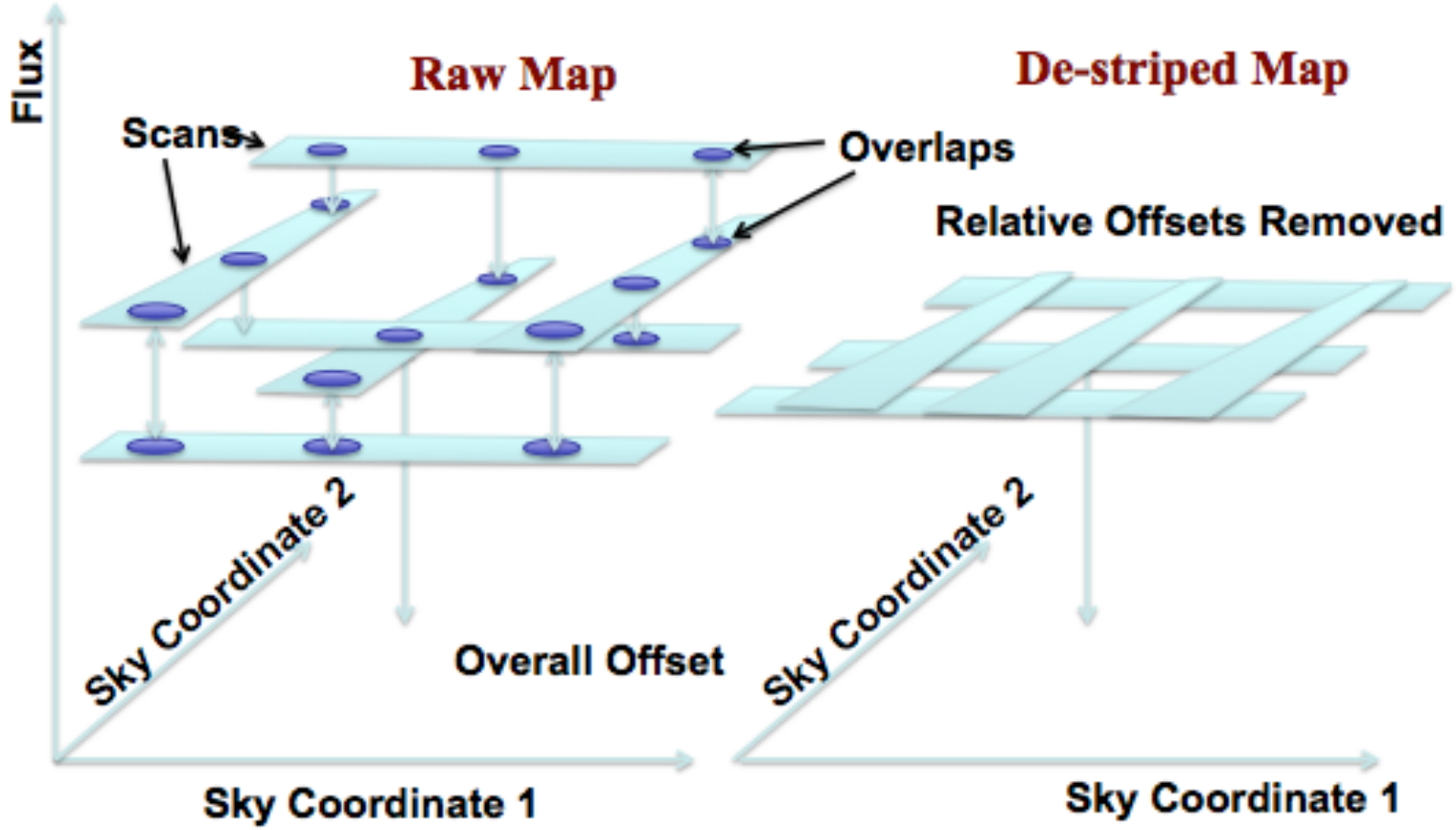
Scan Pipeline Flow Chart



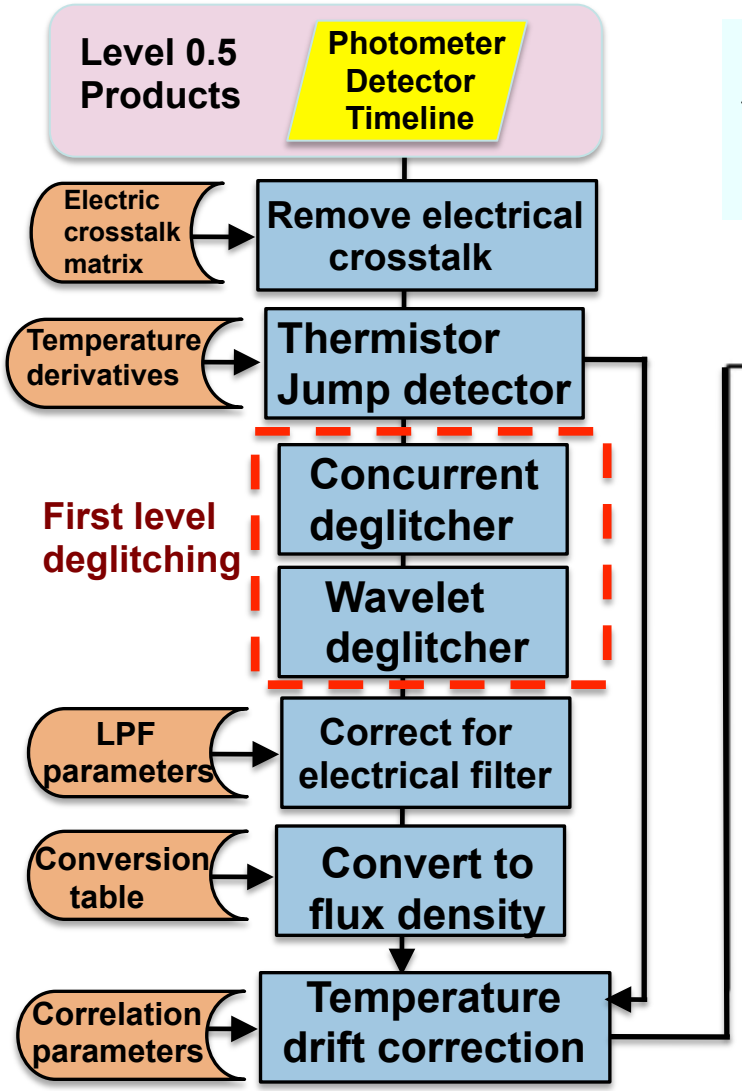
A "reversed sequence" relative to the chain of data acquisition

Destriper: Offsets Removal

Destriper: remove the relative offsets of timelines of individual bolometers by minimizing the dispersions in overlap sky pixels (using the Naïve-Mapper iteratively).



Scan Pipeline Flow Chart



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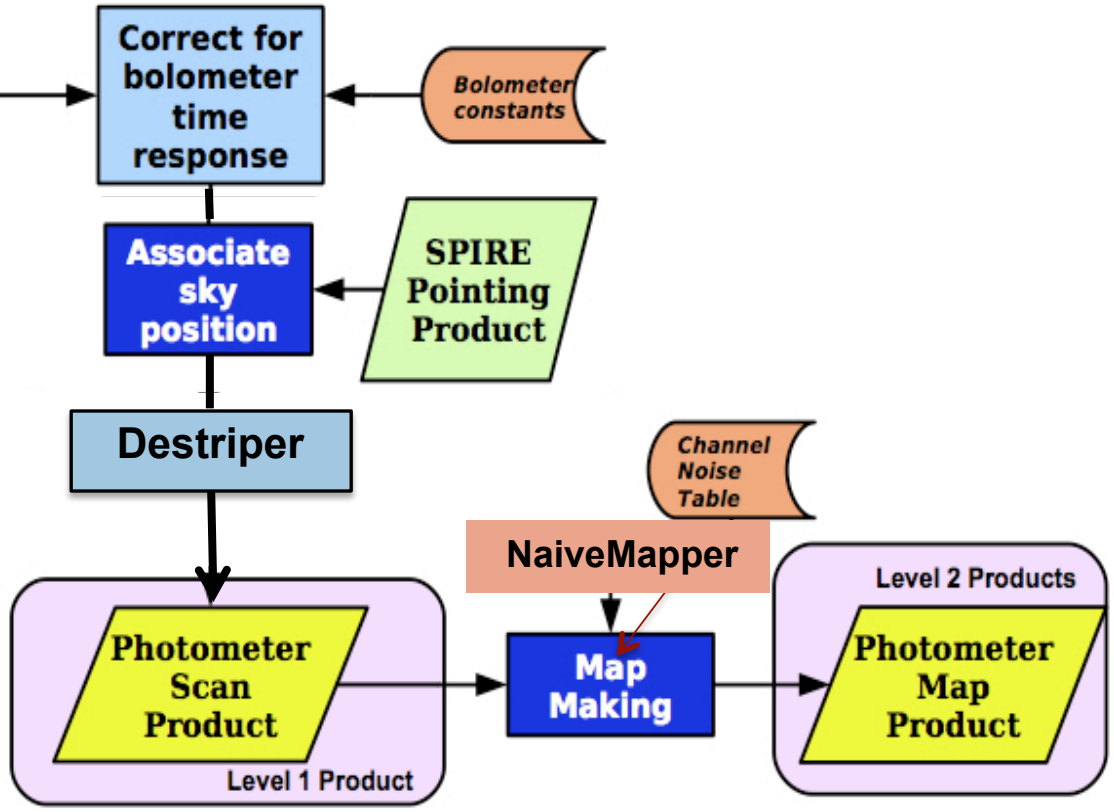
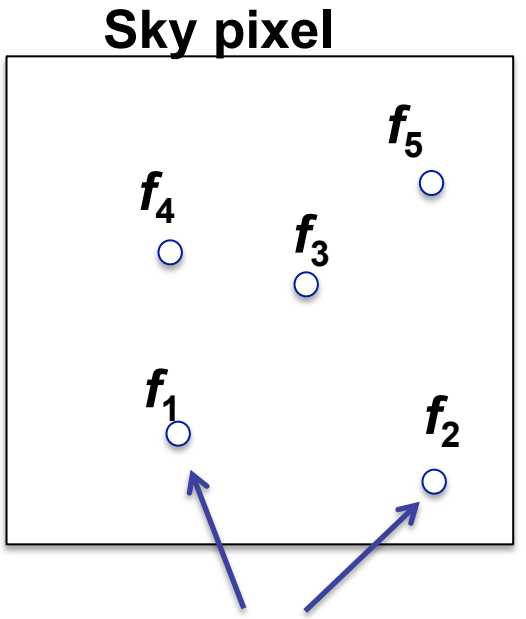


SPIRE Naïve Mapper

Two options:

(1) **No weighting** (pipeline default): Flux of a sky pixel is the **simple average** of all signal samplings (by all bolometers) in the pixel:

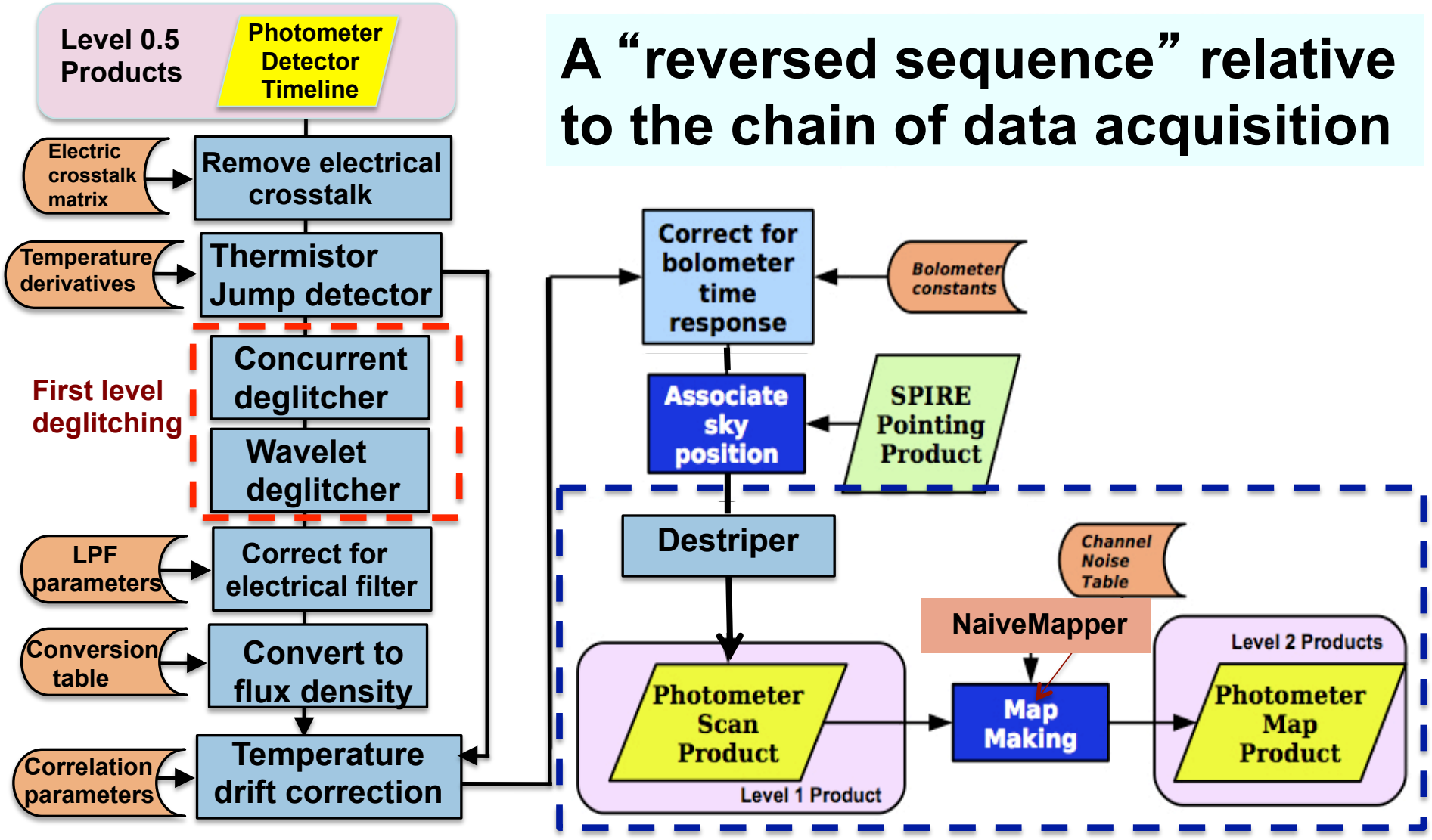
$$f_{pixel} = \frac{\sum_i^n f_i}{n}, \qquad error_{pixel} = \sqrt{\frac{\sum_i^n (f_i - f_{pixel})^2}{n(n-1)}}$$



(2) **Inverse variance (of instrument noise) weighted:** Flux of a sky pixel is the **inverse variance weighted mean** of all signal samplings in the pixel, the variance is calculated using the white noise of the bolometer with which a given sampling is taken:

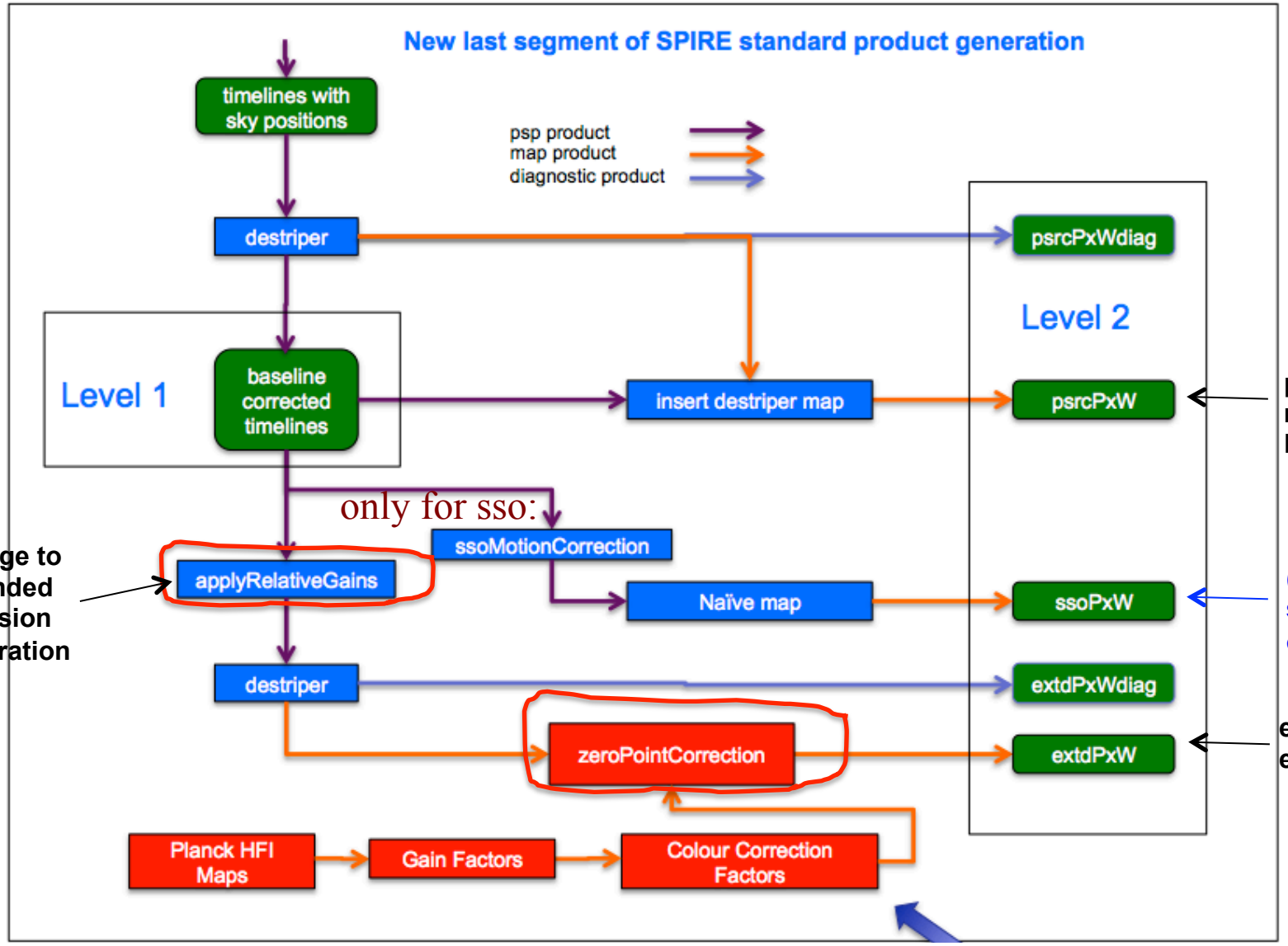
$$f_{pixel} = \frac{\sum_i^n f_i/\sigma_i^2}{\sum_i^n 1/\sigma_i^2} \qquad error_{pixel} = \sqrt{\frac{\sum_i^n (f_i - f_{pixel})^2/\sigma_i^4}{\left(\sum_i^n 1/\sigma_i^2\right)^2 - \sum_i^n 1/\sigma_i^4}}$$

Scan Pipeline Flow Chart



A "reversed sequence" relative to the chain of data acquisition

Details on Level 2 Products Generation



change to extended emission calibration

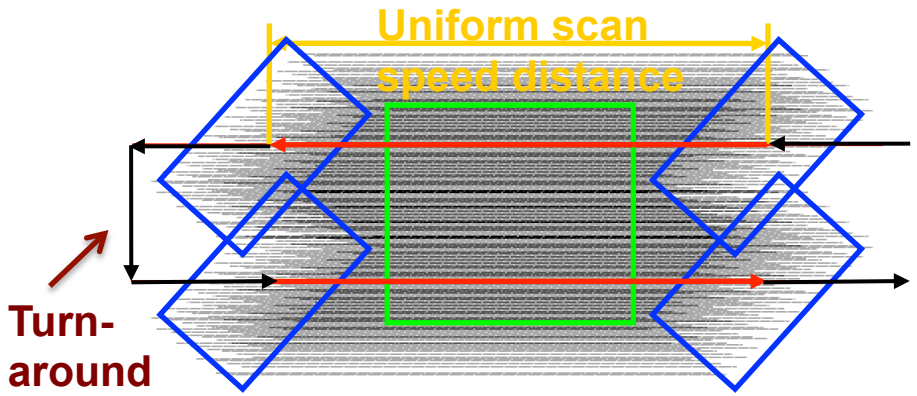
point source maps (PLW, PMW, PSW)

sso maps (only for solar system objects)

extended emission maps

Scan-By-Scan Processing

- The pipeline processes timelines scan by scan (to ease the demand on RAM).
- Problem: ringing at the two ends of each scan due to FFT based modules.
- Solution:
  (1) Before the process, attaching “turn-around” data blocks to ends of the scan.
  (2) After the process, cut-off the “turn-around” data blocks from the scan.



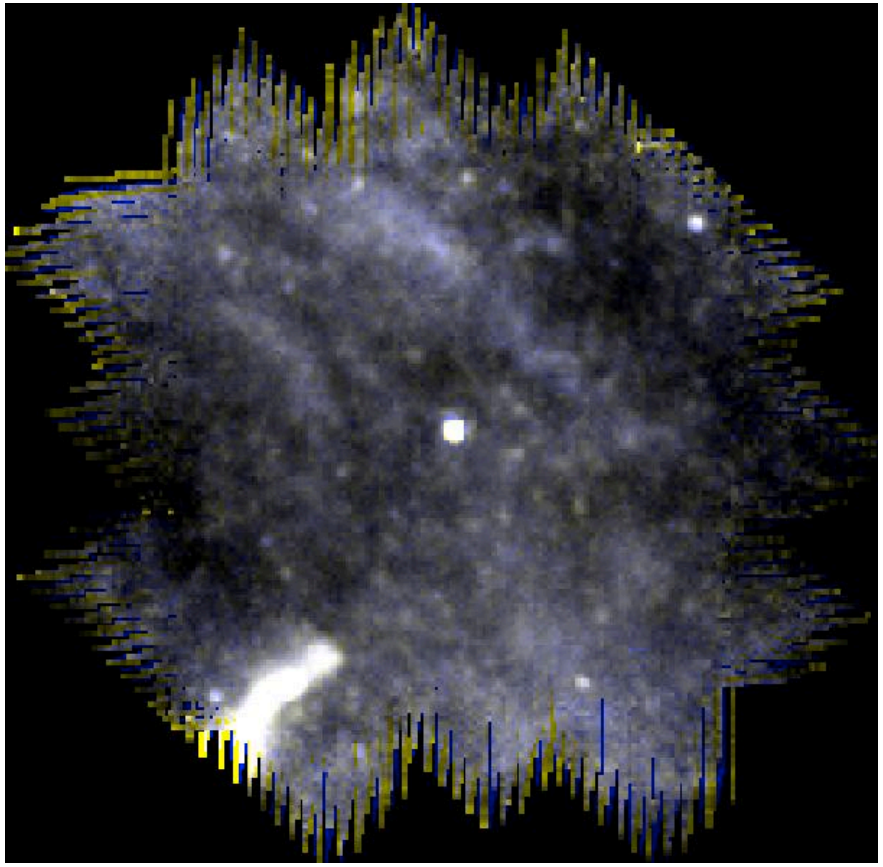
Highlights of a User Pipeline (Jython Script)

```
LEVEL 0.5
pdt=joinPhotDetTimelines(pdt,pdtLead,pdtTrail)                    Add turnarounds
nhkt=joinNhkTimelines(nhkt,nhktLead,nhktTrail)                    to Scans

bat=calcBsmAngles(nhkt,bsmPos=bsmPos)                             Pointing
spp=createSpirePointing(detAngOff=detAngOff,bat=bat,hpp=hpp, siam=siam)   information

pdt = signalJumpDetector(pdt, tempDriftCorr=tempDriftCorr,kappa = 3.0,.....)
pdt=concurrentGlitchDeglitcher(pdt,chanNum=chanNum,kappa=2.0,.....)
pdt=waveletDeglitcher(pdt, scaleMin=1.0, scaleMax=8.0, .....)
pdt=lpfResponseCorrection(pdt,lpfPar=lpfPar)                      Detector effects
pdt=photFluxConversion(pdt,fluxConv=fluxConv)
pdt=temperatureDriftCorrection(pdt,tempDriftCorr=tempDriftCorr)
pdt=bolometerResponseCorrection(pdt,chanTimeConst=chanTimeConst)

psp=associateSkyPosition(pdt,spp=spp)                             Attach Pointing

psp=cutPhotDetTimelines(psp, extend=includeTurnaround)            Detach turnarounds

psp=timeCorrelation(psp,timeCorr)                                 Correct timing
LEVEL 1
applyRelativeGains(level1.getProduct(i), gains = chanRelGains)    Extended Emission

psp=removeBaseline(psp,chanNum=chanNum)                           Baseline Removal

mapPlw=naiveScanMapper(scans, array="PLW")                        Mapping
LEVEL 2
```

Status of SPIRE Photometer Pipeline in HIPE 12.1

- General assessment
  Overall, It works very well.
  In most cases, data from HSA are already science ready!
  (No need for reprocessing.)
- The absolute calibration accuracy is ±6% (4% systematic from flux standard model, 2% RMS).
- An example (on the right):
  The image from HSA looks good.
- Known issue:
  residual stripes due to "cooler burp" (affecting a few observations)

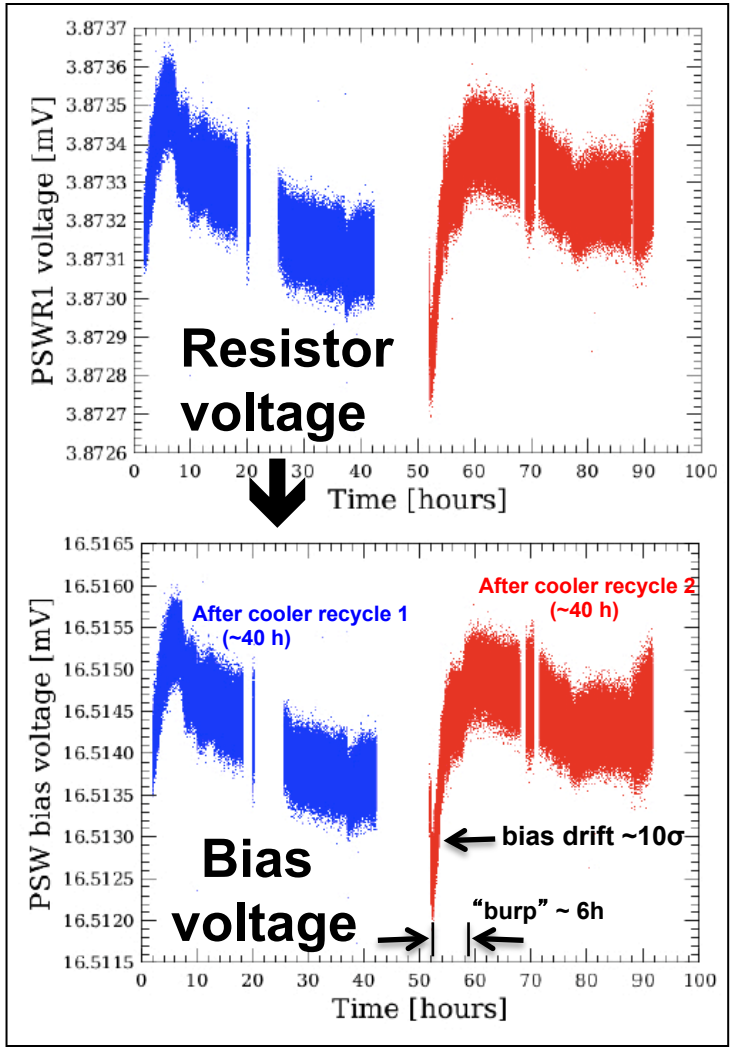
SPIRE 3-color map of NGC 5315 (a planetary nebula)



(Public data taken from HSA)

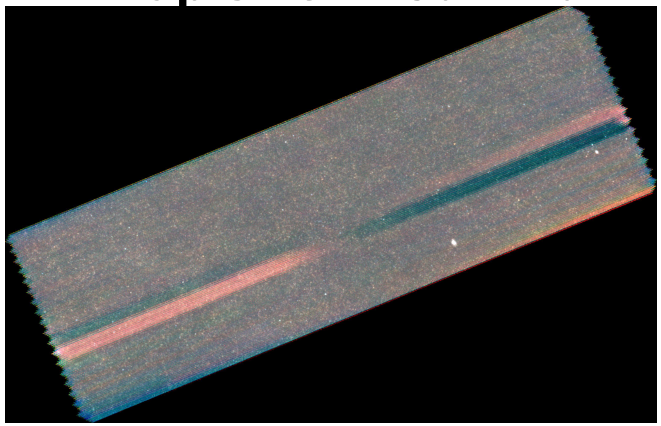
"Cooler Burp"

- Every time when SPIRE is switched on after a cooler recycle, the first ~6 h sees rapid drifts of the temperature and of the bias voltage.
- It causes abnormal drifts in detector timelines, which in turn cause stripes in maps observed during the "cooler burp" period.



Map size: ~ 8d x 2d

An example of stripes caused by cooler burp:

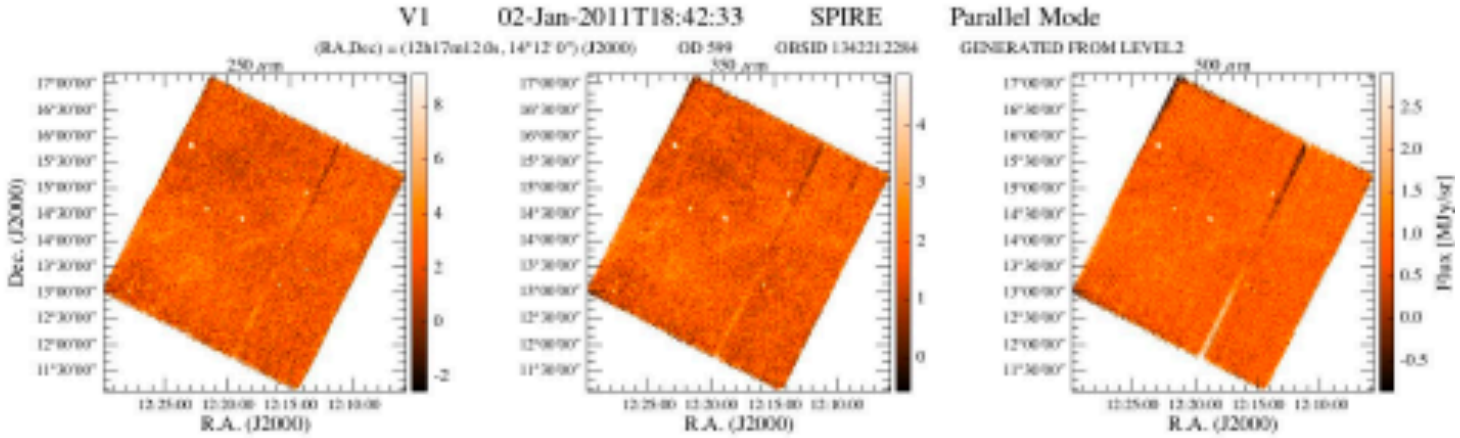


- Already corrected in the standard (SPG) pipeline (since HIPE 12), but a few affected obs still have residual stripes.

Residuals after Cooler-Burp Correction

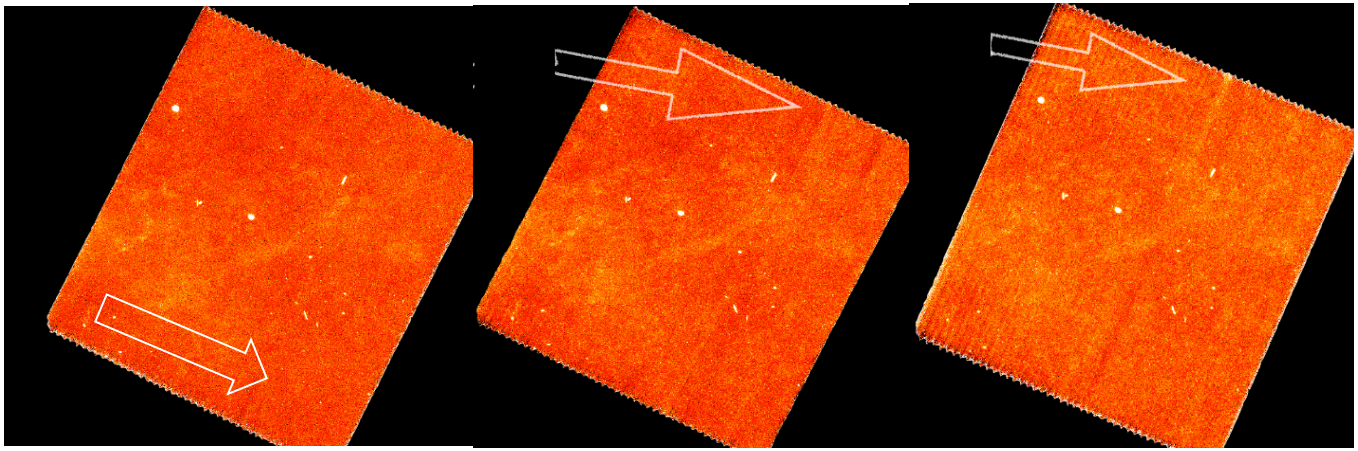
An example for results of the Cooler-Burp correction:

before correction →



PSW **PMW** **PLW**

after correction: →



residual stripes
(much fainter)

Summary

- SPIRE Photometer Scan Map Pipeline handles data in the following observational modes: Small Map, Large Map, SPIRE/PACS Parallel Mode.
- Corrections for instrumental effects (between Level 0.5 and Level 1 products) follow a "reversed sequence" relative to the chain of data acquisition.
- The map-making of SPIRE Phototmeter maps is carried out using a Destriper-NaiveMapper combination.
- The current pipeline (HIPE 12.1) does a good job ("science ready") in general.
- Known issue: residual stripes after "cooler burp" correction (affect only a few obs; will be improved in next HIPE version).