*P*hotodetector *A*rray *C*amera and *S*pectrometer: Map-Making

Babar Ali, Roberta Paladini, Dario Fadda, Steve Lord, Xiang "Cate" Liu, Jeff Jacobson

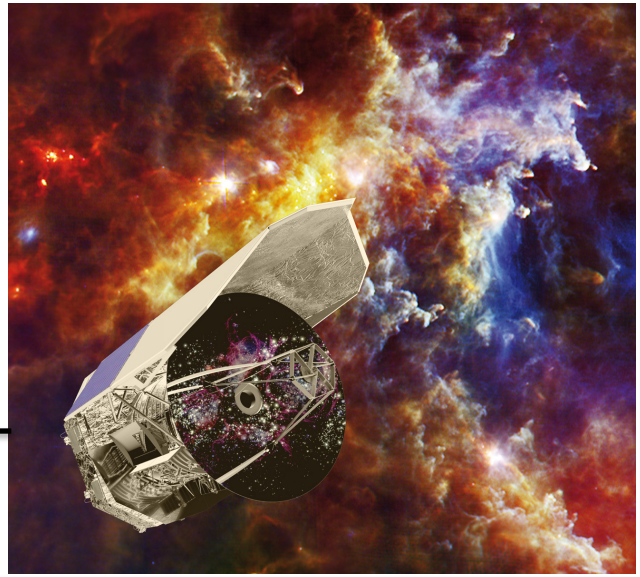
NASA Herschel Science Center

Outline

I. PACS' map-making

II. Options in HIPE
- MADmap
- JScanam

III. External Map-makers
- Scanamorphos
- Unimap
- SANEPIC (*)
- TAMASIS (*)

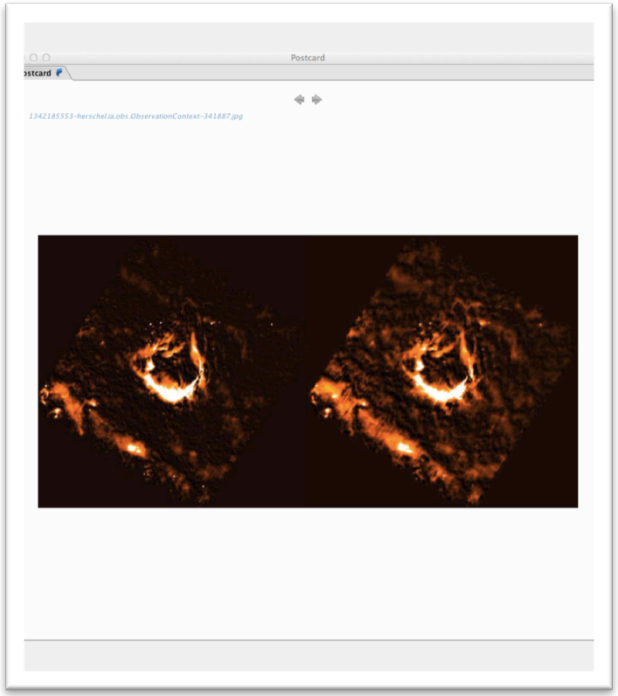


* = Not covered in this presentation

PACS map-making

For Spatially extended sources

- Level 1 products are stable and scientifically useable.
- Level 2+ products (maps) are built with a one-size-fits-all approach which may not be optimal for all science cases.
- In most cases, Level 1 to 2+ reprocessing and tweaking the processing parameters can improve the maps.
- Further, sophisticated L2+ map-makers are available outside of HIPE+HSA processing.



HSA "postcard" of RCW 120 field.

PACS' Two-Part Mapmaking

- PACS bolometer data at Level 1 contains two noise sources that require mitigation

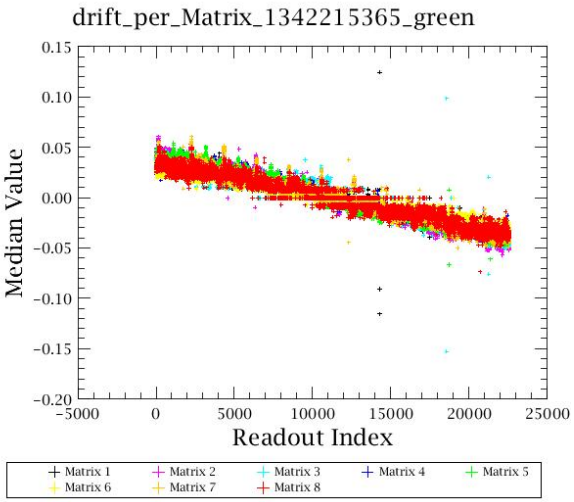
1. Spatially correlated drift in the signal.
2. Temporally correlated "1/f" drift in individual pixels.

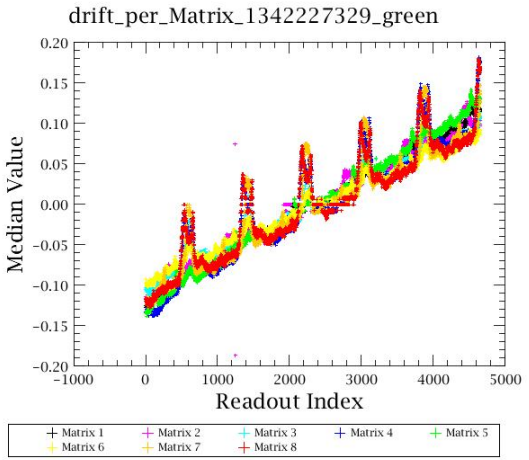
Part 1: Signal Drift

- Drift in the signal level as a function of time.
- All pixels show the same behavior suggesting a common (correlated) origin.
  - Ideas: Focal plane temperature variation, thermal relaxation, ..., ?
- Usually handled as pre-processing of Level 1 data prior to projection and map-making.

Most improvement in Level 2+ maps will come from here from better drift mitigation.

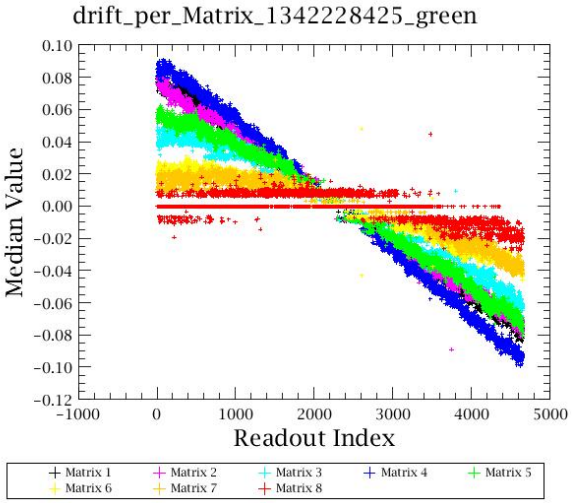
Typical.

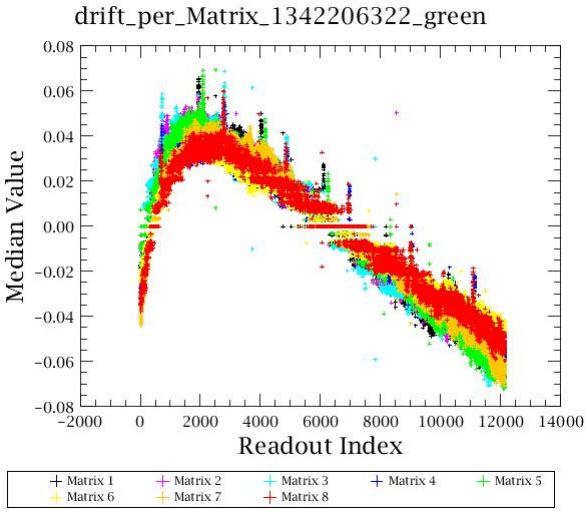




Rare.
Ascending

Strong module-to-module differences





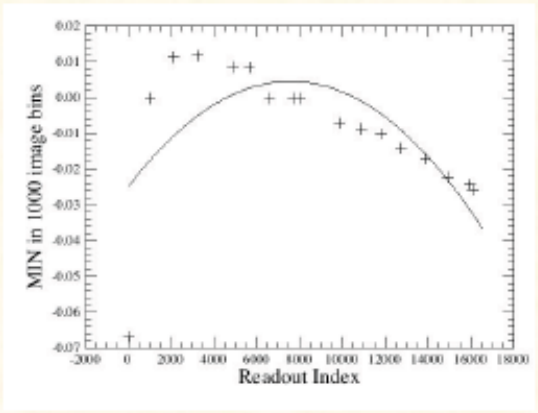
Hook

Recommendations

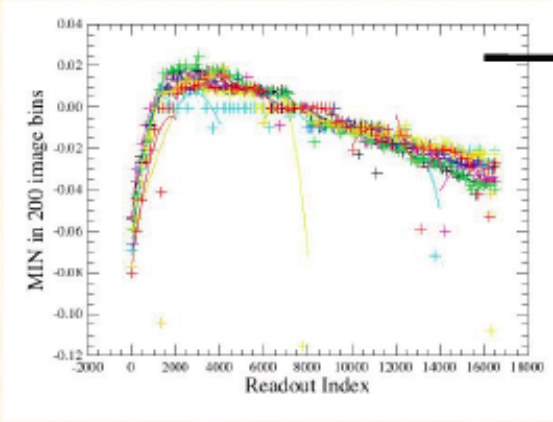
- Reprocess extended emission maps.
- The next slides shows examples of noise artifacts to look in the final maps
- However, some effects are subtle and may still be present.
- For MADmap branch, preprocessing is crucial.

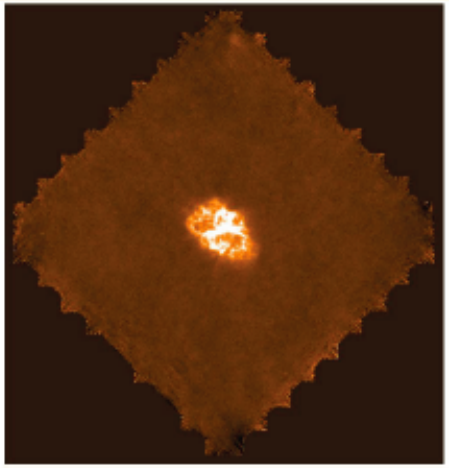
Signature of incorrect preprocessing

Bad

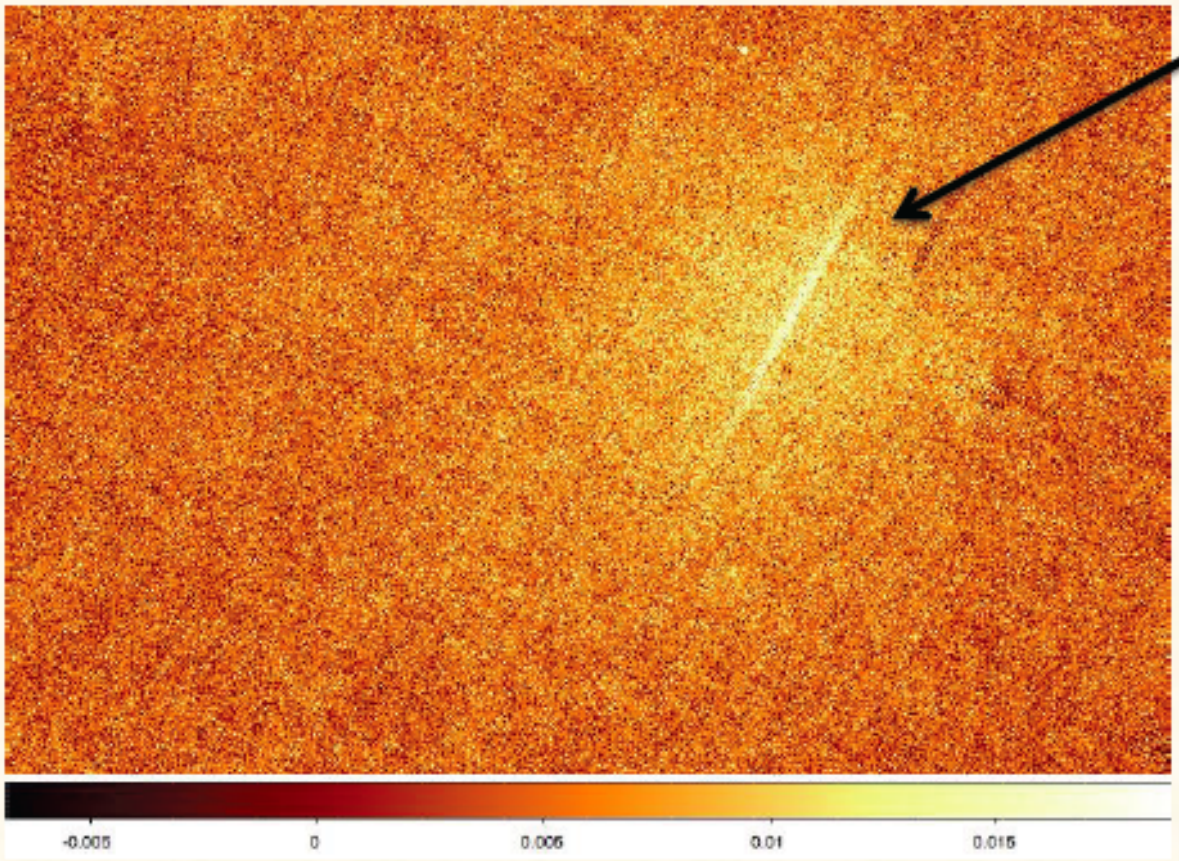


Good

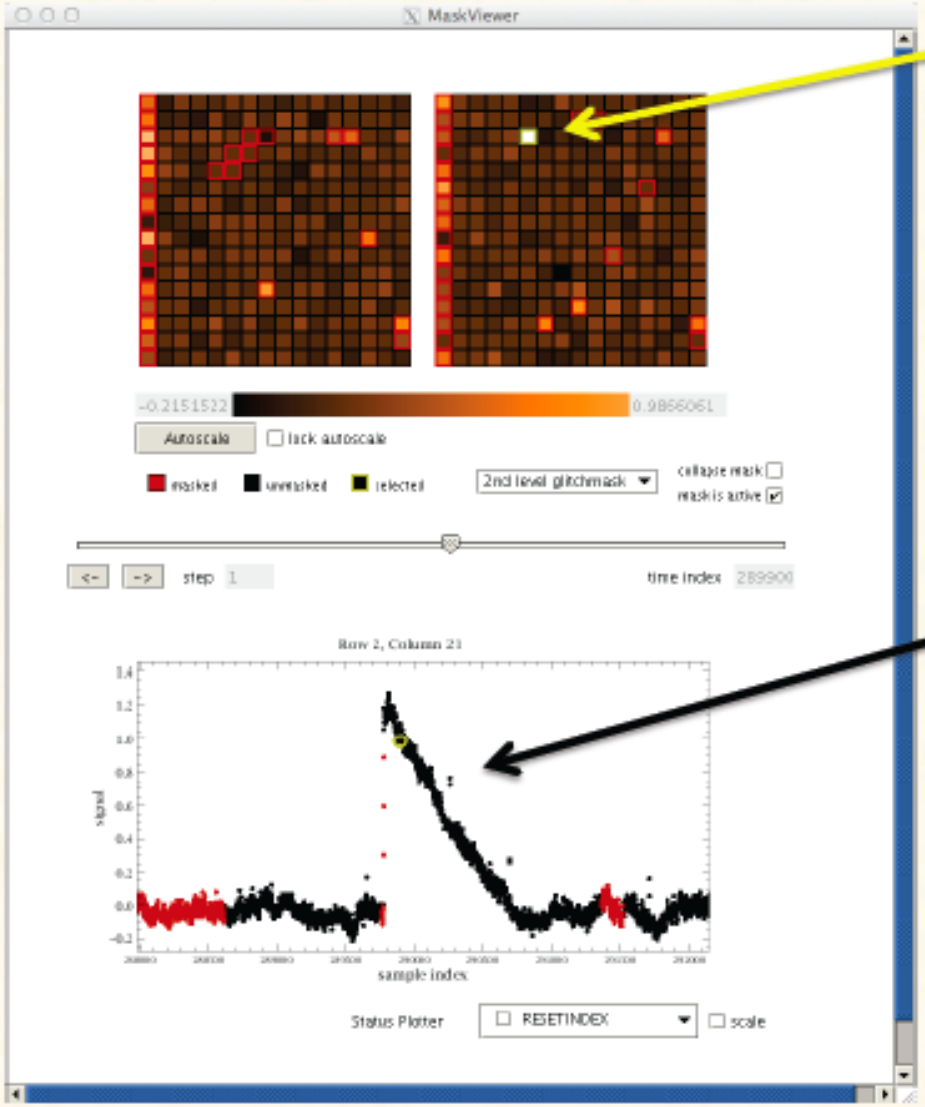




Module jump artifacts



Artifacts on projected maps are usually issues in readouts (next slide).



Example:
Single pixel that went berserk.

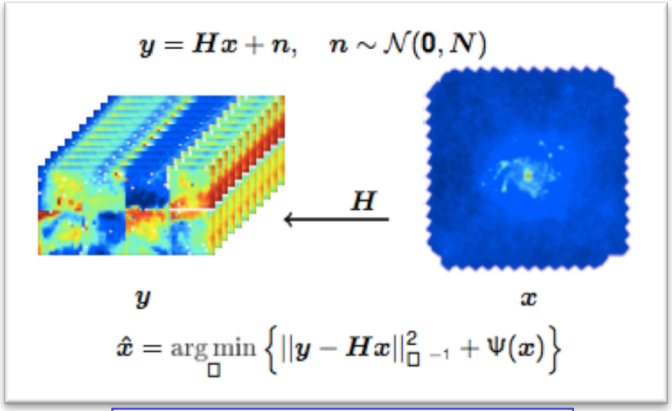
Not a single readout, but 1000s of readouts

Part 2: 1/f noise mitigation & projection

- So called 1/f noise (aka pink noise) is a well-known behavior of bolometers.
  - Originates in both electronics and bolometers.
- Various map-making approaches have been tried over decades.
- Herschel/PACS adopted some and invented new ones.

Two flavors of map-makers

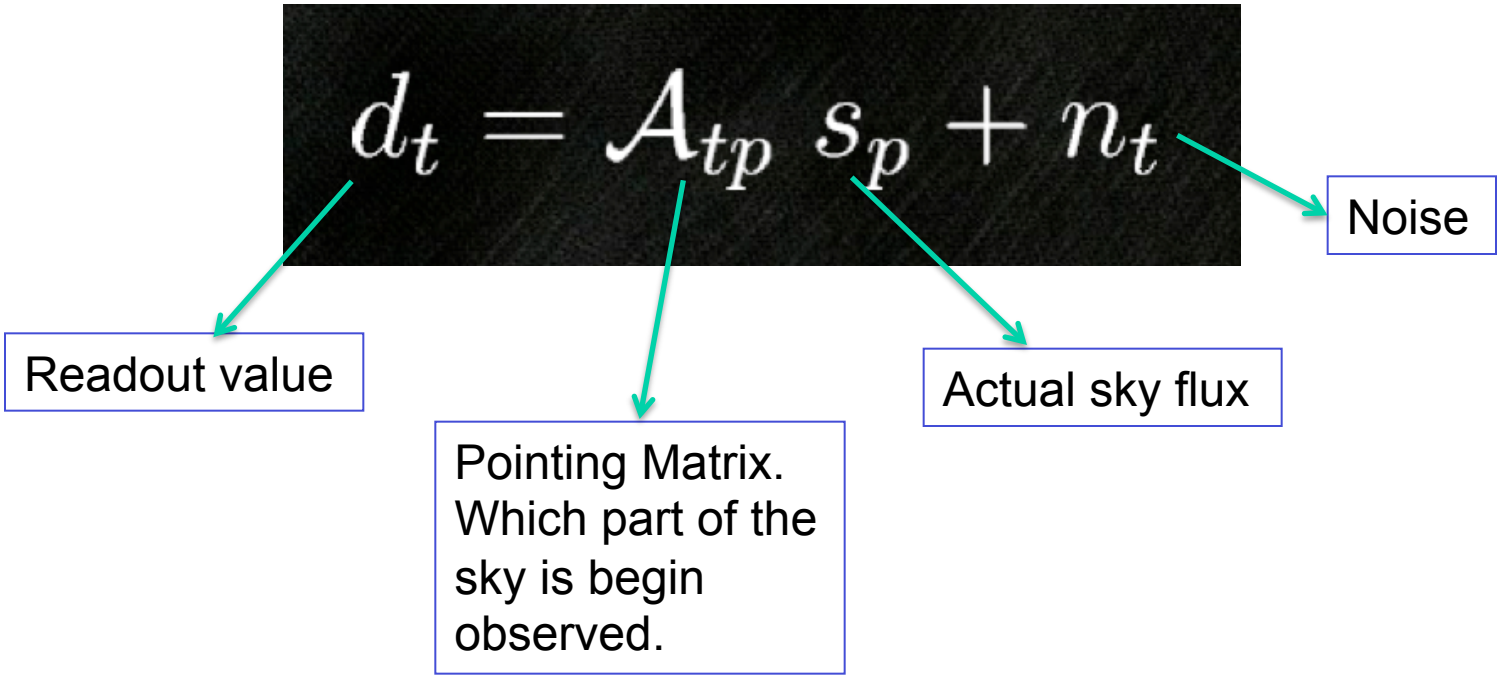
- GLS based approaches.
  - GLS = Generalized Least Square.
  - In fact, GLS+maximum likelihood.
    - MADmap (in HIPE)
    - SANEPIC
    - TAMASIS
    - Unimap
- Scanamorphos / JScanam
  - Algebraic approach which uses redundancy
    - Scanamorphos is written in IDL scripting language.
    - JScanam is port of Scanamorphos in HIPE



TAMASIS projection

GLS + maximum likelihood

- Start by defining a relationship between observed readout signals and actual flux values.



GLS + maximum likelihood

- The equation may be simple or made as complex as the map-maker desires.
- Examples of more sophisticated approaches:
  - SANEPIC: Adds spatially correlated noise
  - TAMASIS: Adds the effects of telescope motion, jitter, on-board averaging of PACS signal.
- One unique equation per readout per pixel.
- Typical observation ~ 10^5-10^7 equations.

GLS + maximum likelihood

- Simultaneously solve each of the equation with a best-fit map.
  - Use linear algebra / matrix to set up the system of equations.
  - Use probability distribution of the noise to define a maximum likelihood solution.
    - Speeds up the process.
- Results:

Naivemap. Simple average of all overlapping readouts on a given part of the sky.

Optimalmap. The best-fit solution.

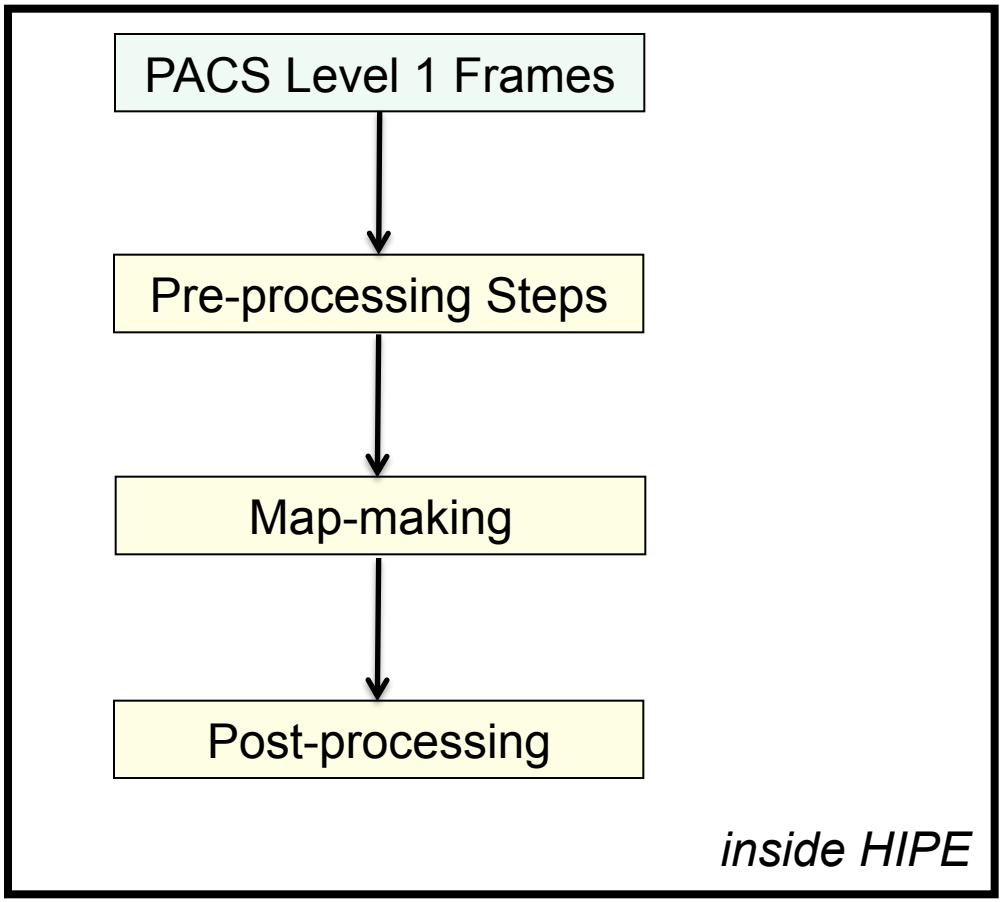
GLS based mappers

MADmap

- Available in HIPE itself.
- Based on code developed by Berkeley CMB group to remove 1/f noise from bolometer.
- Significant addition in PACS to mitigate the signal drift (not in the original code).
- Most interactive re-processing in MADmap deals with the pre-processing …

  … not the 1/f removal and projection.

MADmap work flow



MADmap Demo

Documentation Reference

PACS data reduction guide, Chapter 9
NHSC Tutorials
    https://nhscsci.ipac.caltech.edu/sc/index.php/Pacs/DataProcessing
    PACS-401: MADmap map-making
HIPE Academy Video Tutorials
    http://www.youtube.com/hipeacademy/

NON-GLS based mappers

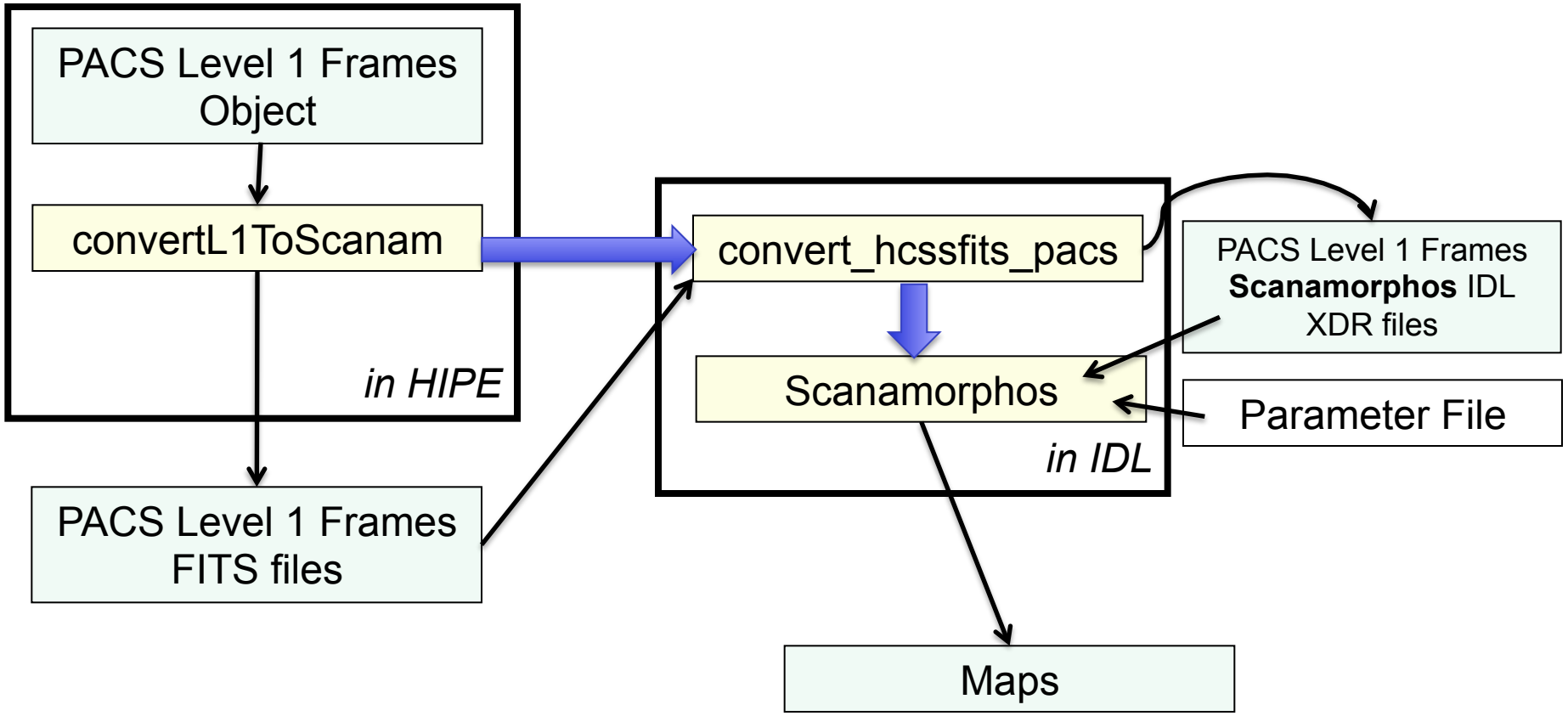
Scanamorphos

***Scanamorphos* is an IDL software to build maps from scan observations made with bolometer arrays**, in particular with the PACS and SPIRE photometers onboard the *Herschel* space telescope (wavelength range of operation: 70 to 500 μm). The prototype software has been developed on SPIRE simulated data and on real data from *P-Artemis*, an instrument of the same design as one of the PACS subarrays, but operating on the ground (mounted on APEX). After the launch and performance verification of Herschel, it has been extensively tested on both SPIRE and PACS flight data.

Description from the Scanamorphos website

- IDL-based standalone package
- Widely used for PACS map-making
- Can handle single scan data

Scanamorphos work flow



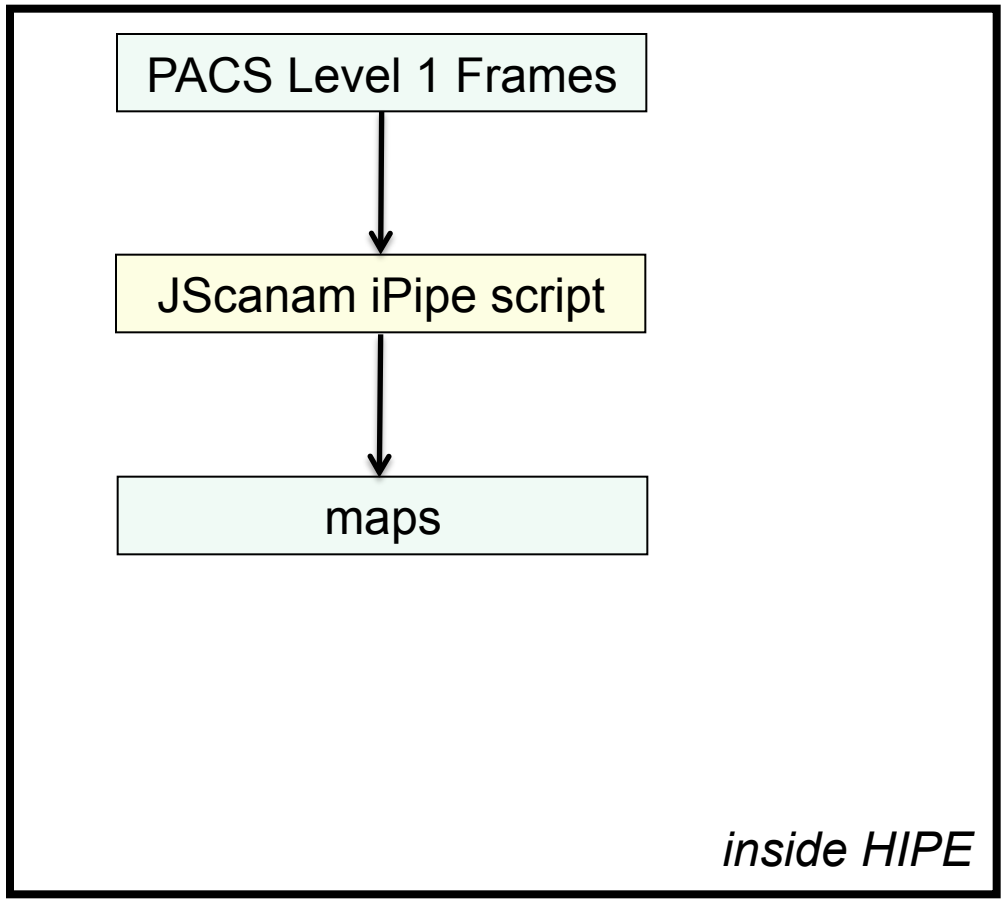
Scanamorphos Demo

Documentation Reference

Website

http://www2.iap.fr/users/roussel/herschel/

JScanam Workflow



JScanam Demo

Documentation Reference

Website

http://www2.iap.fr/users/roussel/herschel/

NON-GLS based mappers

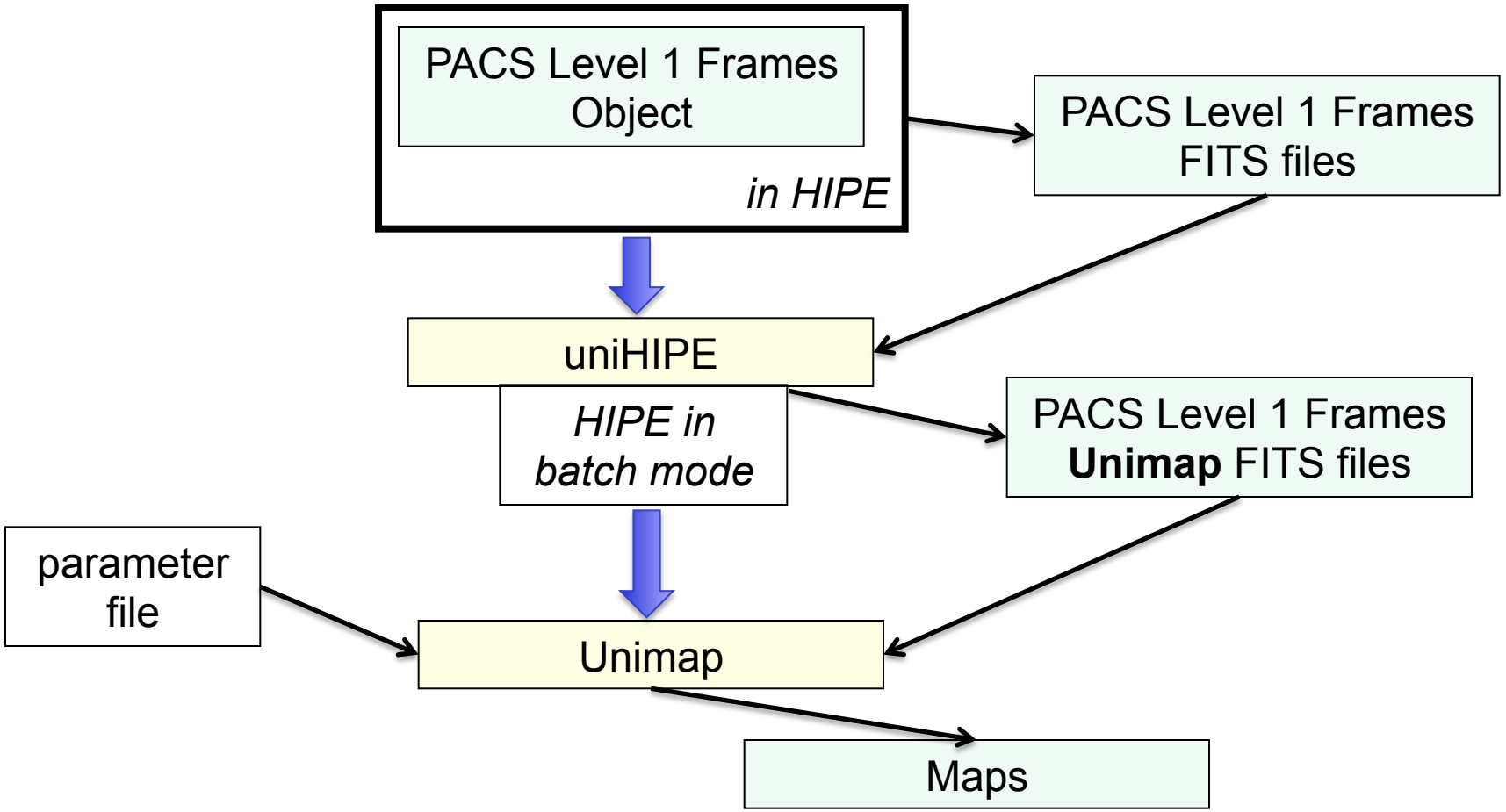
Outside HIPE

Unimap

- General purpose map-maker: Not just for Herschel.
- Successor of ROMAGAL package, written in MATPLOT
- Primary developer:

  Lorenzo Piazzo, DIET-University of Rome

Unimap work flow



Unimap Demo

Documentation Reference

Unimap websites

http://w3.uniroma1.it/unimap/

http://herschel.asdc.asi.it/index.php?page=unimap.html

NHSC Tutorials

https://nhscsci.ipac.caltech.edu/sc/index.php/Mapping/UnimapTutorial