# On-the-fly data processing with Scanamorphos: application to ArTéMiS

software initially developed to make maps from *Herschel* PACS & SPIRE scans
now tailored to ground-based/balloon-borne instruments (ArTéMiS, NIKA2, PILOT)

main task: subtraction of the low-frequency noise
implemented principle: maximal use of the redundancy in the data (no filtering)

low-frequency noise: both **correlated drifts** and **flicker noise**

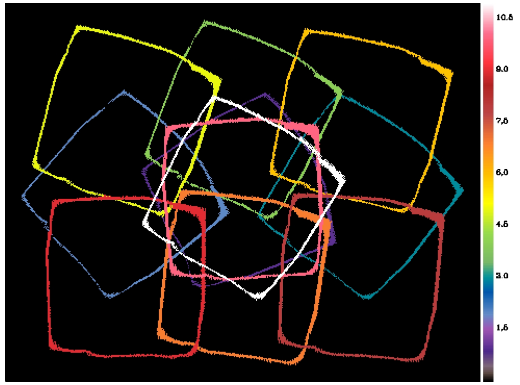
thermal fluctuations for *Herschel*

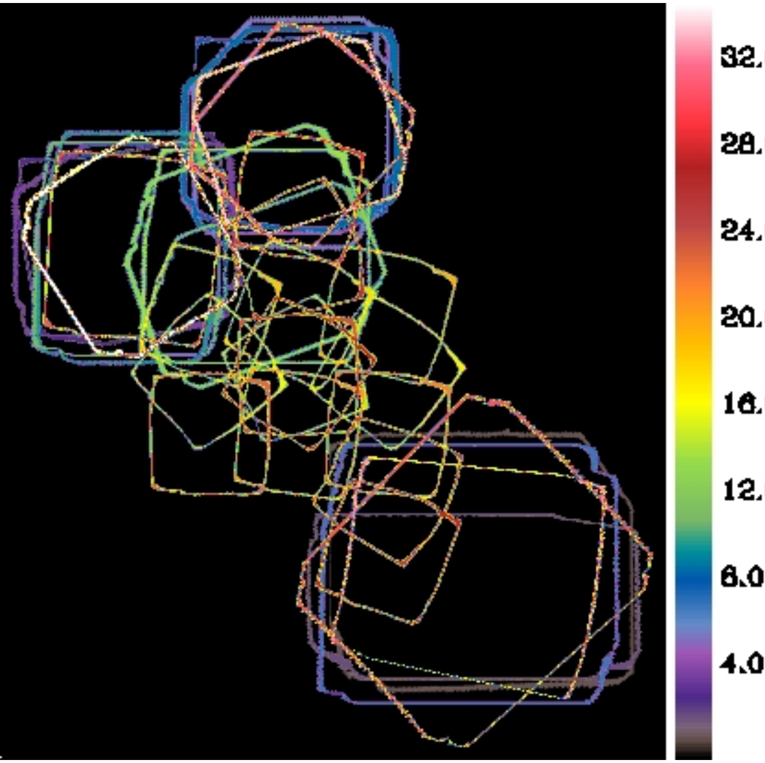
**mainly the atmosphere for ground-based instruments**

algorithm for *Herschel* described in [Roussel 2013, PASP 125, 1126]
updates and user guide for ArTémiS: [https://arxiv.org/abs/1803.04264]

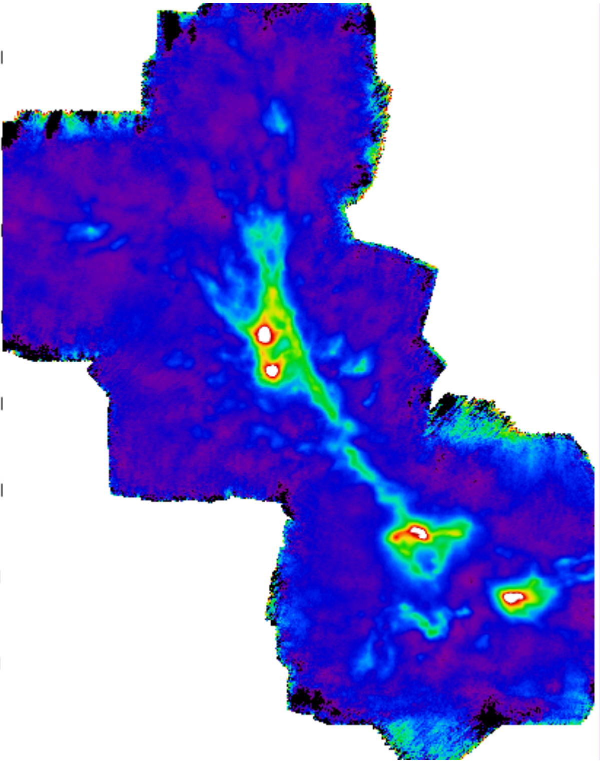
Scan geometry is crucial to obtain optimal results:

– adjust the scan length to the angular scales
on which recovery of extended emission is needed

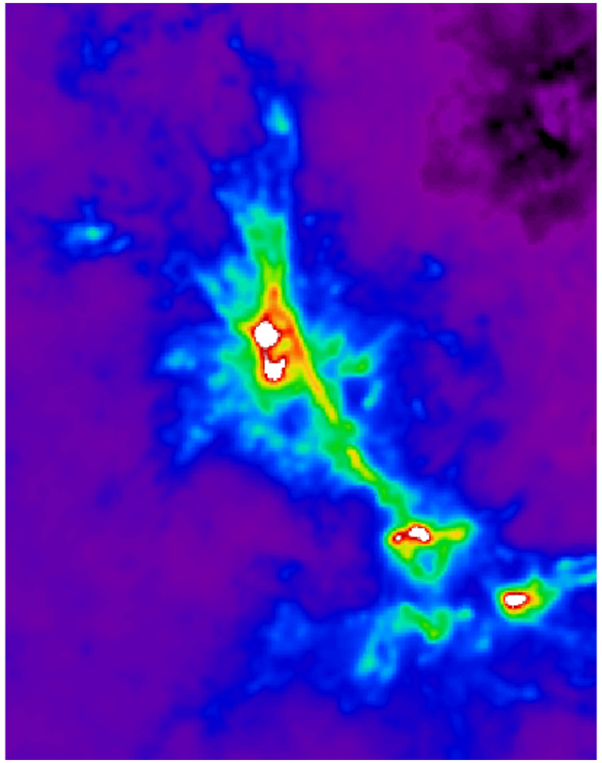




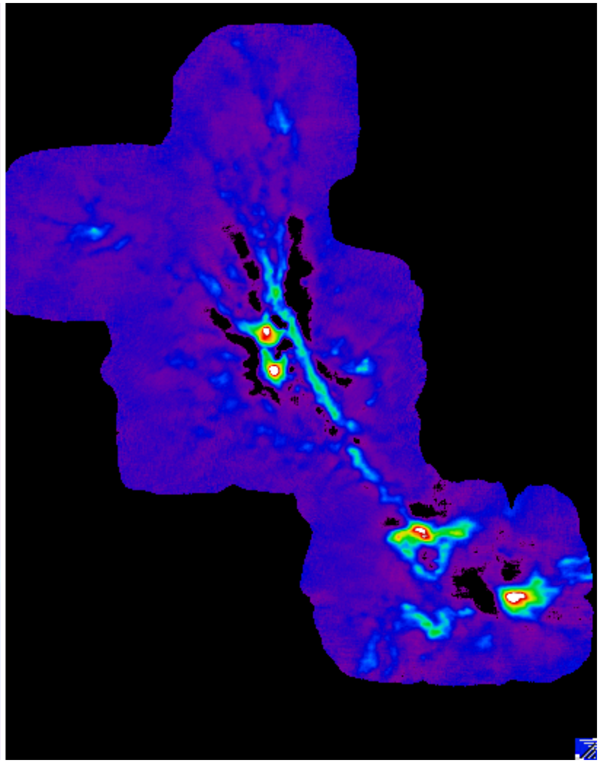
scan outlines
for N6334 350 $\mu$m mosaic



ArTéMiS (Scanamorphos)



SPIRE



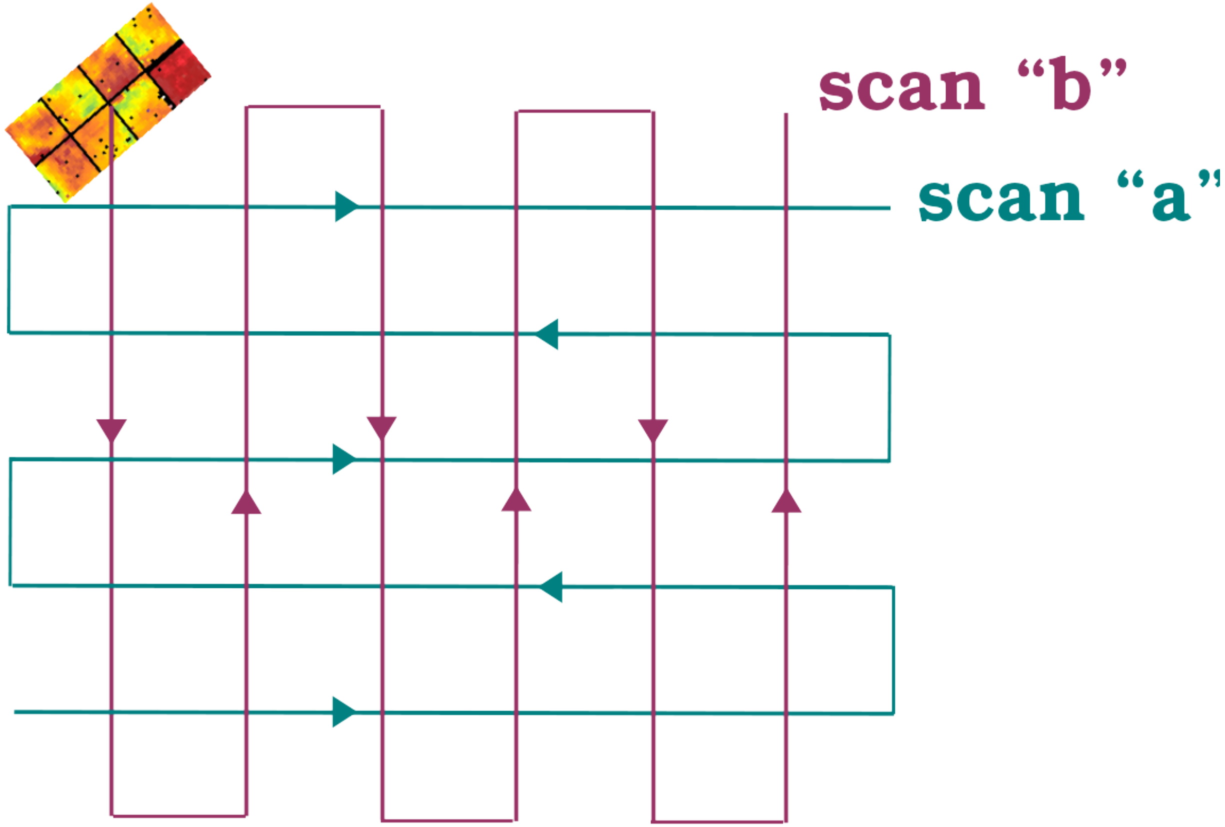
ArTéMiS (pipeline default)

Scan geometry is crucial to obtain optimal results:

– adjust the scan length to the angular scales on which recovery of extended emission is needed

– cover each region of interest with 2 well distinct scan directions (ideally orthogonal scans)

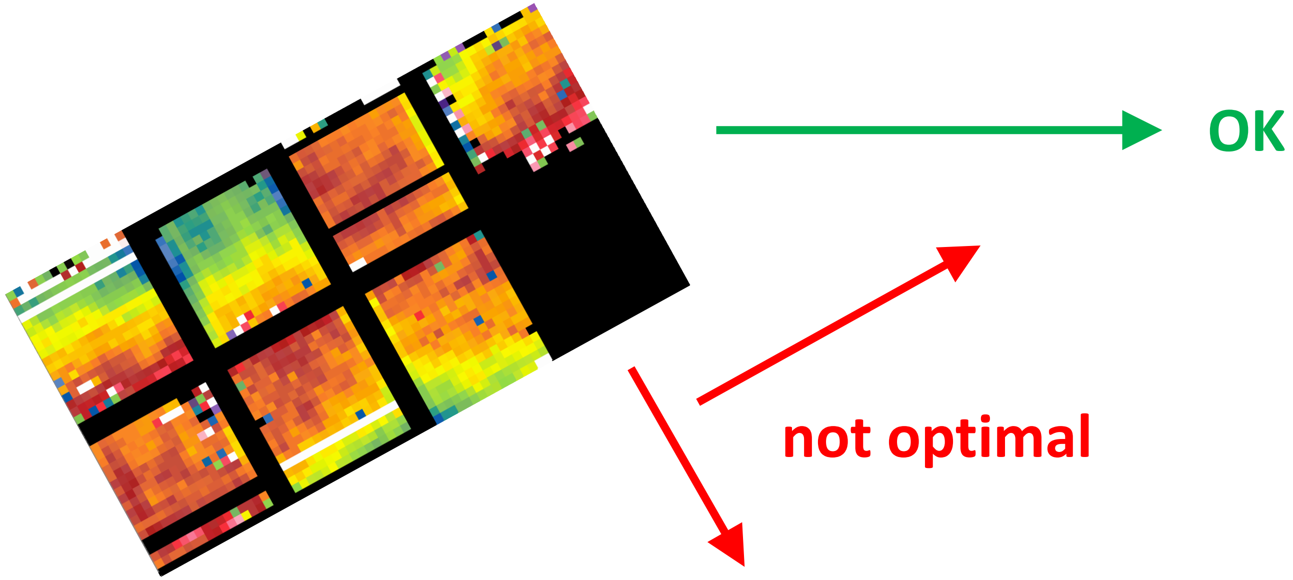
otherwise: not enough information to disentangle drifts from signal



Scan geometry is crucial to obtain optimal results:

– adjust the scan length to the angular scales on which recovery of extended emission is needed
– cover each region of interest with 2 well distinct scan directions (ideally orthogonal scans)

– avoid scanning parallel to the array axes



OK

not optimal

Drifts are additive $\Rightarrow$ all multiplicative effects (flatfield, opacity correction) must be corrected beforehand.

recorded signal R = time-invariant sky emission S
+ atmosphere + instrumental drifts D (low-f noise)
+ white noise + glitches HF (high-f noise)

$$\mathbf{R(t, b) = S(p) + D_{aver}(t) + D_{indiv}(t, b) + HF(t, b)}$$

variables: time t, bolometer b, sky pixel p

definition of a **stability length $l_s$**

within $l_s$ , S is considered uniform and D stable (rejection of compact sources / glitches)

chosen to contain ~ 7 samples per crossing for simple statistics

for ArTéMiS: on the order of 0.5 FWHM (depends on scan speed and sampling rate)

iterative process to subtract the drifts
exploitation of all the available redundancy ⇒ { large memory requirement
$t_{proc} \sim 2 \times t_{obs}$ (on-target)

- first step: **baseline subtraction** (linear fits to signal on whole scan legs)
  ⇒ removal of drifts and sky gradients on scales larger than scan legs
  uses a **fully-automatic source mask** if the `/galactic` option is set

- second step: subtraction of the average drift on small timescales

  $$\boldsymbol{\Delta(t_1, t_2) = R(t_1, b_i) - R(t_2, b_j)}$$
  $$= S(p) - S(p) + D_{aver}(t_1) - D_{aver}(t_2) + (D_{indiv}+HF)(t_1, b_i) - (D_{indiv}+HF)(t_2, b_j)$$

  **coaddition over $(p, b_i, b_j)$** → $\boldsymbol{D_{aver}(t_1) - D_{aver}(t_2)}$ + mean of uncorrelated terms

- third step: subtraction of the **individual drifts** on successively smaller timescales
  (timescale decreased by a factor 3 each time)

usage for ArTéMiS:

1) within the pipeline (APIS): apply flux calibration and opacity correction
2) format the data for input to `scanam_artemis` (interface provided with the code)
3) process the data
4) optionally make maps within the pipeline

output:
- maps assembled in a cube (signal, error, weight, subtracted drifts)
- processed data reinjected into pipeline structures

`scanam_artemis` available on: [www2.iap.fr/users/roussel/artemis](www2.iap.fr/users/roussel/artemis)
as well as the user guide with illustrations (N6334 mosaic)

THANKS TO THE ORGANIZERS !

TRAVEL GRANT FROM RADIONET

# Scanamorphos for ArTéMiS:
# step by step on an example

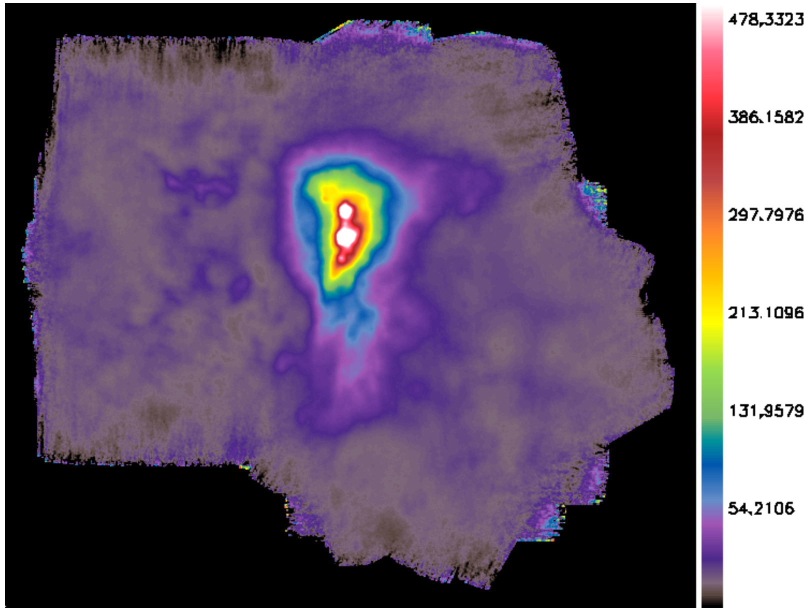
to speed up the processing:

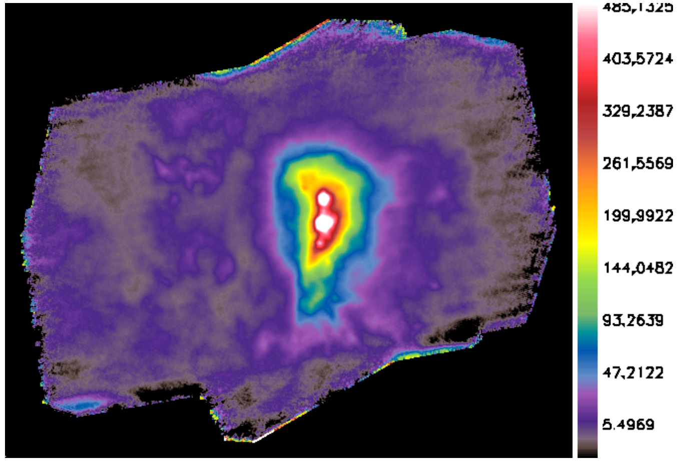
demo on a set of 2 central scans on a very bright target: Sgr B2

for demo purposes only !

data already calibrated (cf tutorials by F. Schuller and P. André)

map
composed
of 7 scans





map you will
obtain
(hopefully !)

scans 23904 and 32910 taken in 2016

## interface pipeline → Scanamorphos and formatting of input data

make sure that obs1_artemis_config.pro contains the relevant info:

```
   project_name = ’E-097.C-0184-2016’
   calibration_table = ’calibration_table_350_2016’
```

```
IDL > dir_out = …
```

directory where input structures, temporary files and output cube will be written

```
IDL > list = [23904, 32910]
```

```
IDL > format_input_scanam_artemis, dir_out=dir_out, list_scannum=list
```

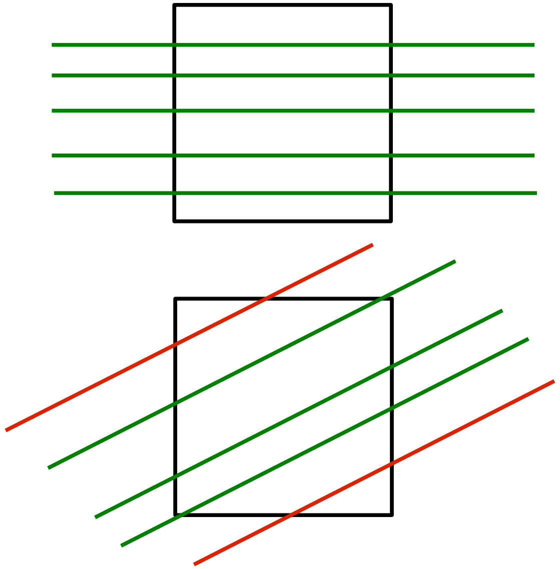
( `array=350` not necessary, since this is the default)

→ creation of the `scanlist_artemis` ascii file and the input structures in dir_out

# interactive processing

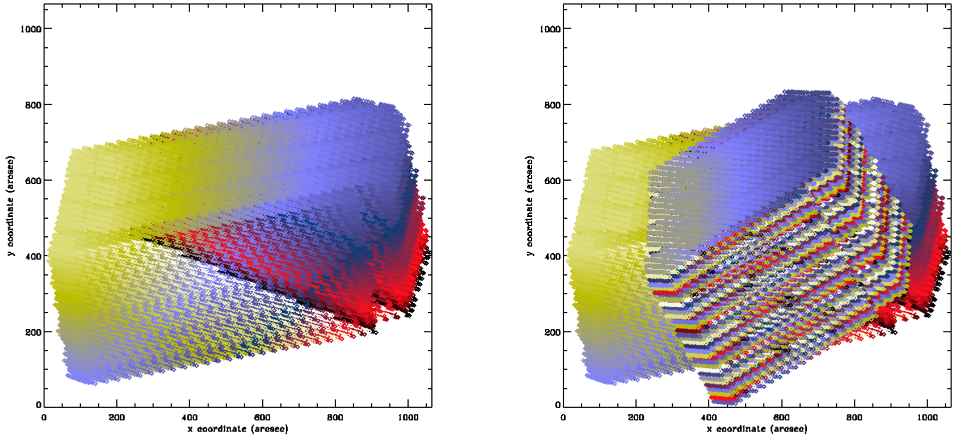
```
IDL > scanam_artemis, /galactic, /visu, /vis_traject, dir_scanlist=dir_out
```

1) data ingestion and determination of astrometric frame

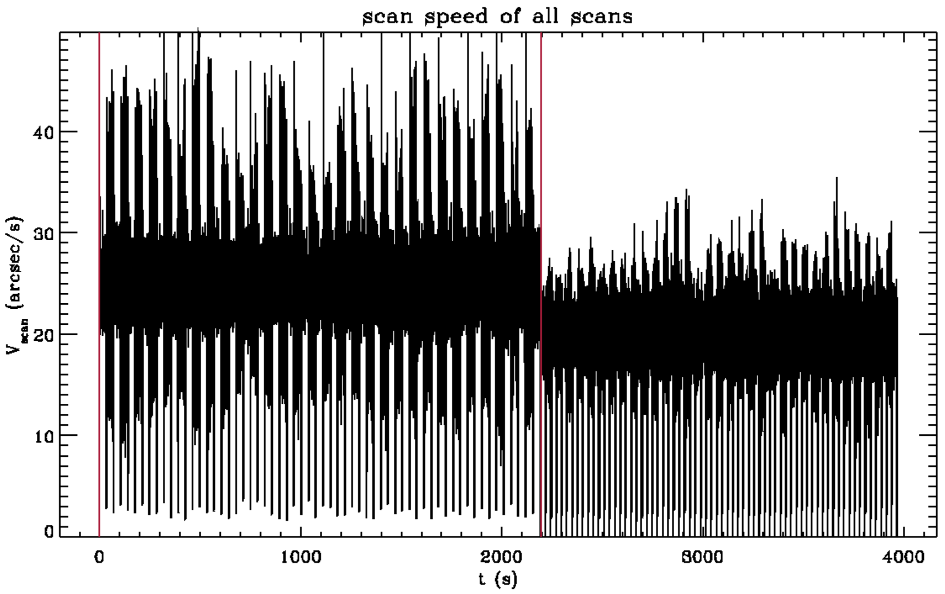


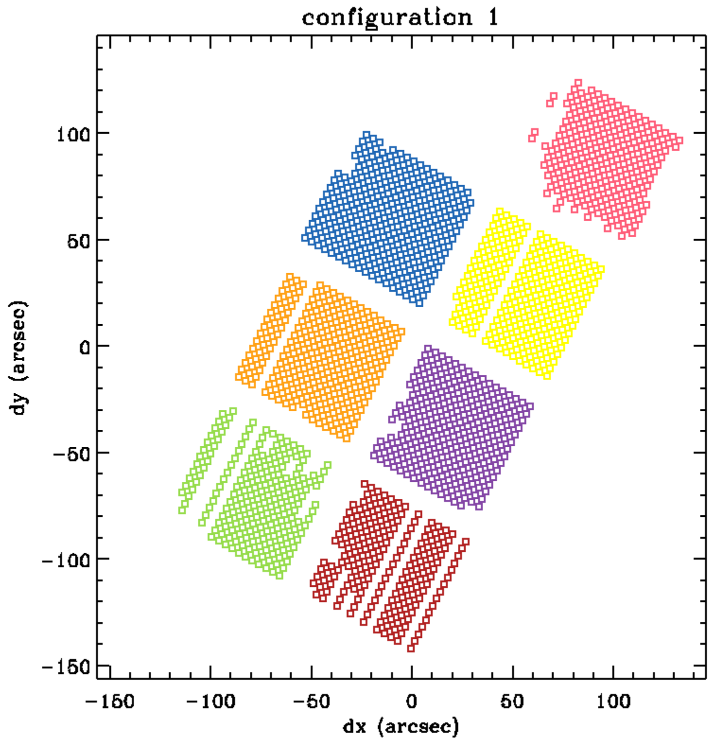
if possible: for the processing, use the orientation that maximizes the number of samples within a pixel of size $l_s$ for most scan legs

`/vis_traject` option: visualization of OTF array trajectories

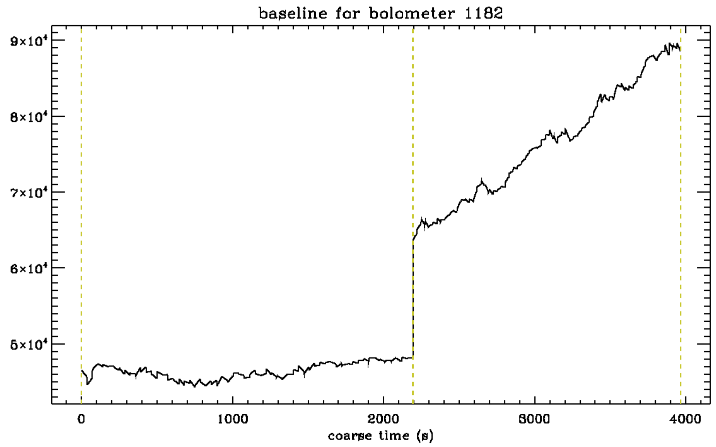


# information about scan speed and array geometry:



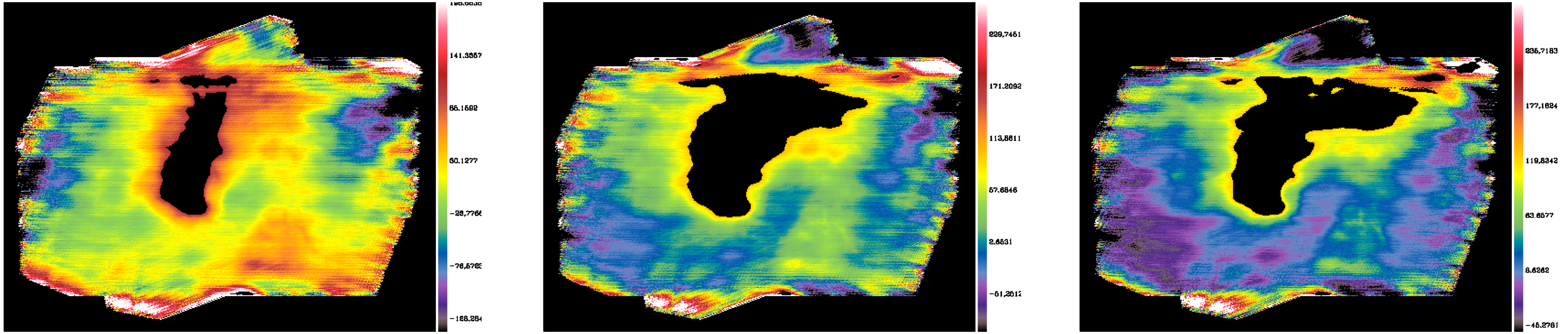


2) computation of high-frequency noise (white noise)
for weighting and noise thresholds
(updated several times during the processing)

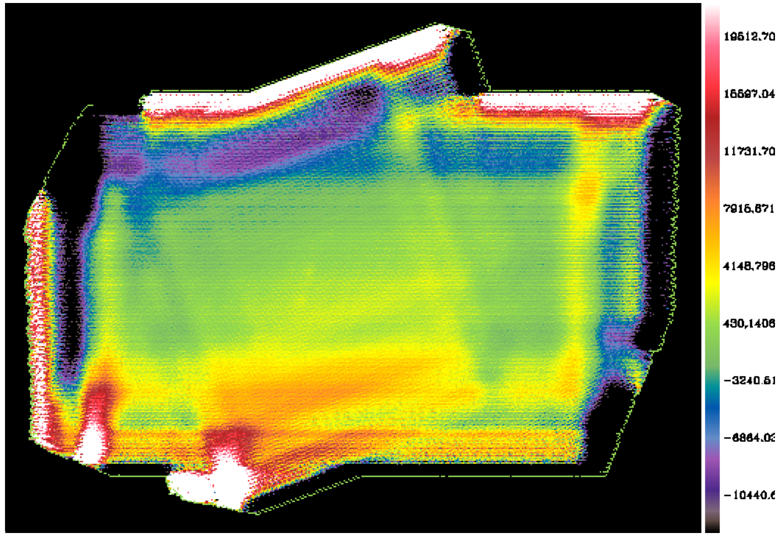


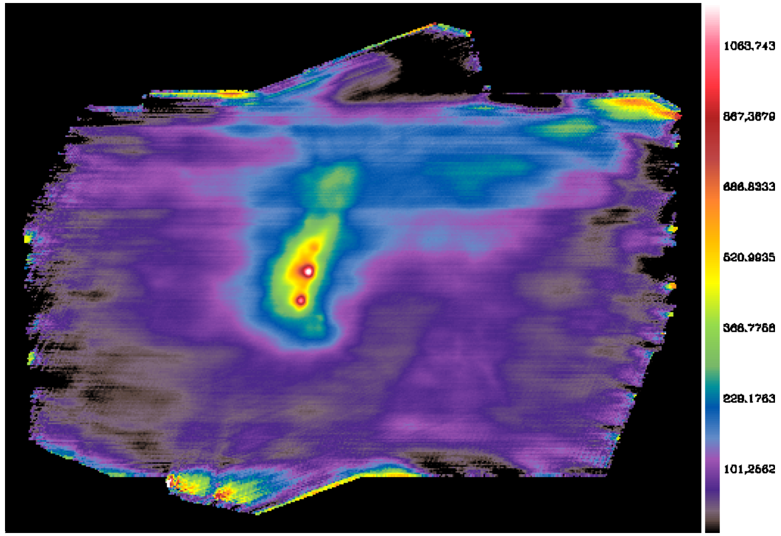
3) initial baseline subtraction: several iterations
linear fits to the average signal
first on whole scans, then on segments of 4 scan legs,
then on individual scan legs

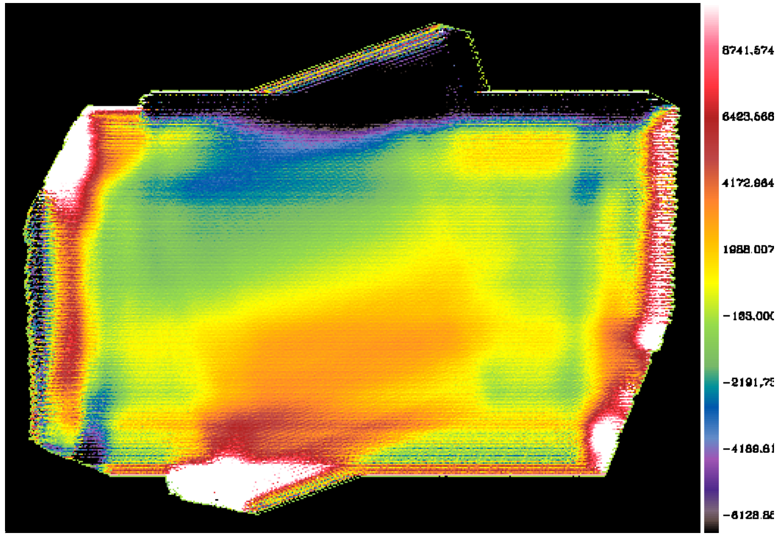
meanwhile: construction of an automatic and iterative source mask
(if the `/galactic` option is set ; do not use for diffuse sources !)



# before and after the initial baseline subtraction:

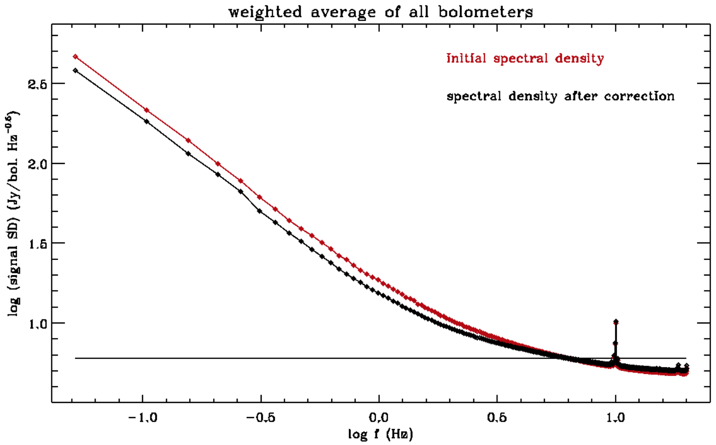






← what's been subtracted (with offsets)

power spectral densities before and after →

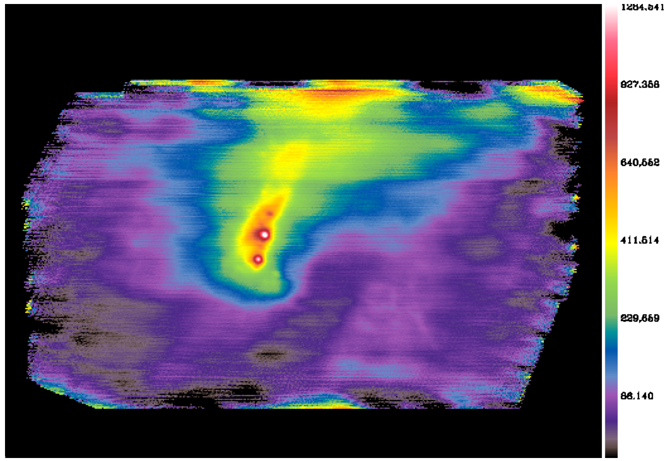


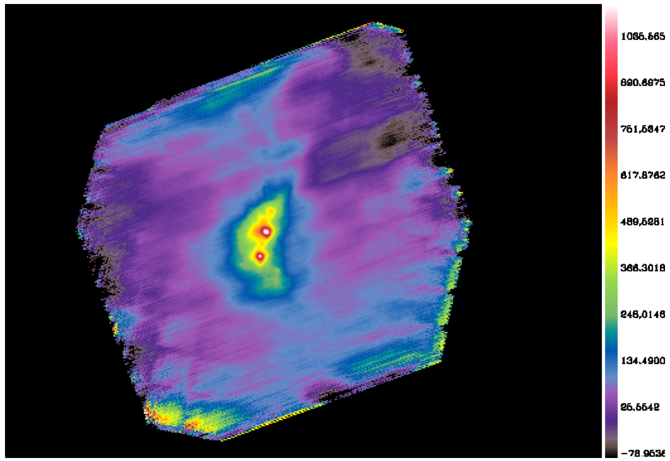
to project and display maps of individual scans at any point during the processing:

```
IDL > do_map_scans_nearest_artemis, map_scans, weight_scans, $
      file_scalars=file_scalars, ind_scans=ind_scans, ind_subscans=ind_subscans, $
      maxnoise=maxnoise
```

(copy/paste this command from the header of `do_map_scans_nearest_artemis.pro`)

```
IDL > for i = 0, nscans - 1 do disp_ima, win=20+i, $
      map_scans(*,*,i), weightmap=weight_scans(*,*,i), $
      [min_map= ..., max_map= ..., title='scan '+chain(i)]
```





4) subtraction of the average drift on small scales (smaller than scan legs): will take a while....

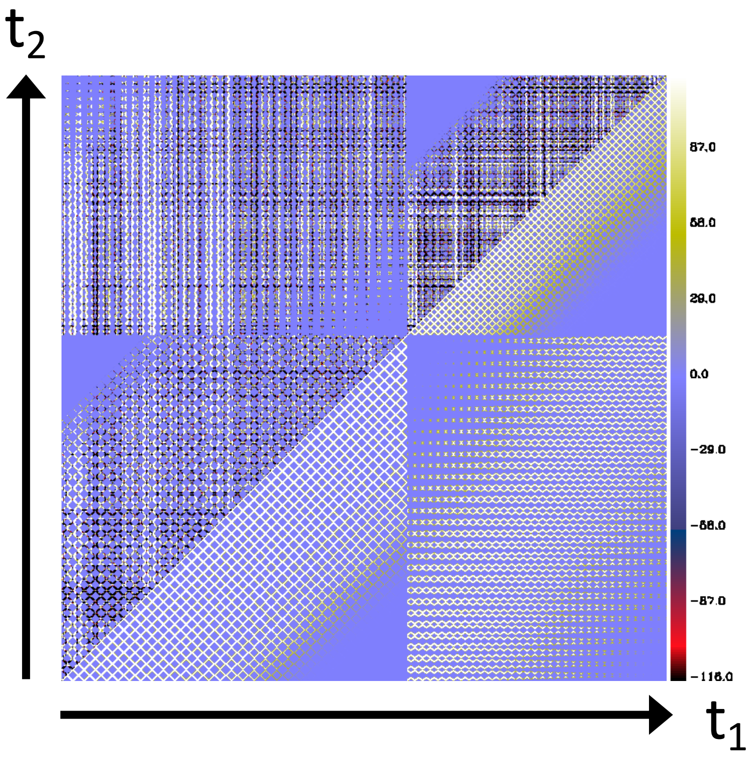
$$\Delta(t_1, t_2) = R(t_1, b_i) - R(t_2, b_j)$$

$$= S(p) – S(p) + D_{aver}(t_1) - D_{aver}(t_2) + (D_{indiv}+HF)(t_1, b_i) – (D_{indiv}+HF)(t_2, b_j)$$

coaddition over $(p, b_i, b_j)$ → $D_{aver}(t_1) - D_{aver}(t_2)$ + weighted mean of uncorrelated terms

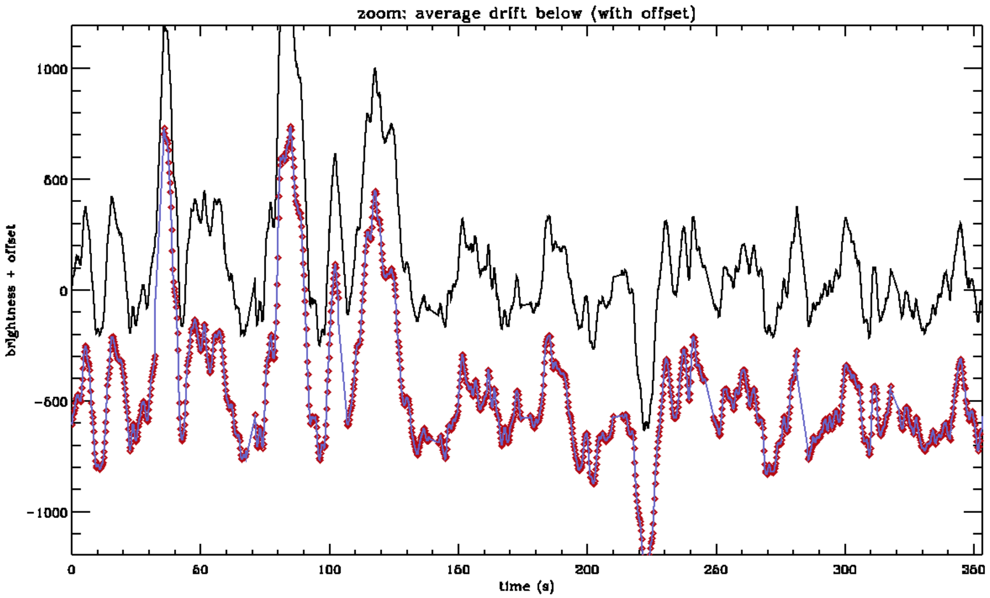
incremental population of $D_{aver}(t_1) - D_{aver}(t_2)$ matrix

(below diagonal: associated weights)



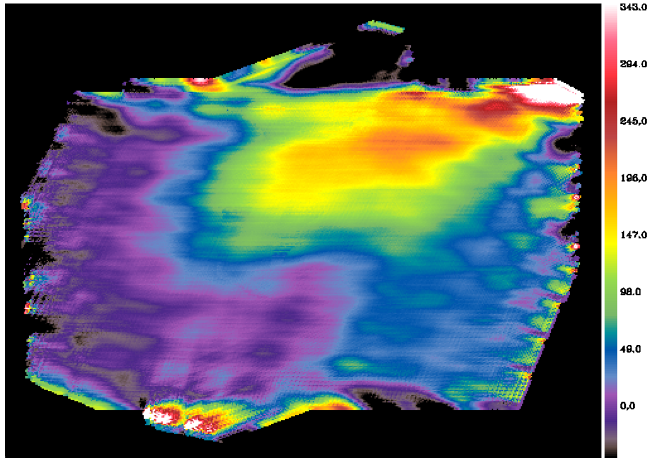
iterative scanning of $D_{aver}(t_1)$ - $D_{aver}(t_2)$ matrix

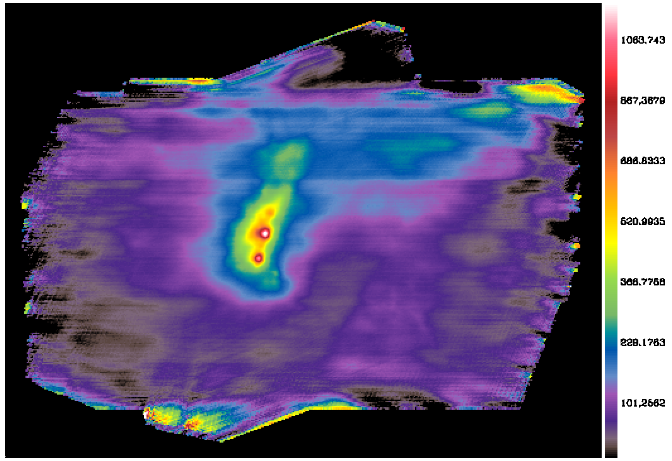
→ $D_{aver}(t)$ time series



projection of $D_{aver}(t)$

compared with map at previous step

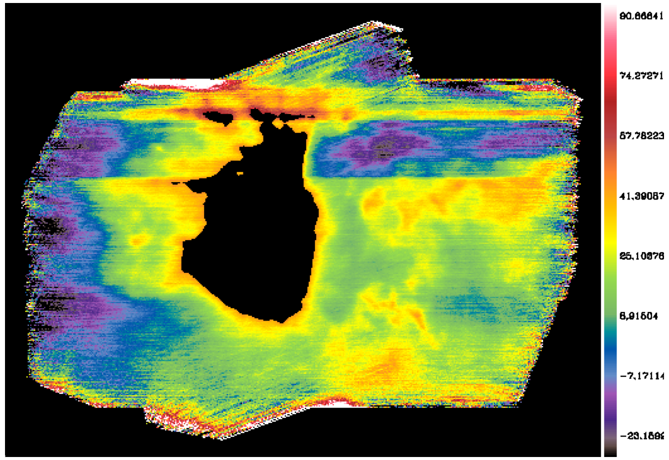


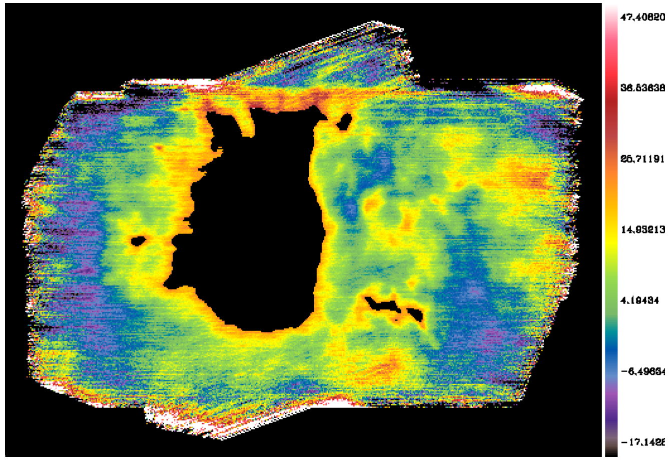


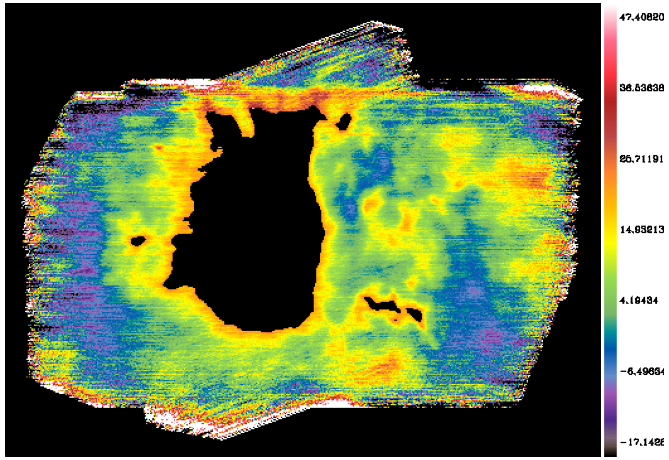
solution of $D_{aver}(t_1) - D_{aver}(t_2)$ matrix not unique
(true drift + spurious component with the same periodicity as the scans)

$\Rightarrow$ baseline subtraction repeated to remove the spurious component
fits on individual scan legs refined: for each subarray separately

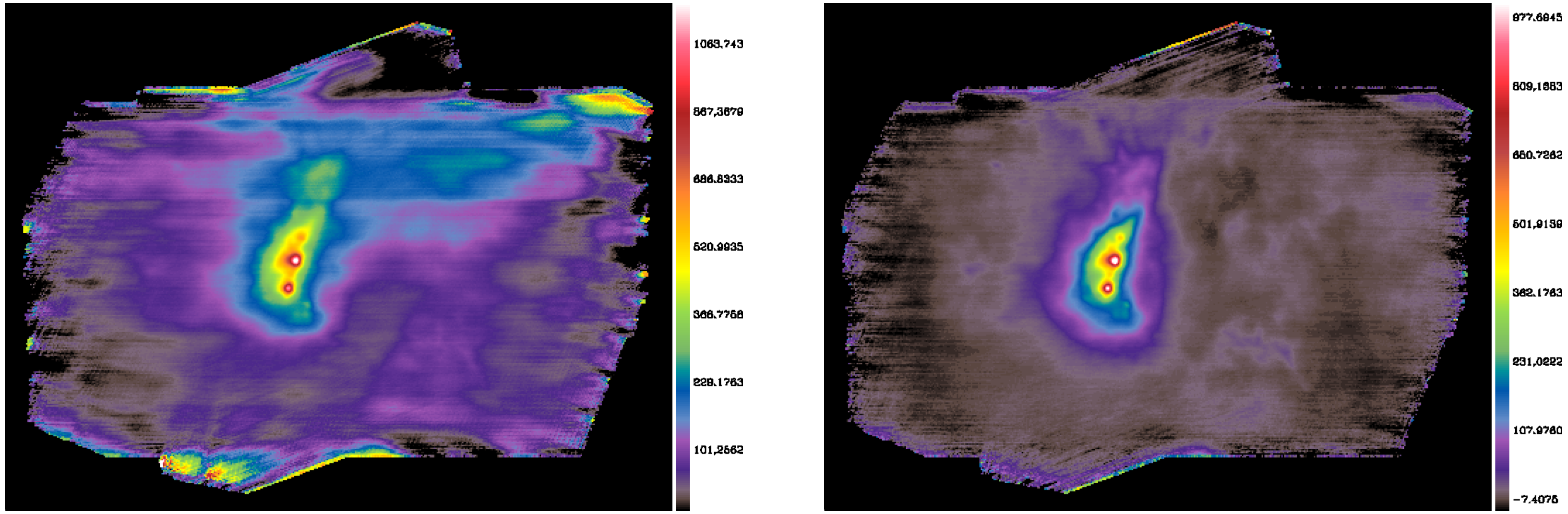
iterative source mask:

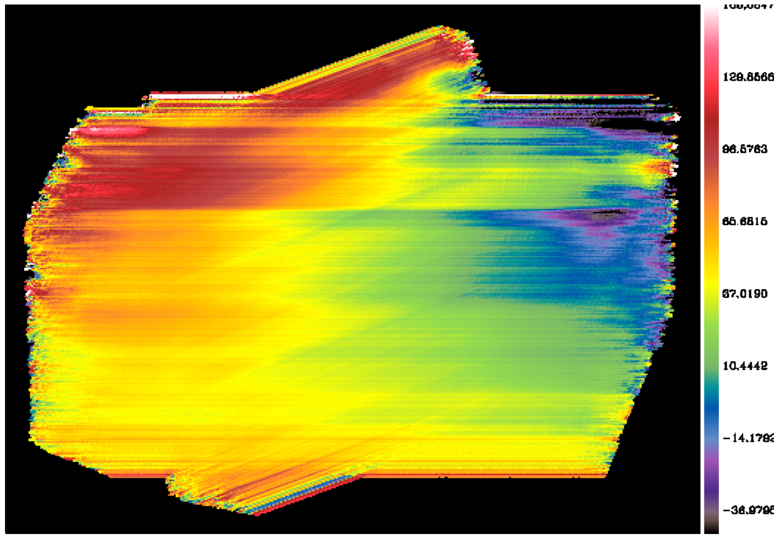






# before and after average drift + second baseline subtraction:



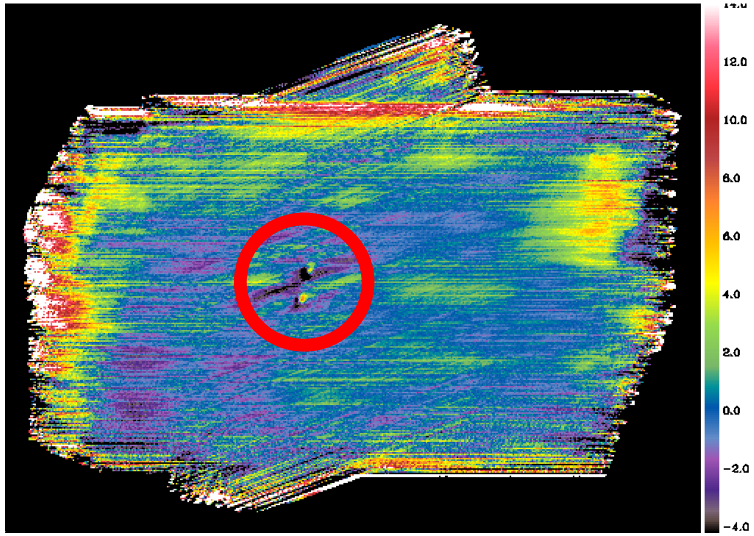


← subtracted baselines (with offsets)

5) subtraction of the individual drifts (flicker noise) on timescales of ~ 1/4 the minimum scan leg duration, followed by baseline subtraction again

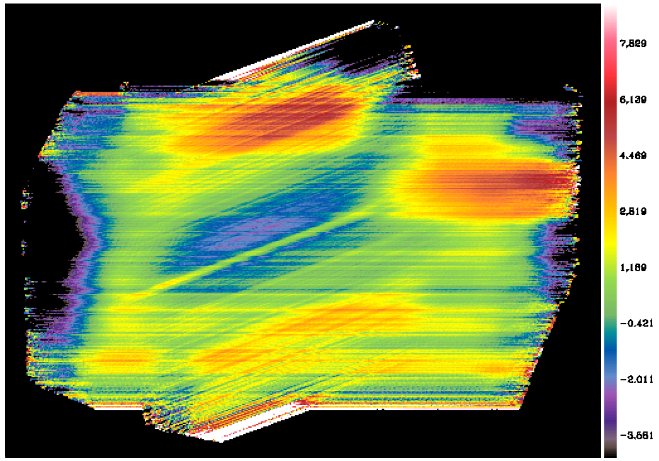
iterated on successively smaller timescales (decreased by a factor 3 each time) until reaching the stability length crossing time $t_c = l_s / v_{scan}$

projected drifts on 5.4 s timescale:

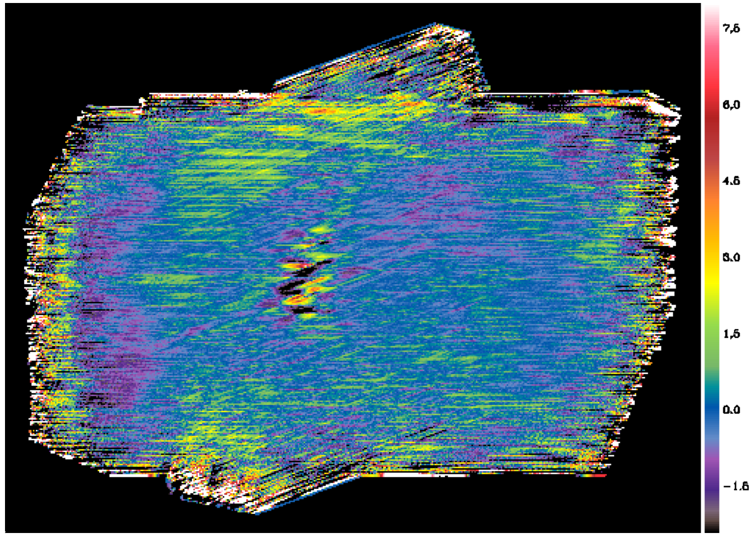


← typical artefacts caused by small pointing errors

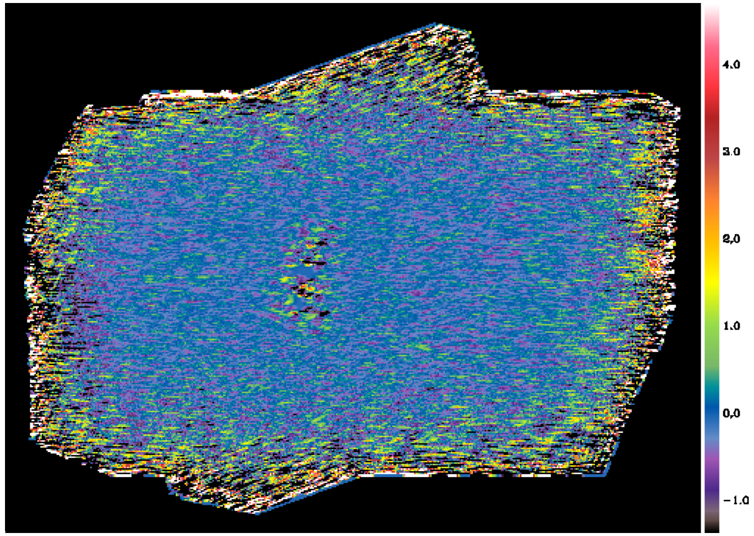
iterated baselines:



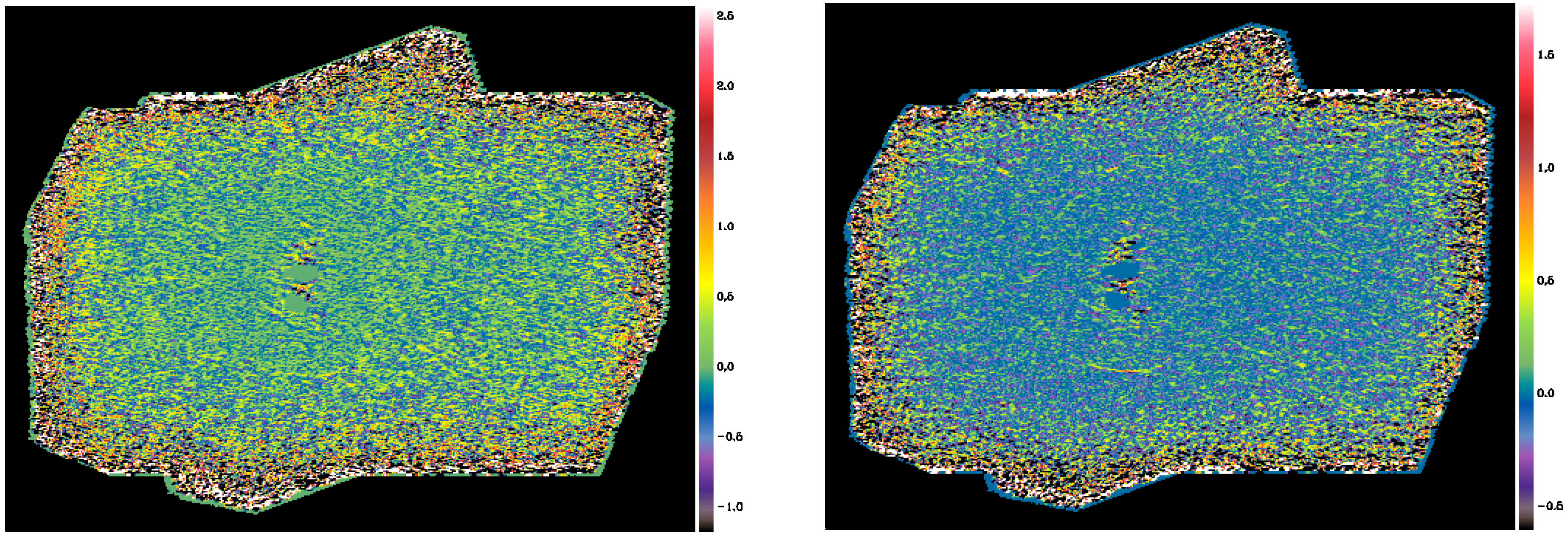
projected drifts on 1.8 s timescale:



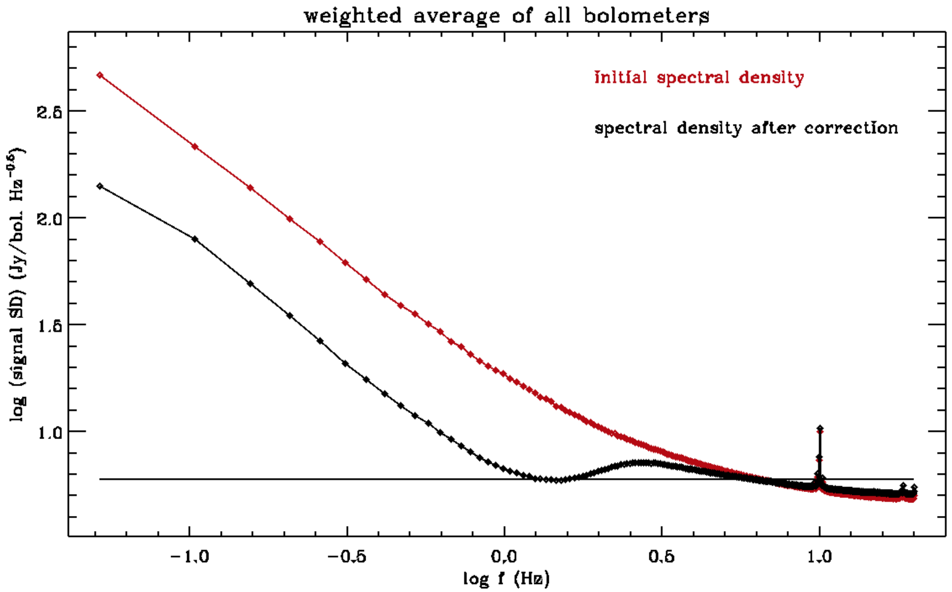
on 0.6 s timescale:

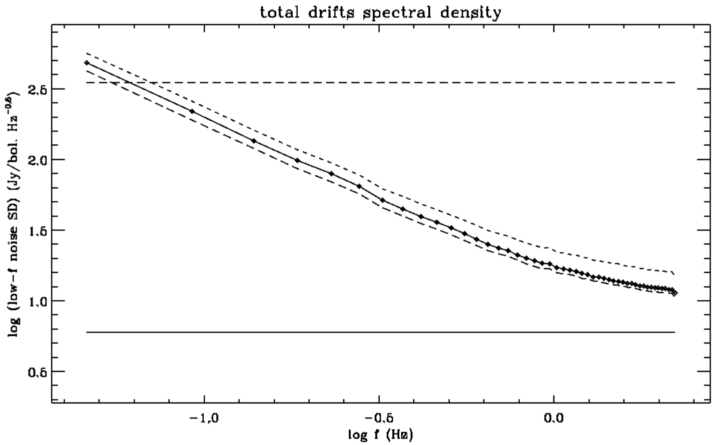


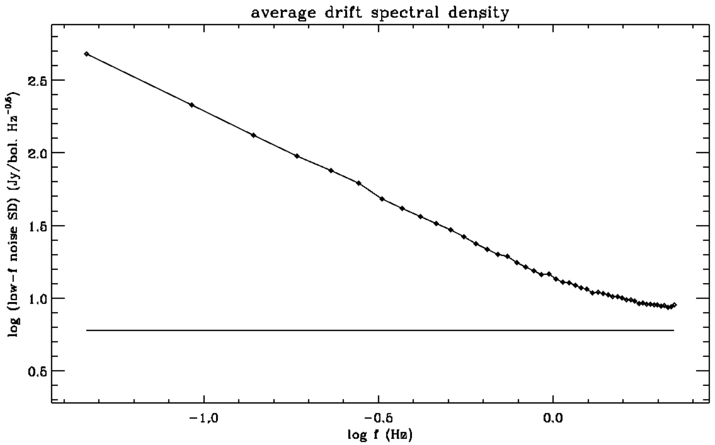
on 0.2 s timescale:

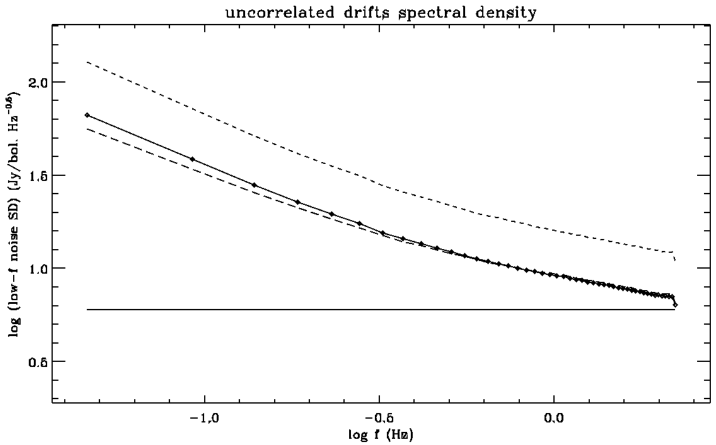


power spectral densities:

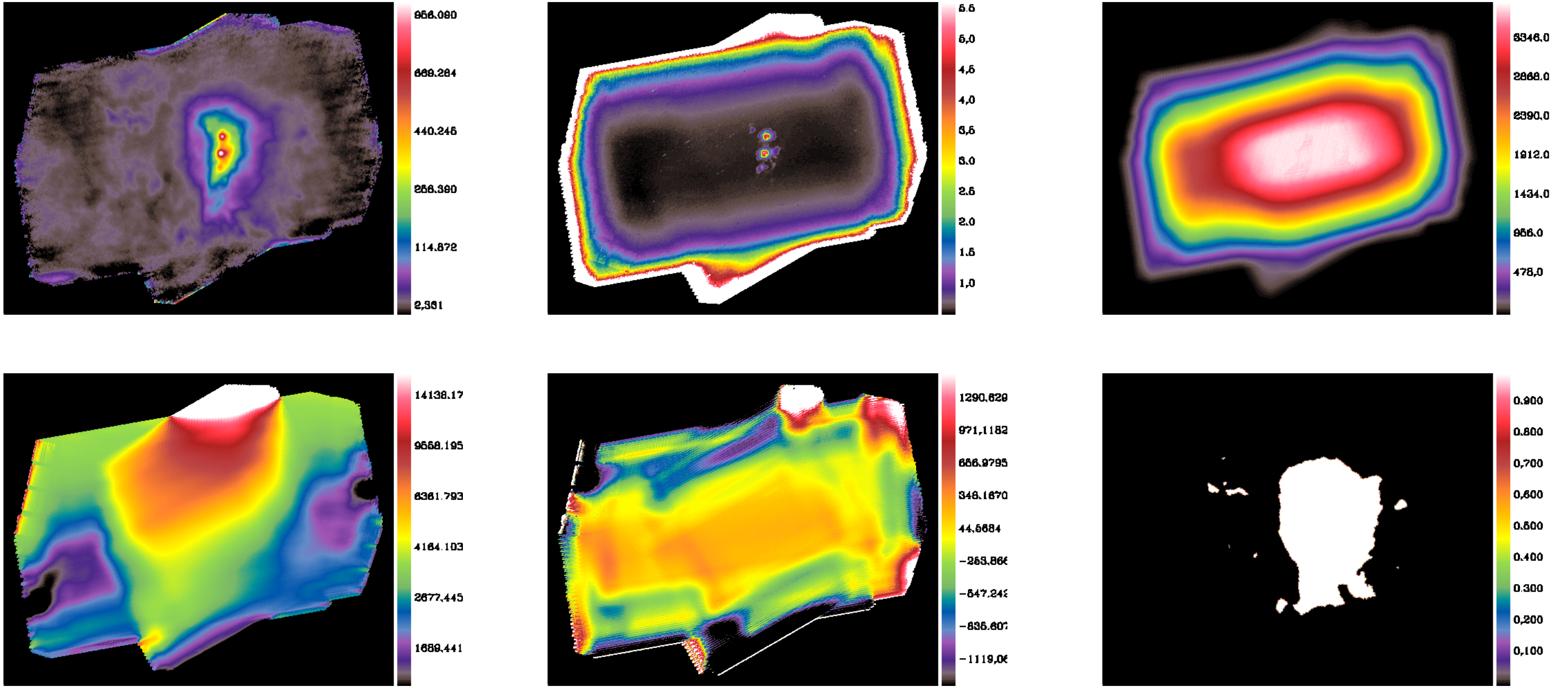








output maps (assembled in a fits cube):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1290.629
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