PFS N1 H4RG PERSISTENCE ANALYSIS

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PERSISTENCE PROPERTIES OF PFS N1 H4RG

THE ANALYSIS OF 2020-12 EXPERIMENT DATA

Summary of 2020-12 experiment log

Dataset	Visit	Flat count	Flat exptime (sec/frame)	Dark duration (hrs)
#1	22780-22783	670	52.43	0.2
#2	22784-22798	1500 x 4 frames	104.86	1.2
#3	22799-22812	8800	524.29	1.5
#4	22813-22825	12700	524.29	2
#5	22825-22838	18900	524.29	2
#6	22839-22861	25900	524.29	5
#7	22862-22890	1500 x 4 frames	104.86	3
#8	22891-22939	3300 x 4 frames	209.72	10
Dark	22940-22947	-	-	-
#9	22948-22954	3100	209.72	0.5
#10	22955-22959	3100	209.72	0.5
#11	22960-22964	3300	209.72	0.5
#12	22965-22969	3300	209.72	0.5
#13	22970-22974	3300	209.72	0.5
#14	22975-22979	3300	209.72	0.5

The 13 datasets (a flat frame with various luminosity and short darks) were taken in addition to above datasets.

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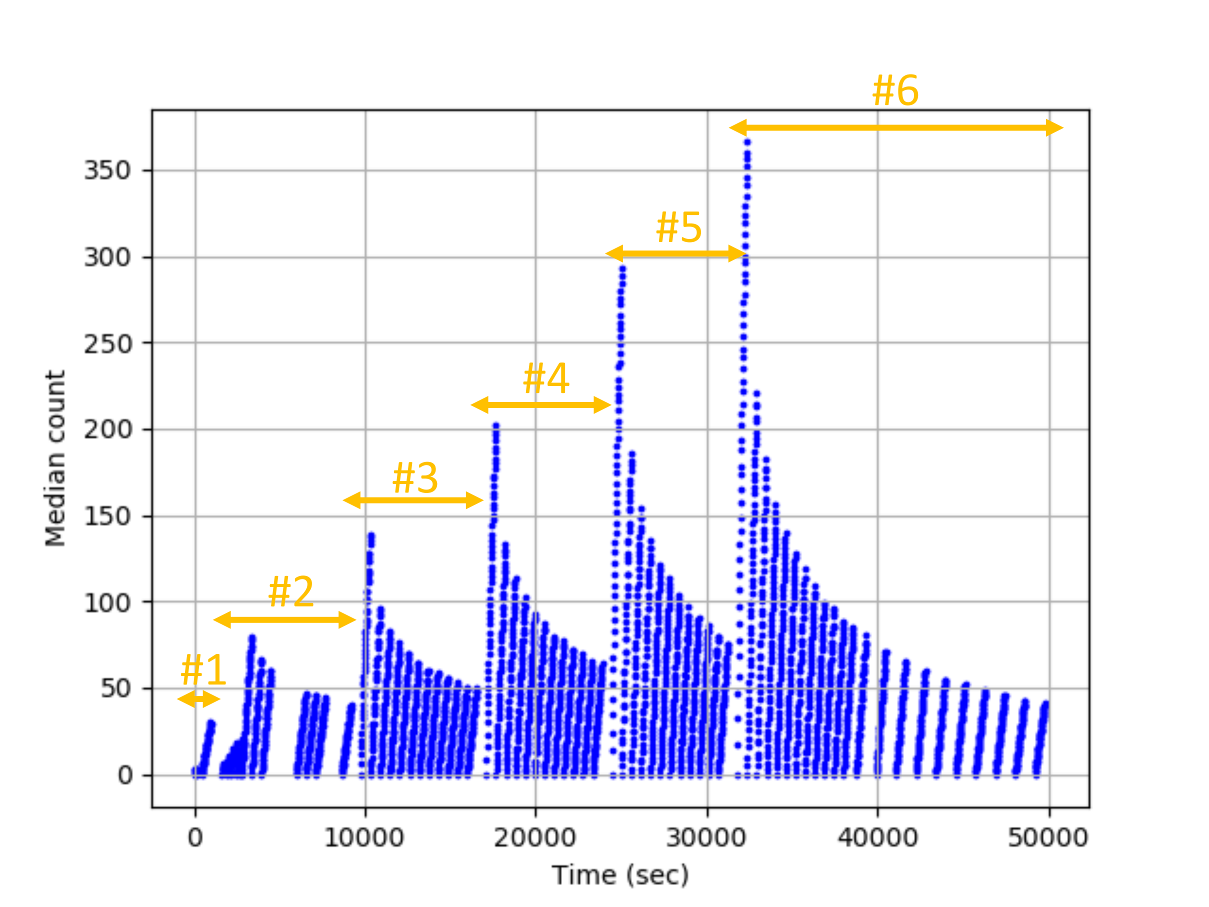
The 13 datasets (a flat frame with various luminosity and short darks) were taken in addition to above datasets.

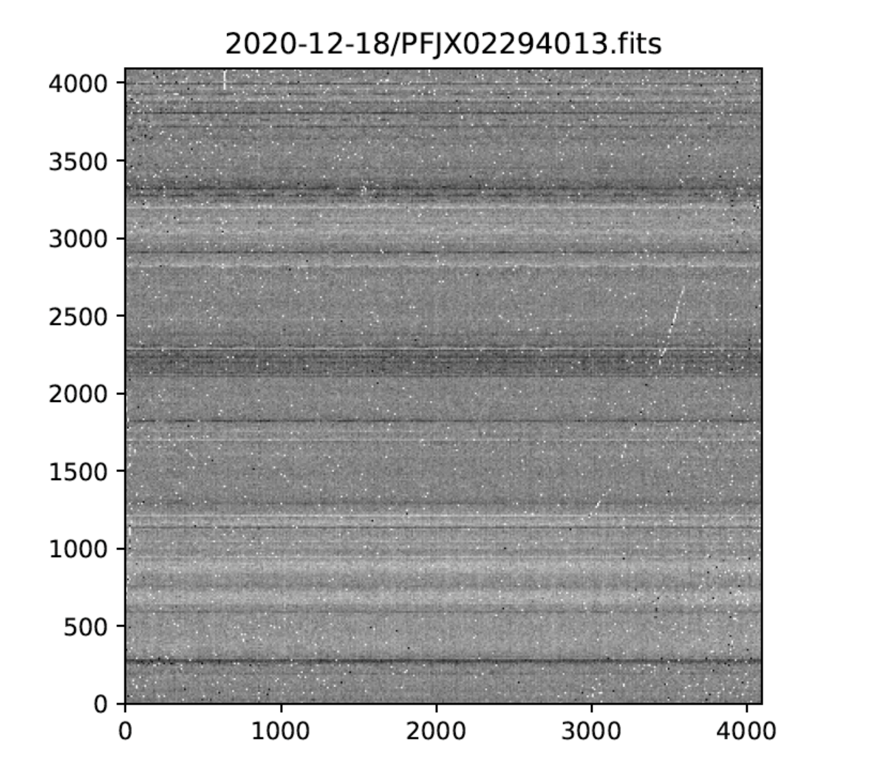
Summary of 2020-12 experiment log

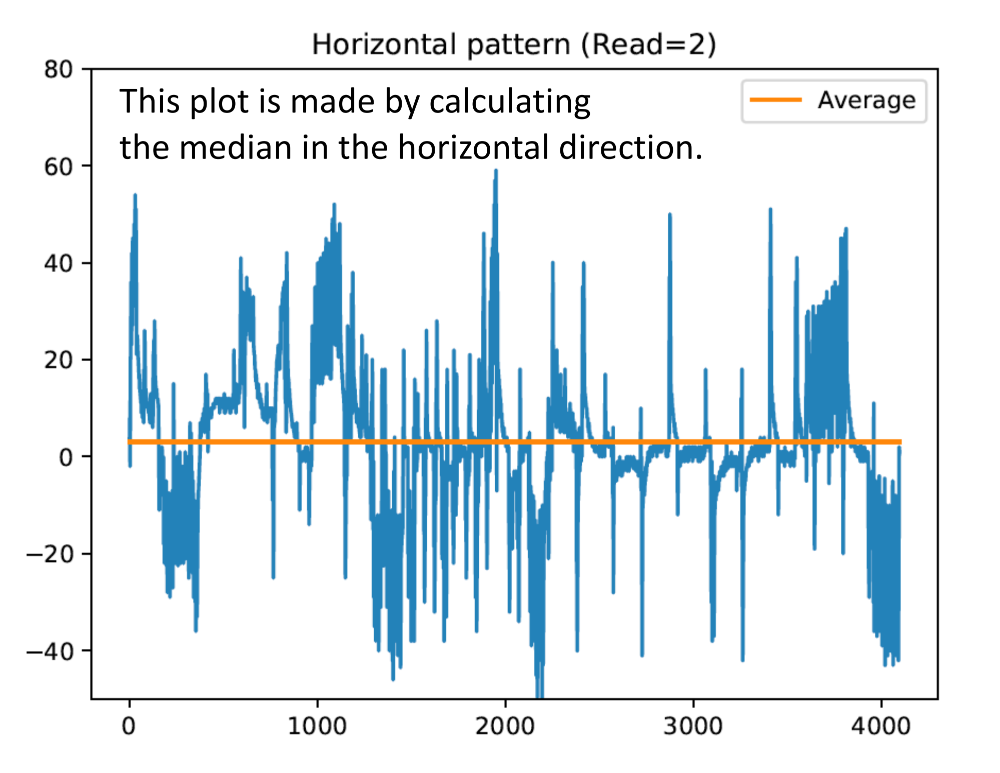
- Persistence as a function of time



USB noise

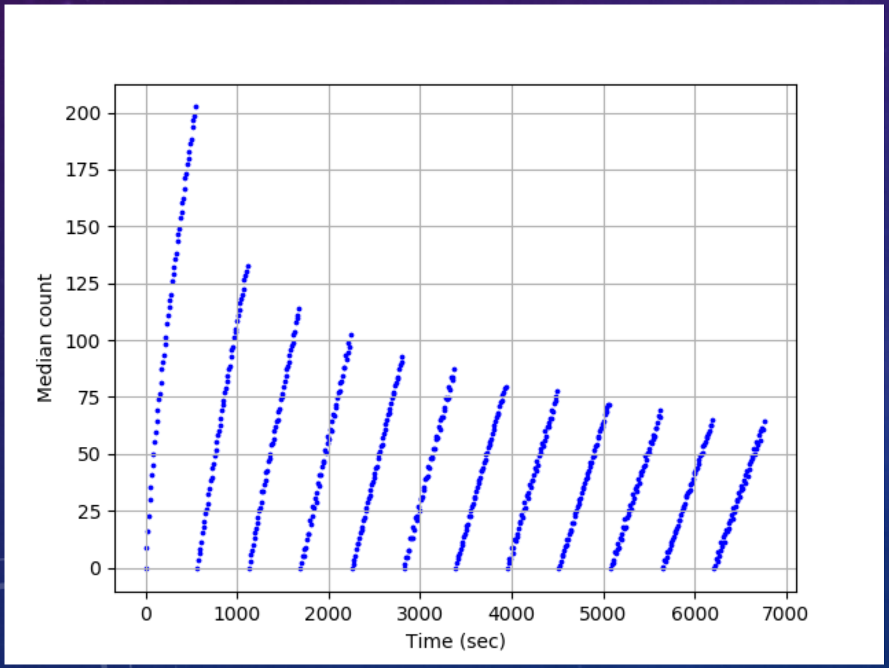
- Horizontal noise pattern appears in the dark images.

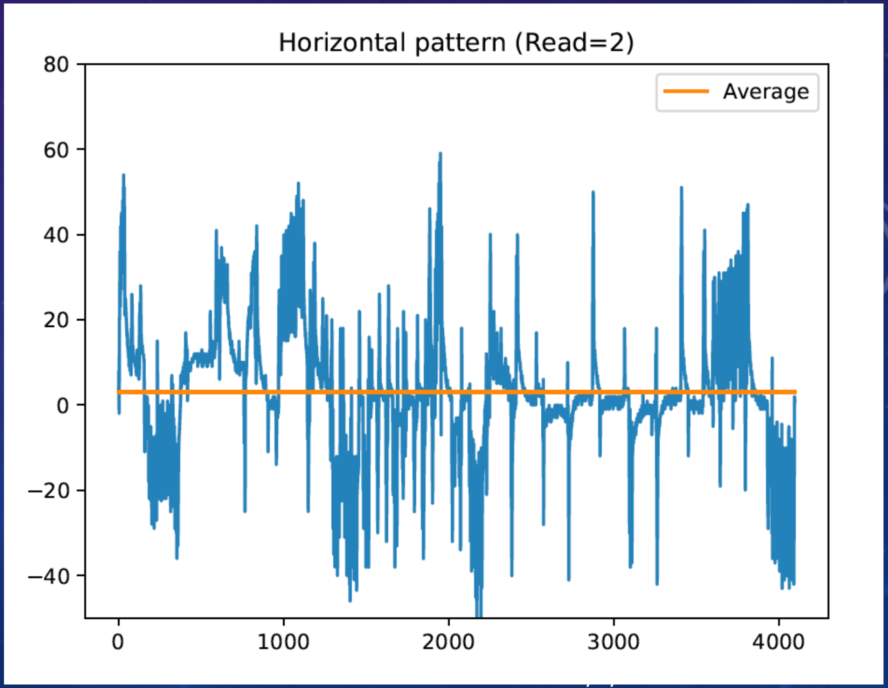




USB noise

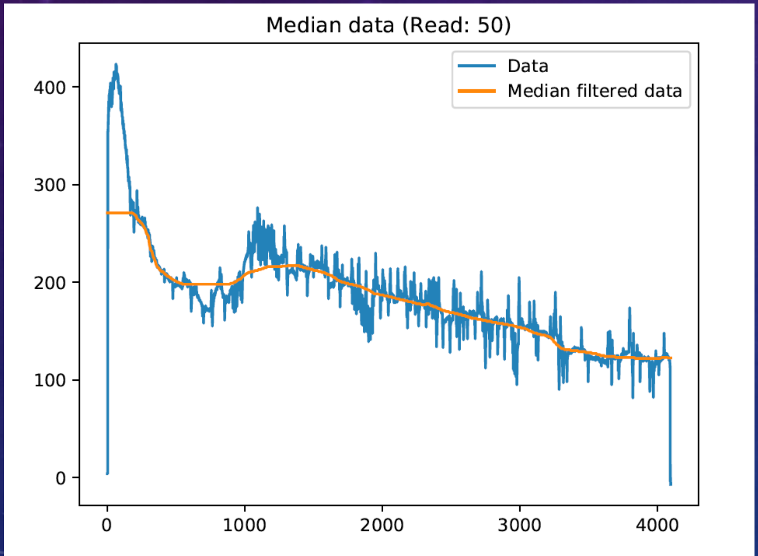
- The noise pattern is very variable.
- By averaging the counts of the whole area, the decaying persistence signal can be examined without the USB noise.
- In order to investigate the persistence pixel by pixel, the noise pattern must be removed.
  - The noise amplitude is comparable to the persistence signal per frame.

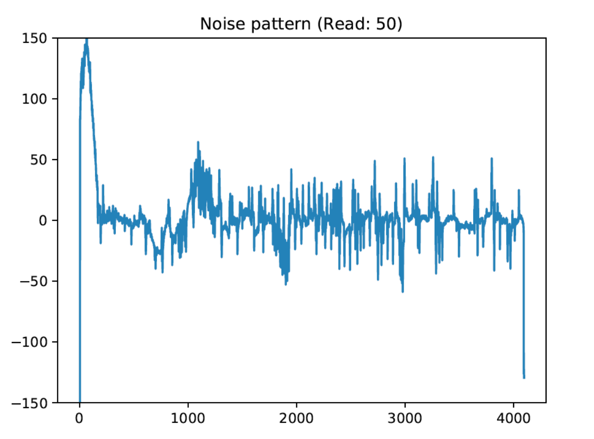


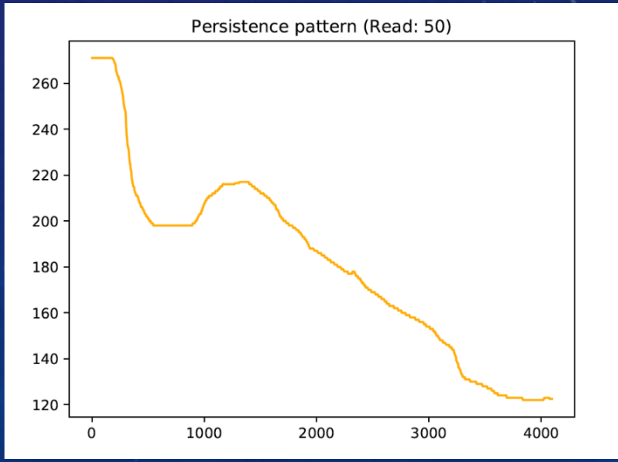


Removal of USB noise pattern

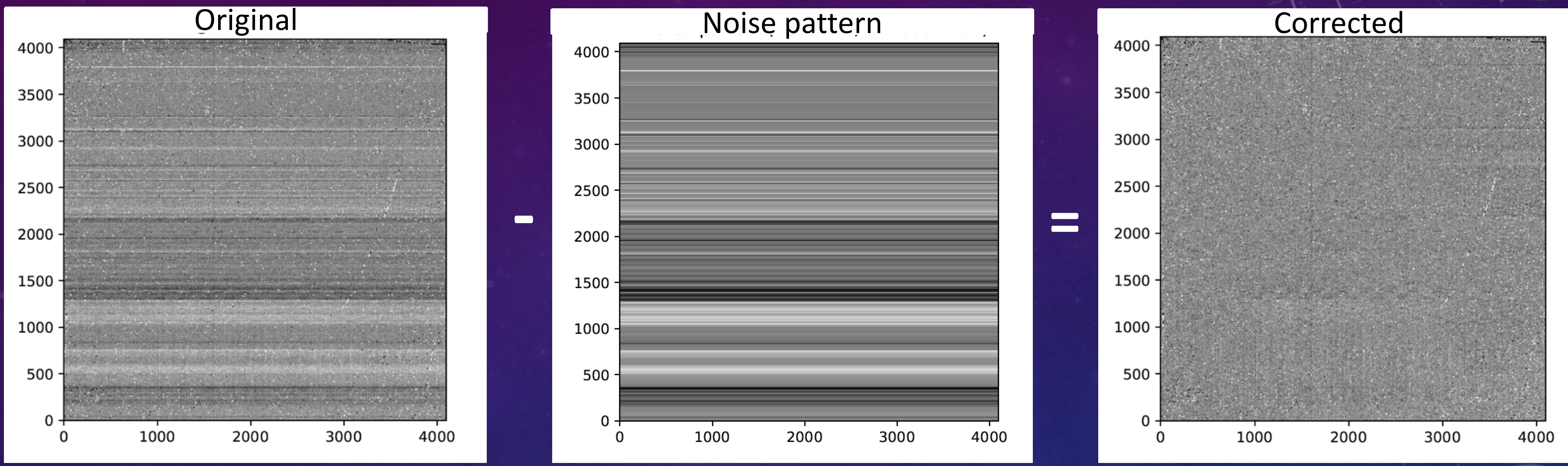
- The noise pattern is separated from the persistence signal by the median filter.

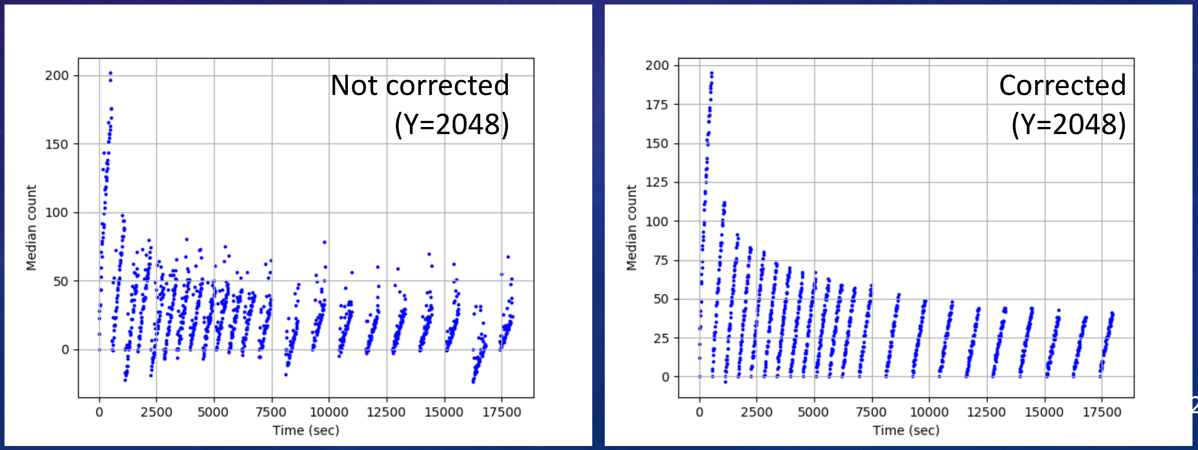






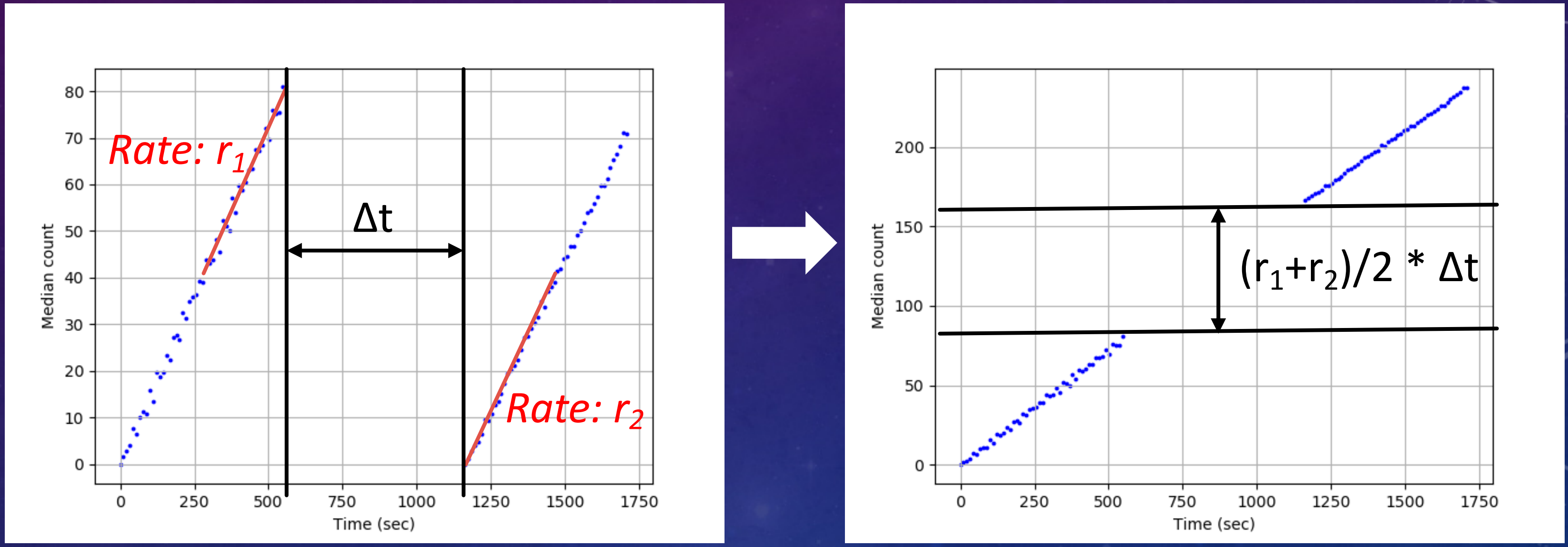
Removal of USB noise pattern





Cumulative persistence plot

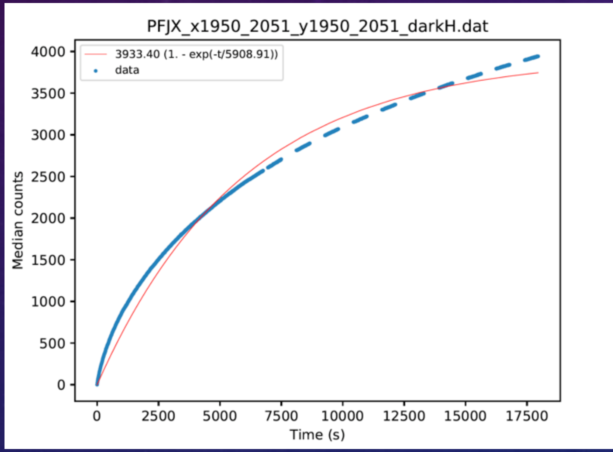
- Cumulative persistence was plotted by interpolating the persistence rate.



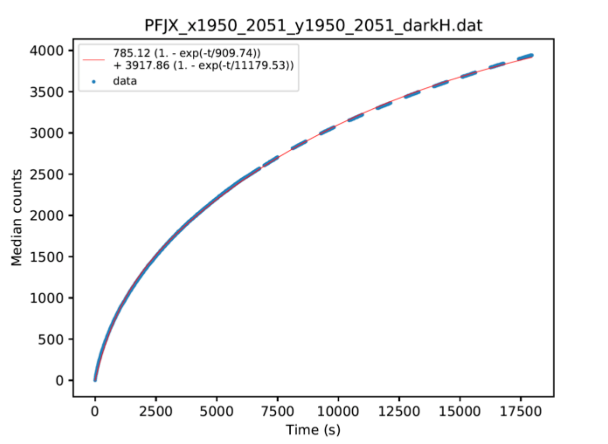
Exponential function fitting analysis

- Fitting function: $f(t) = \sum_{i=1}^{n} a_i \left(1 - \exp\left(-\frac{t}{\tau_i}\right)\right)$

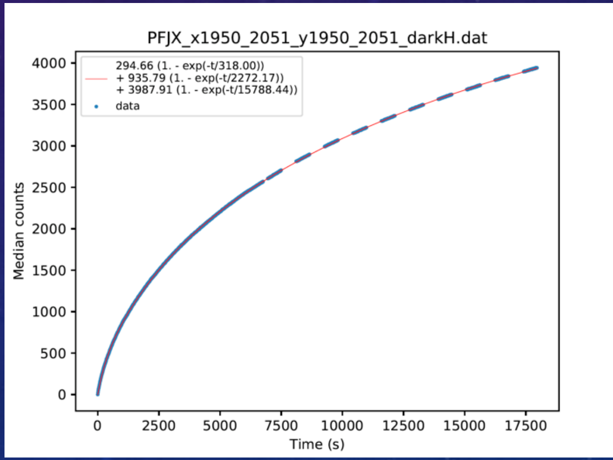
n=1



n=2

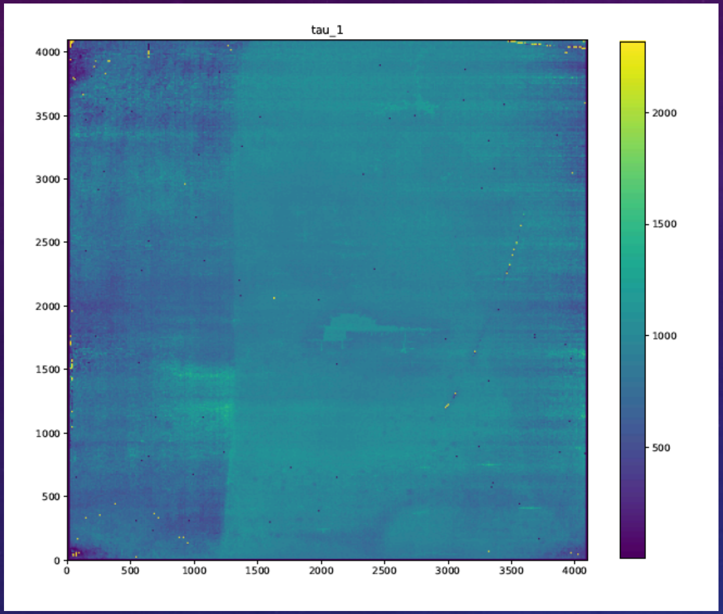


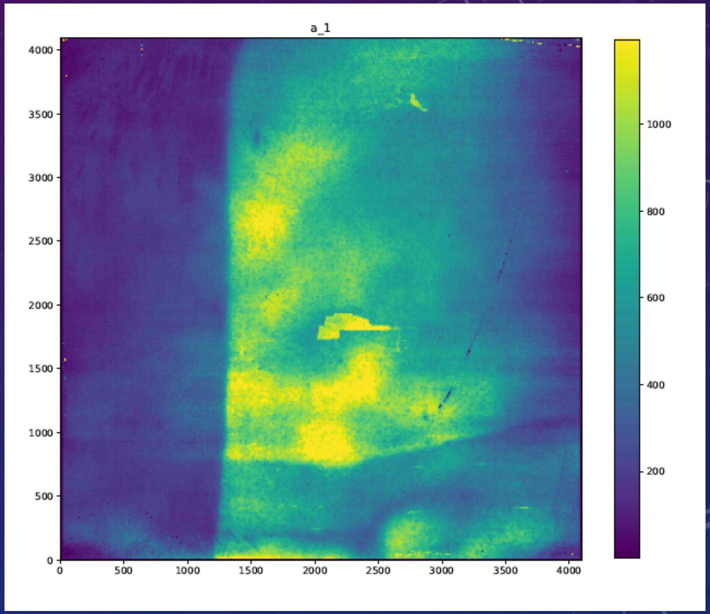
n=3

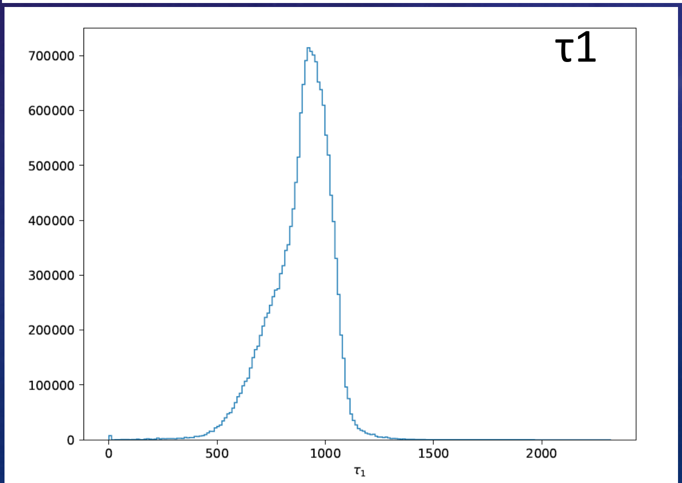


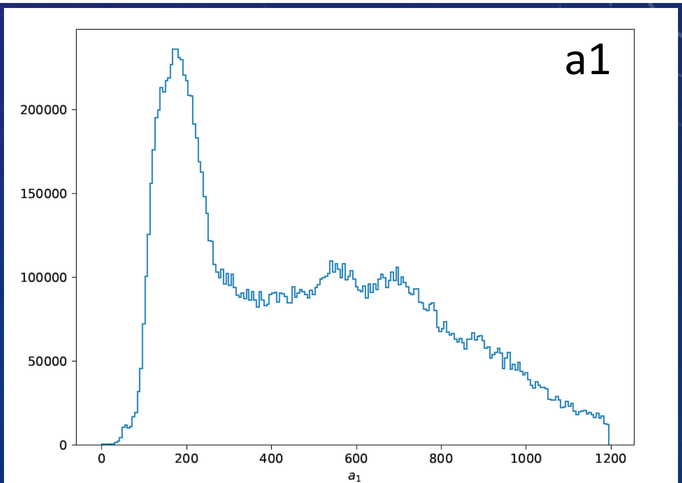
Map of fitting parameters

- Dataset: #6 (median of 11x11 pixels area)
- 2 exponential components









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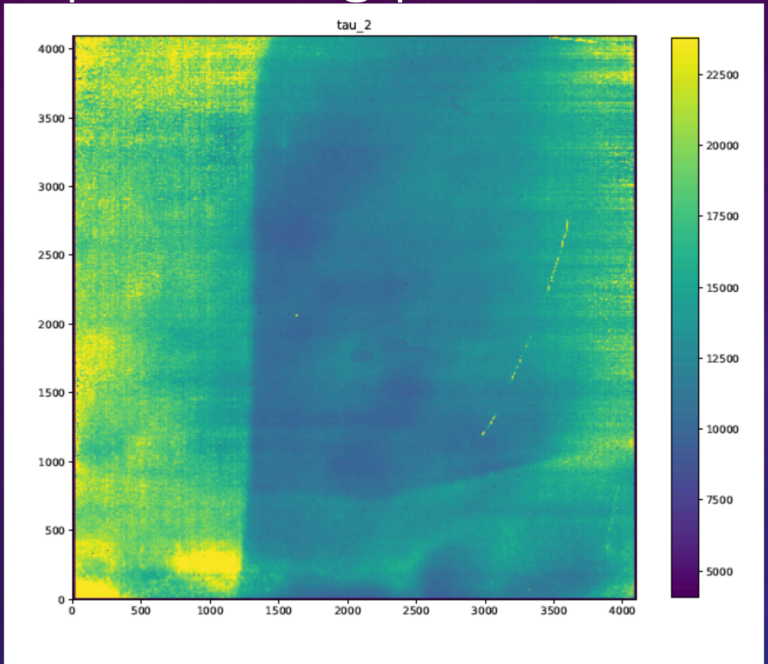

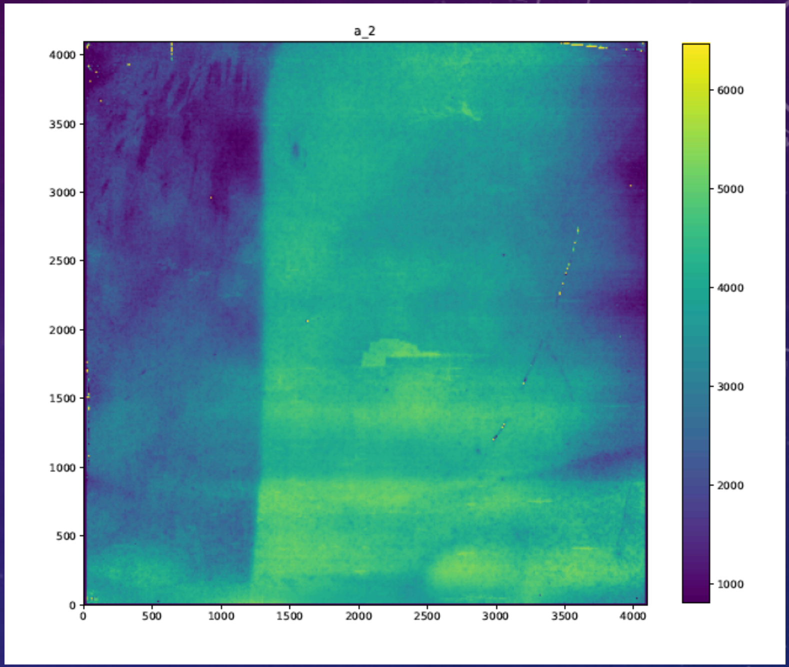

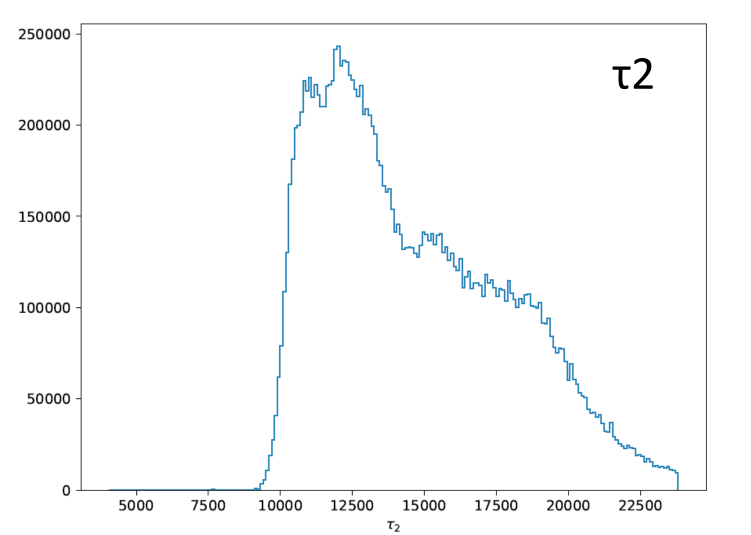

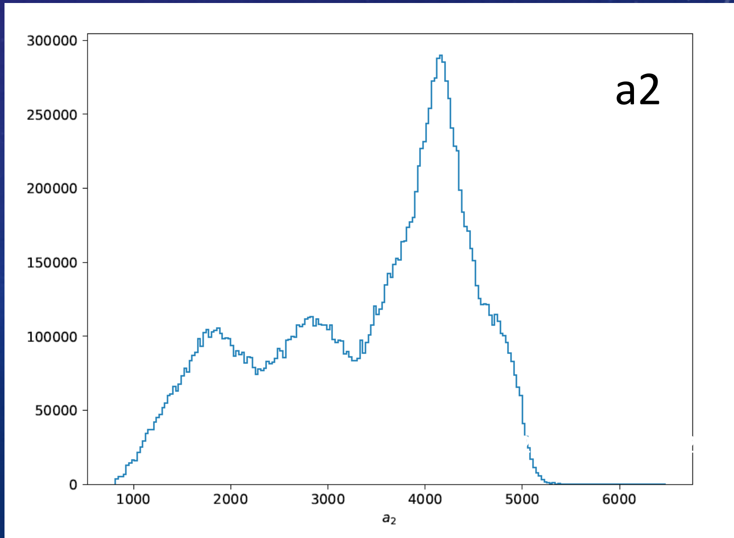

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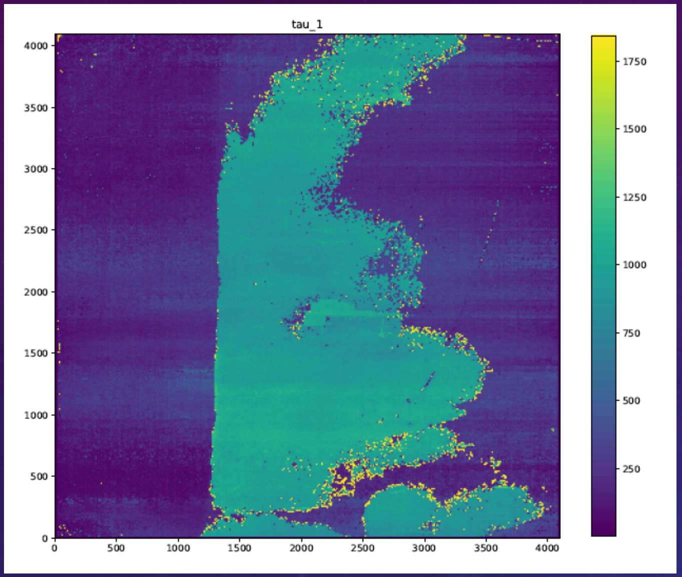
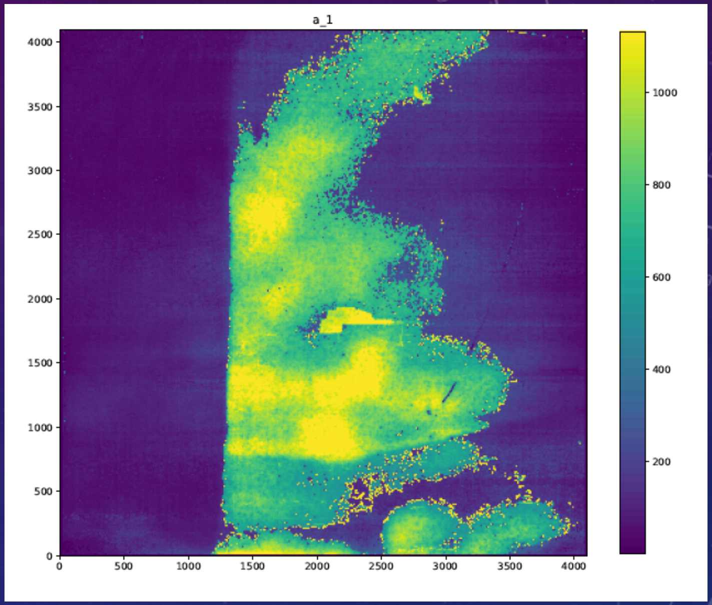
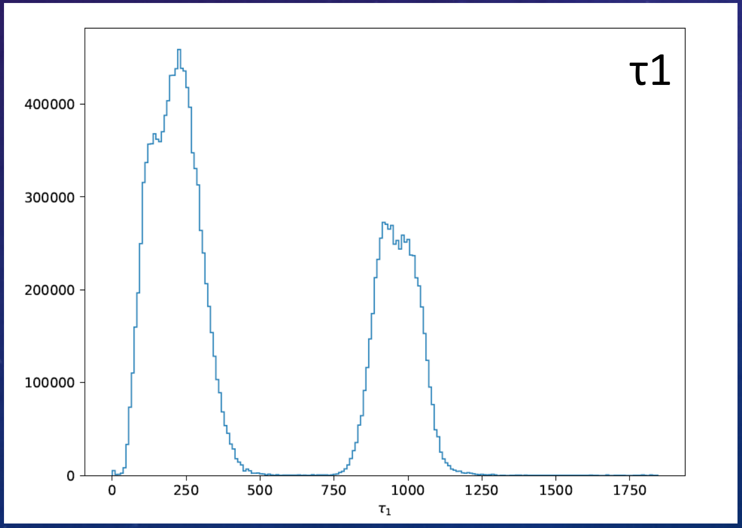
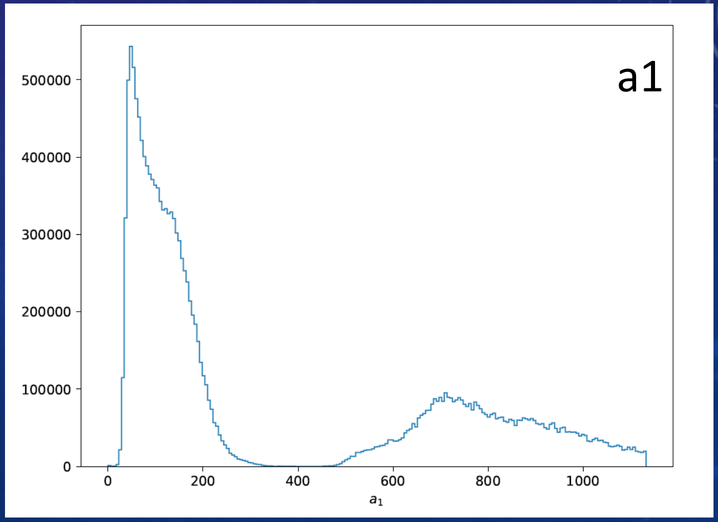




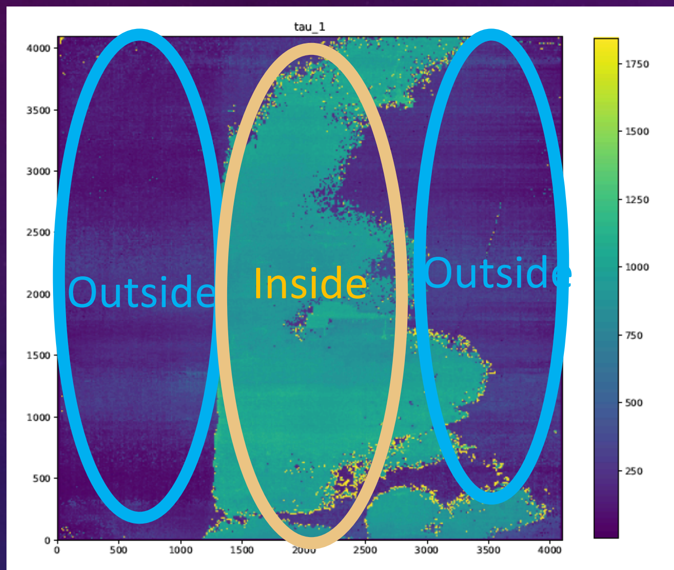


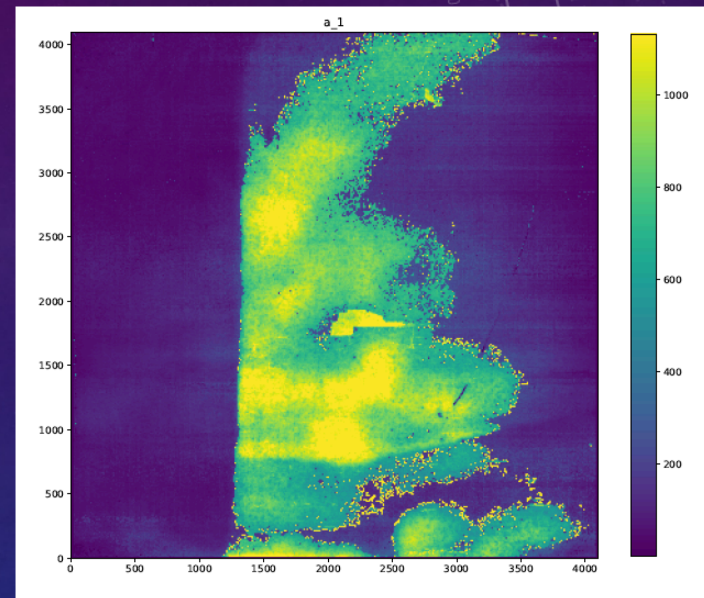


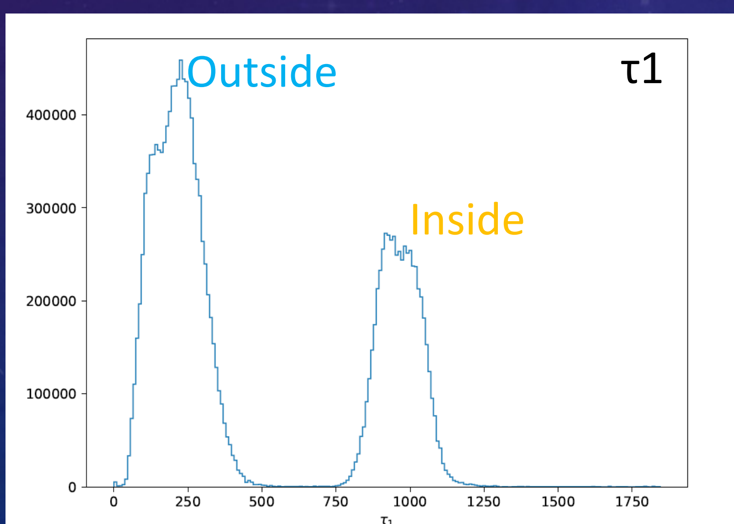
Map of fitting parameters

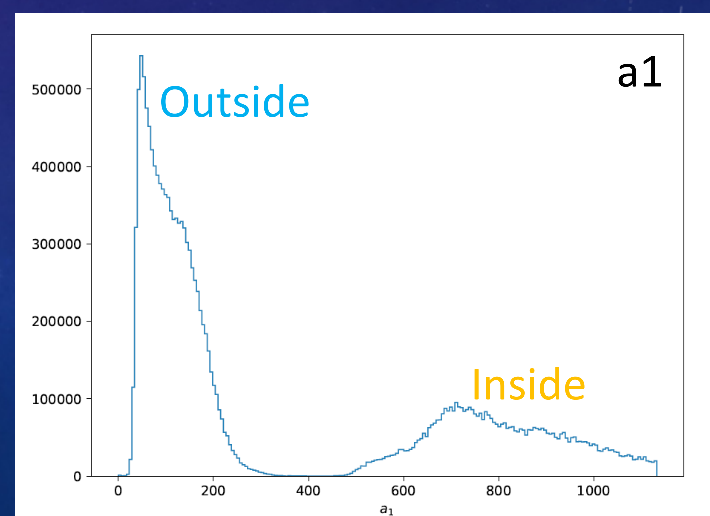
- Dataset: #6 (median of 11x11 pixels area)
- 3 exponential components

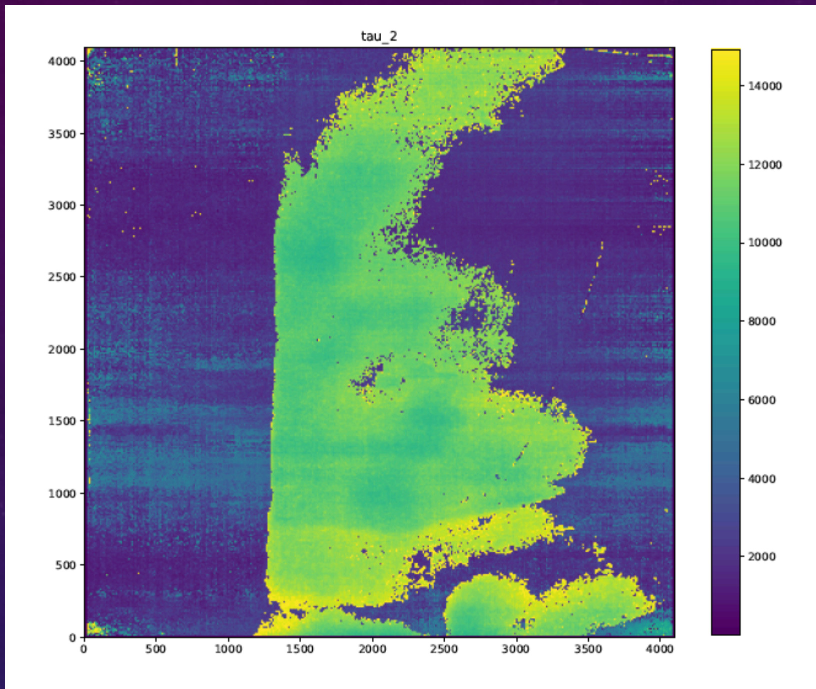
The map consists of two distinct regions.

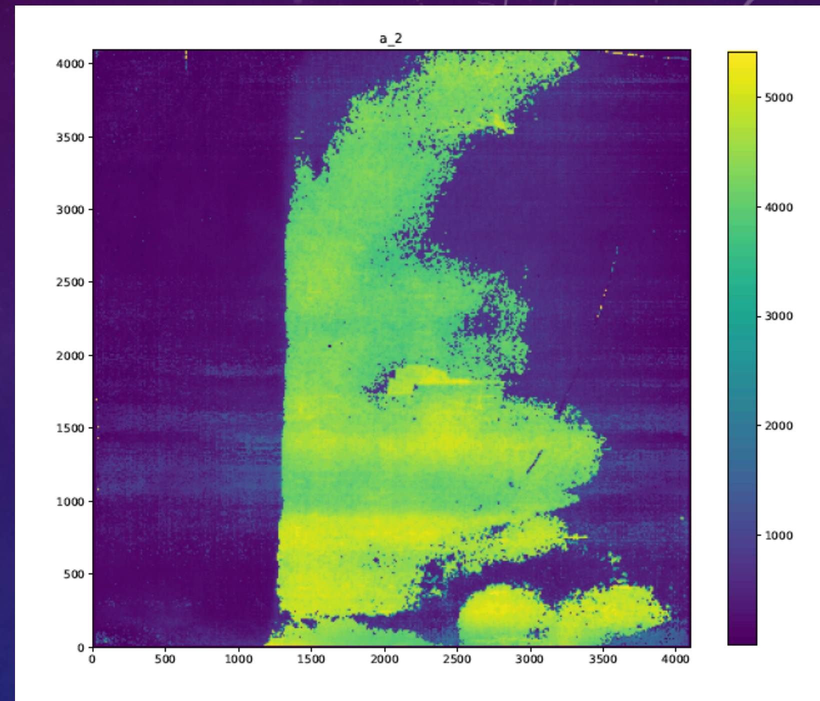


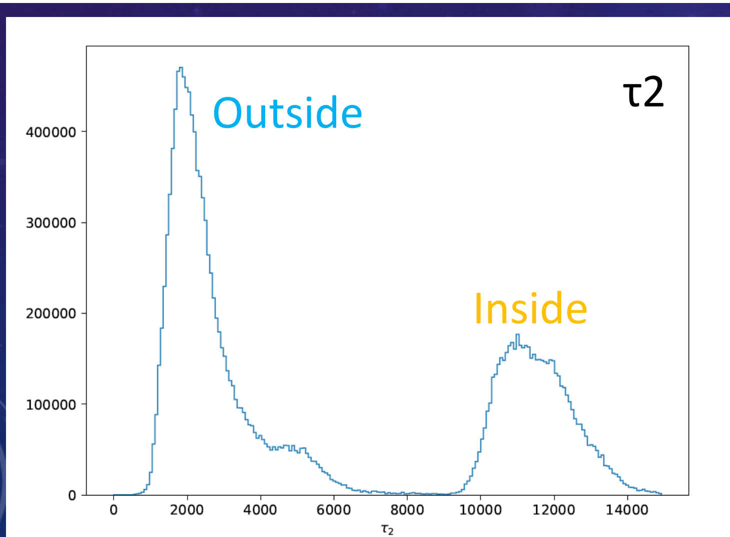


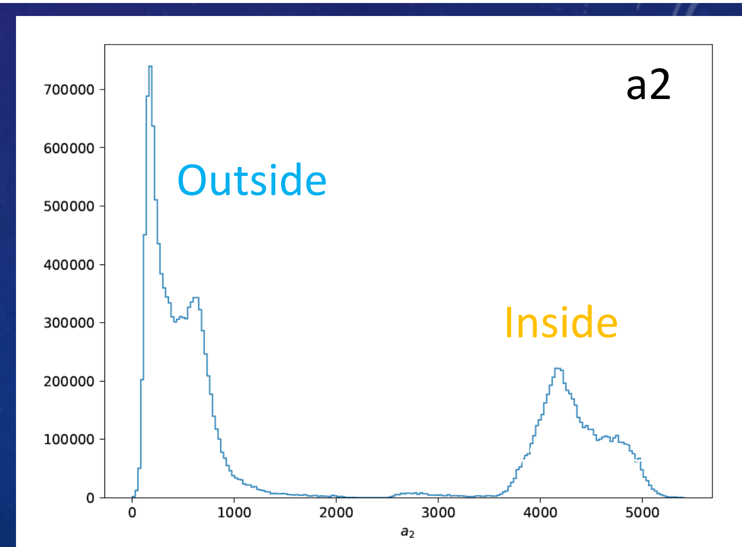


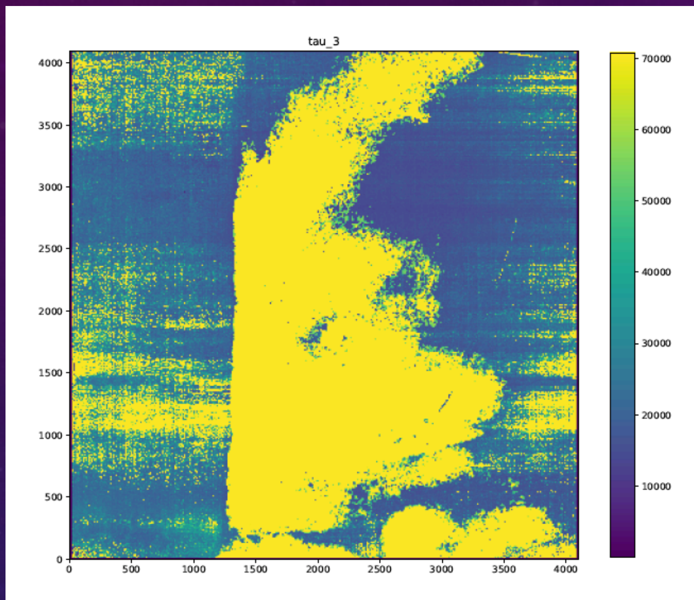


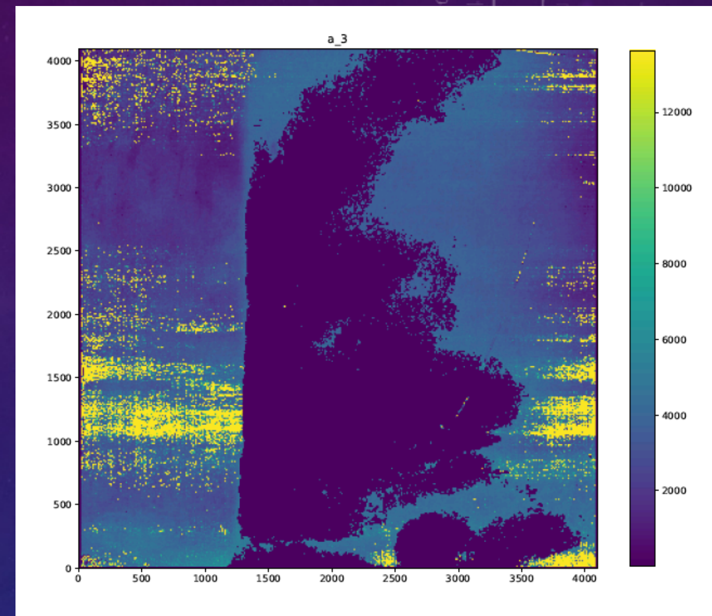

tau_2

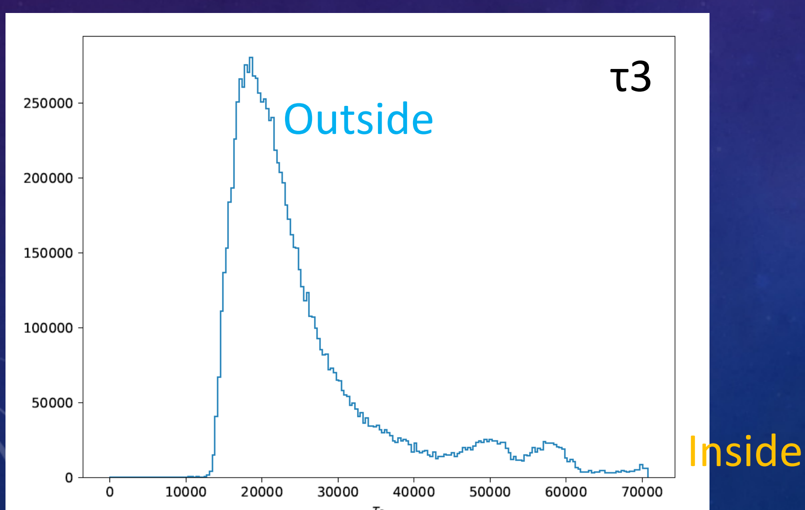

a_2

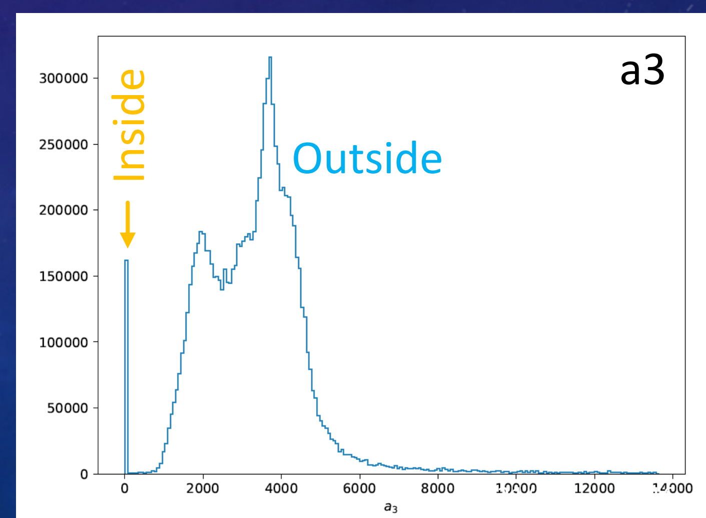

τ2
Outside
Inside
τ_2


a2
Outside
Inside
a_2


tau_3


a_3

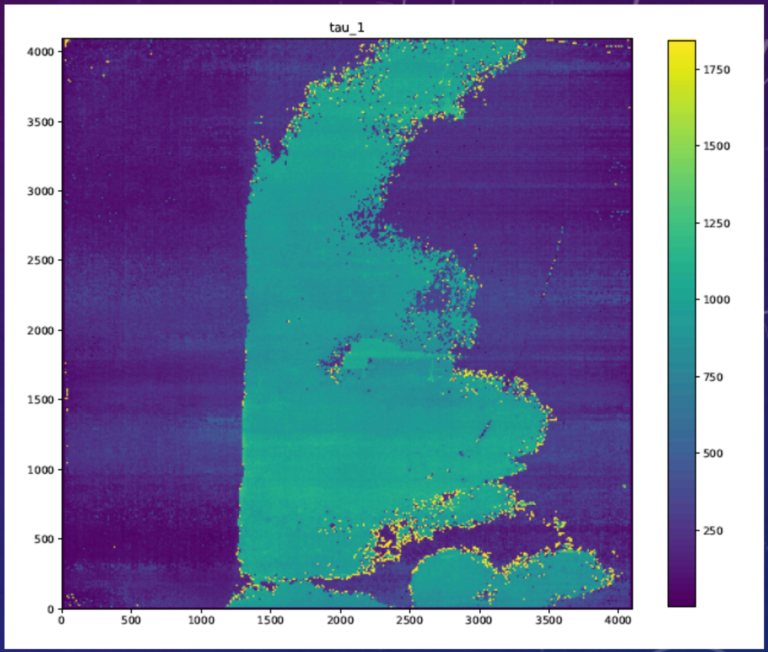

τ3
Outside
Inside
τ_3


a3
Inside
Outside
a_3

Summary of persistence map

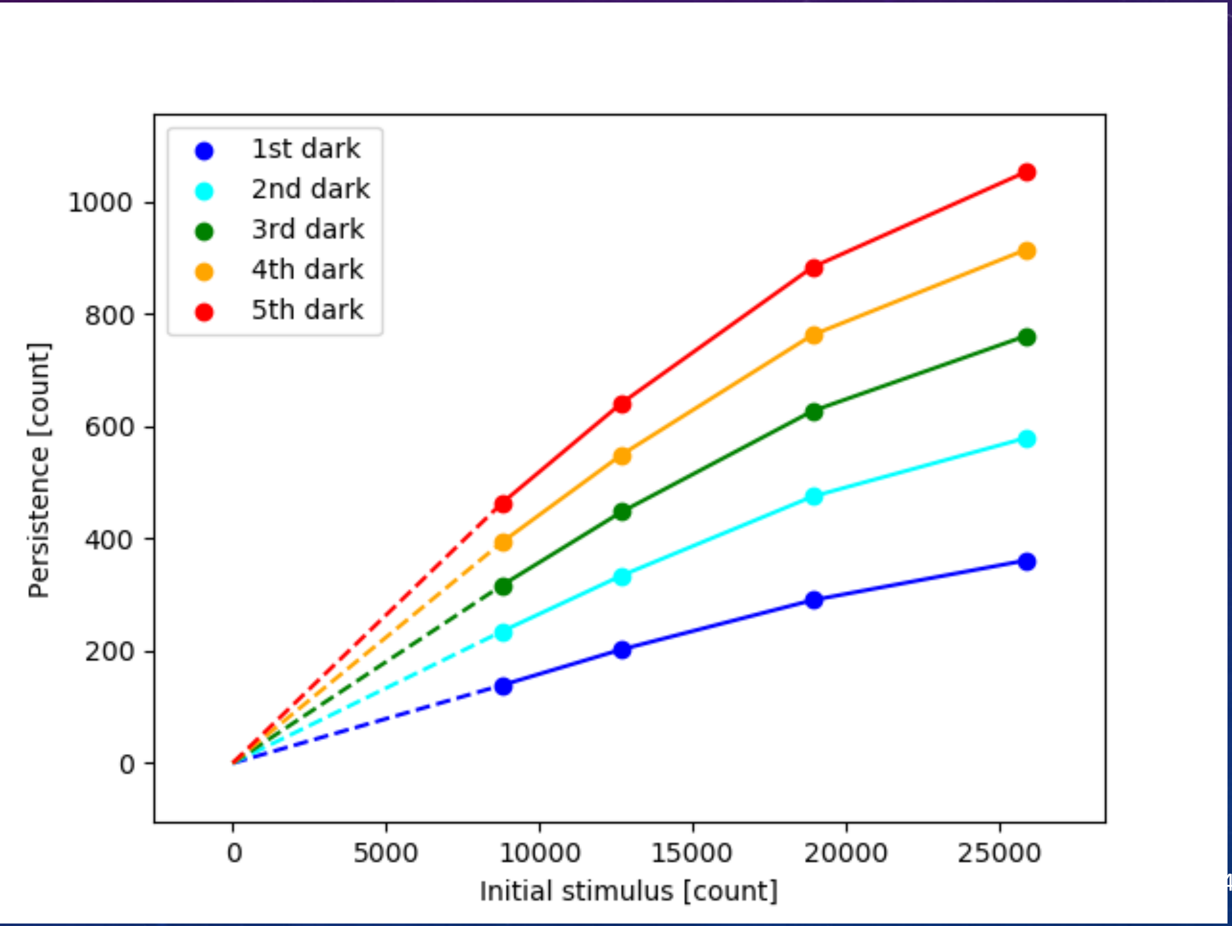
◆ 3 components fit

- Outside region:
    - (τ1, τ2, τ3) ~ (250, 2000, 20000) [sec]
    - (a1, a2, a3) ~ (100, 500, 4000) [count]
- Inside region:
    - (τ1, τ2, τ3) ~ (1000, 12000, -) [sec]
    - (a1, a2, a3) ~ (800, 4500, 0) [count]



Dependence on the initial stimulus

- Persistence seems to be proportional to the initial stimulus.
    - Persistence starts to saturate at >20000 counts?



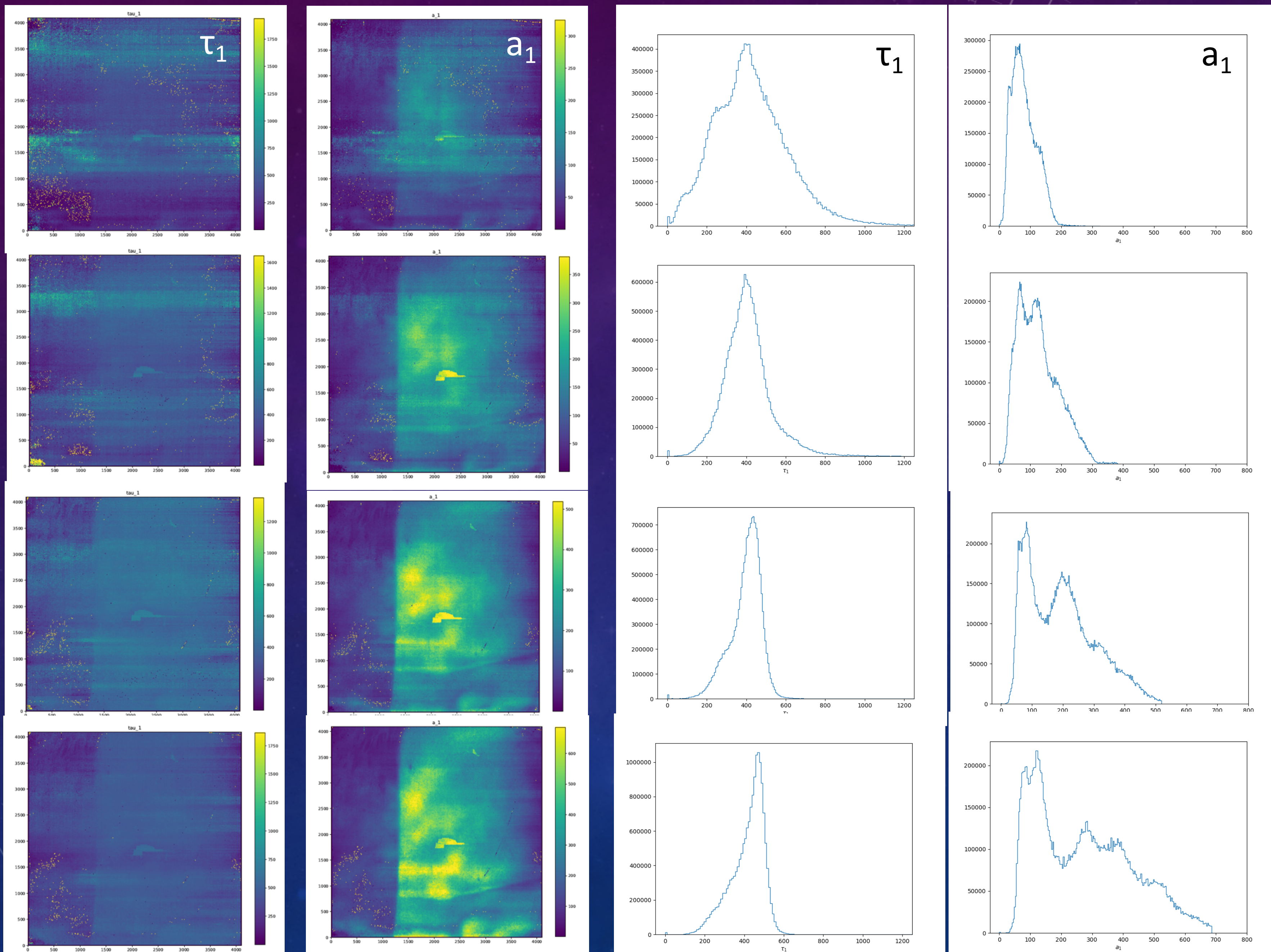
Dependence on the initial stimulus (2 component fit)

#3
8800

#4
12700

#5
18900

#6
25900
(t<2hrs)



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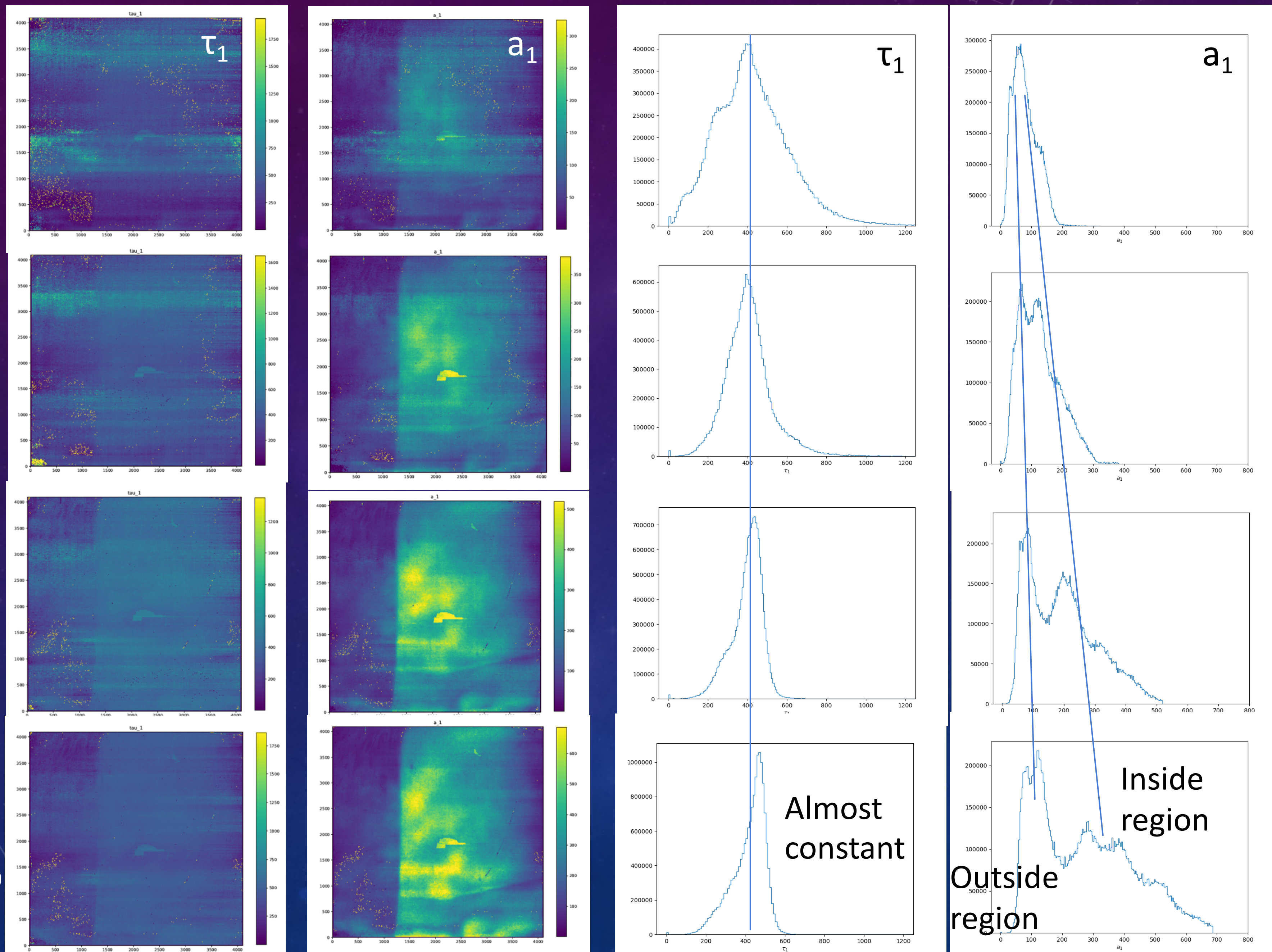
(t<2hrs)



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18900

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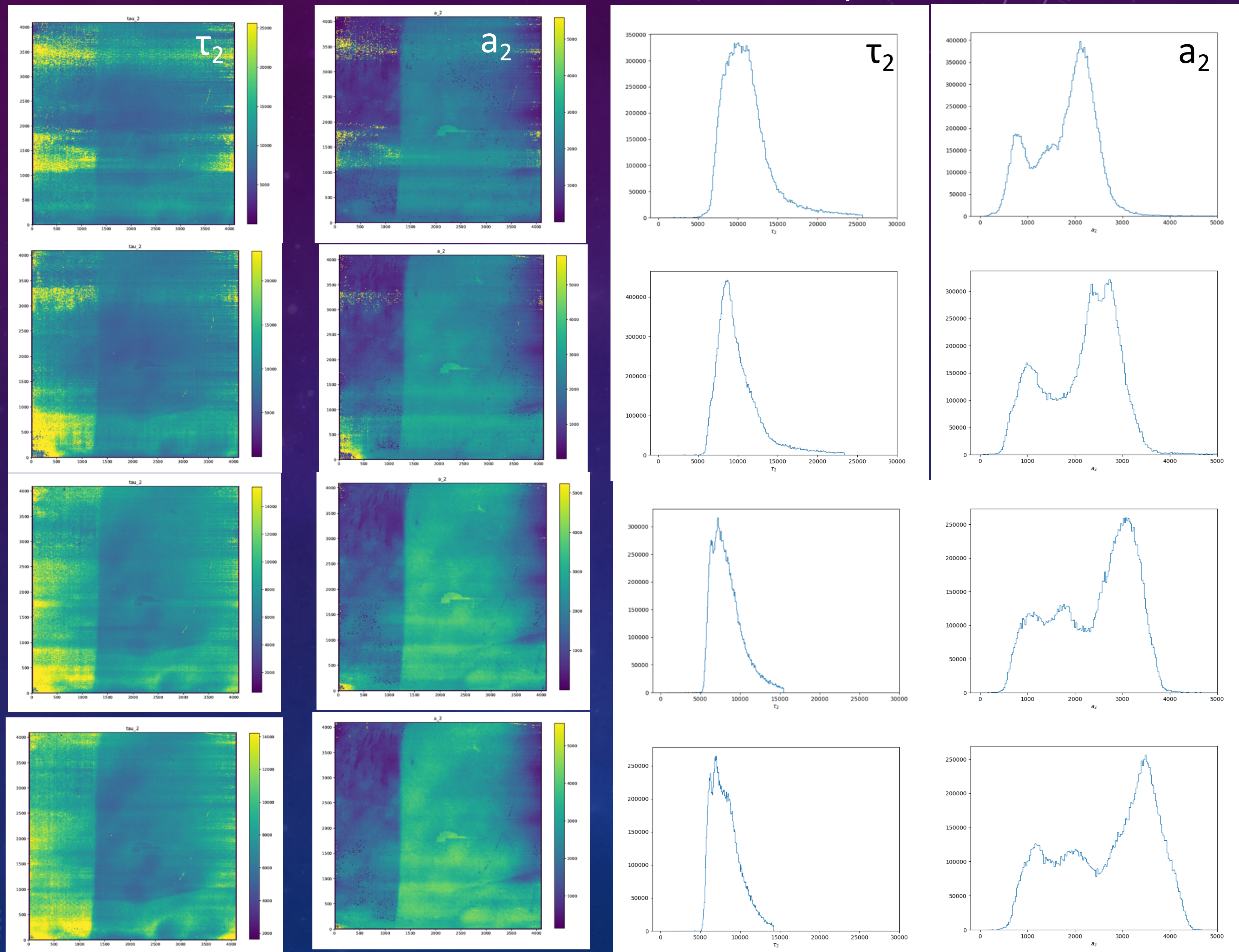
25900
(t<2hrs)



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8800

#4
12700

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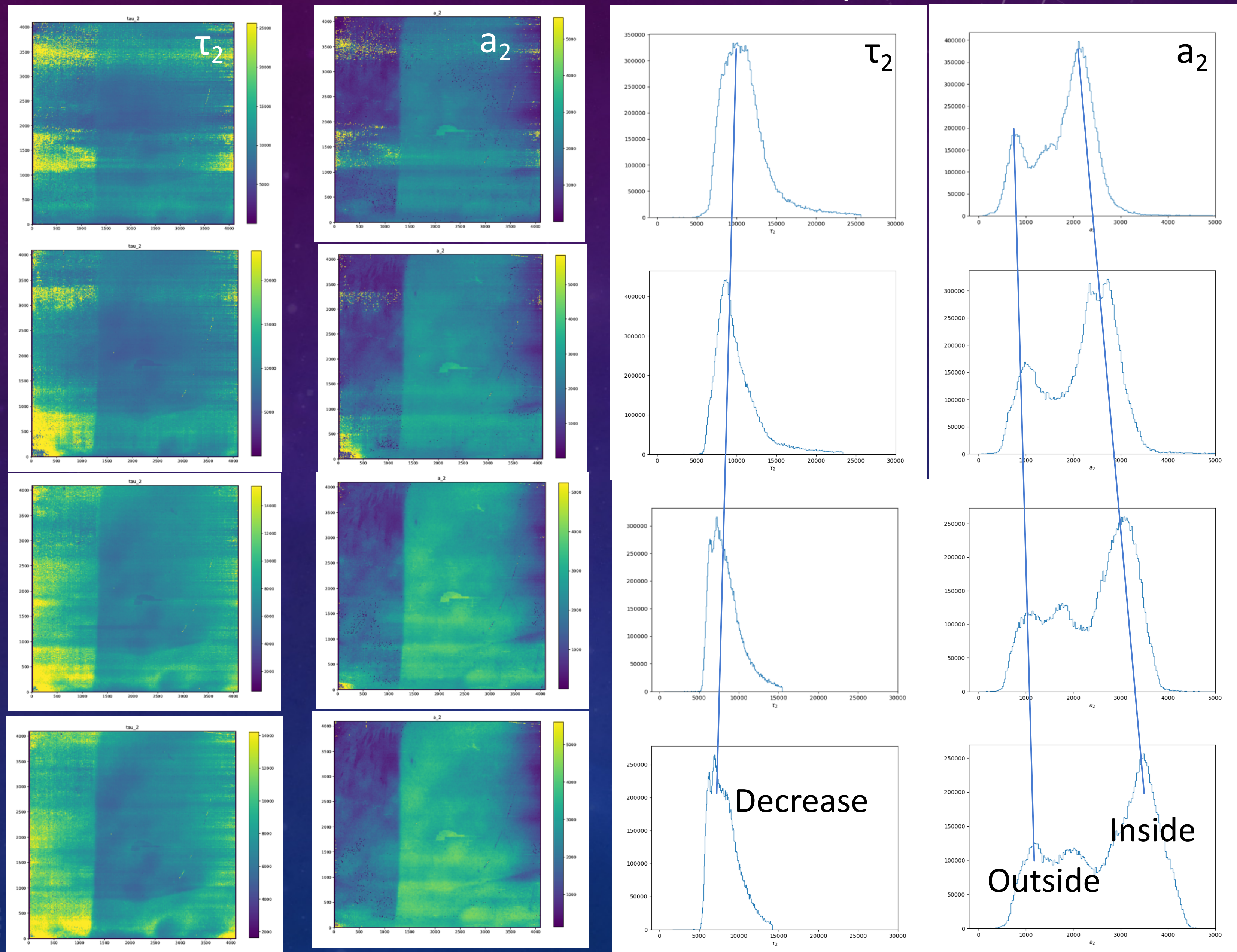
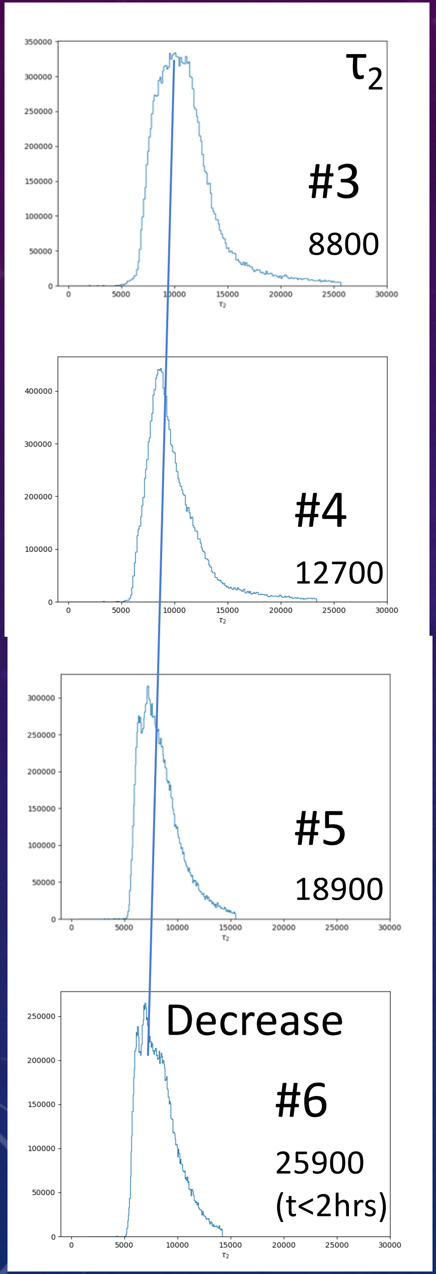
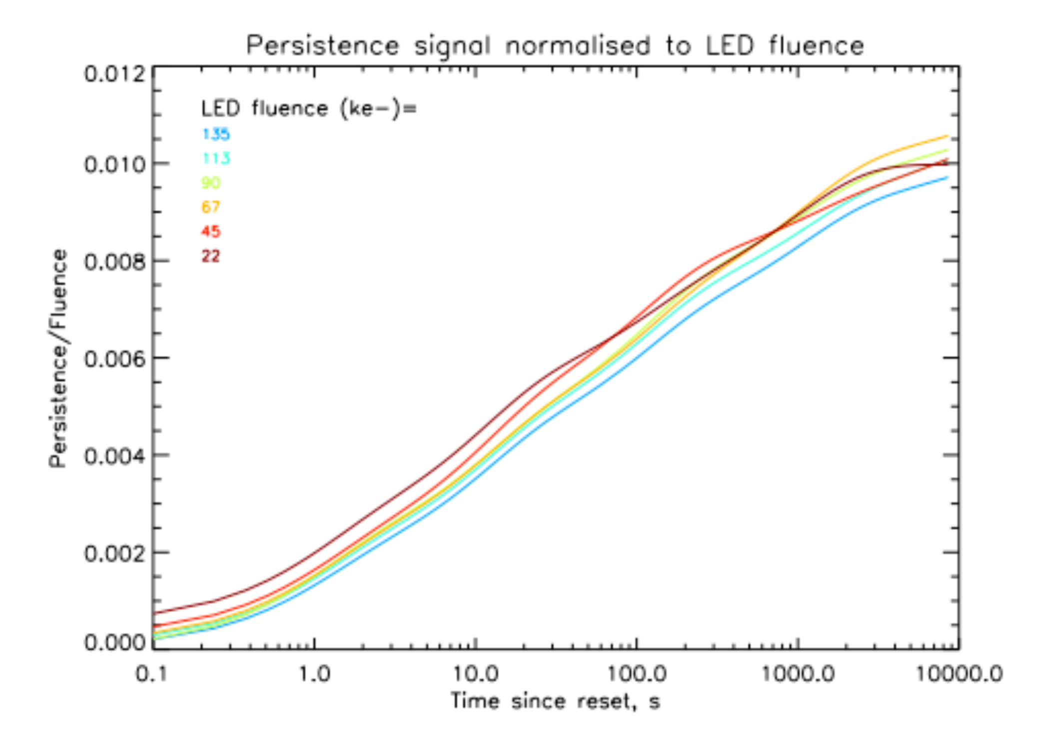


Dependence on initial stimulus?

2 components fit



- Does τ2 depend on the initial stimulus?
- Just a contamination of persistence signals from multiple flat frames?



Tulloch & George 2019 showed that the persistence curve does not depend on the initial stimulus.

FEEDBACK TO THE NEXT TEST

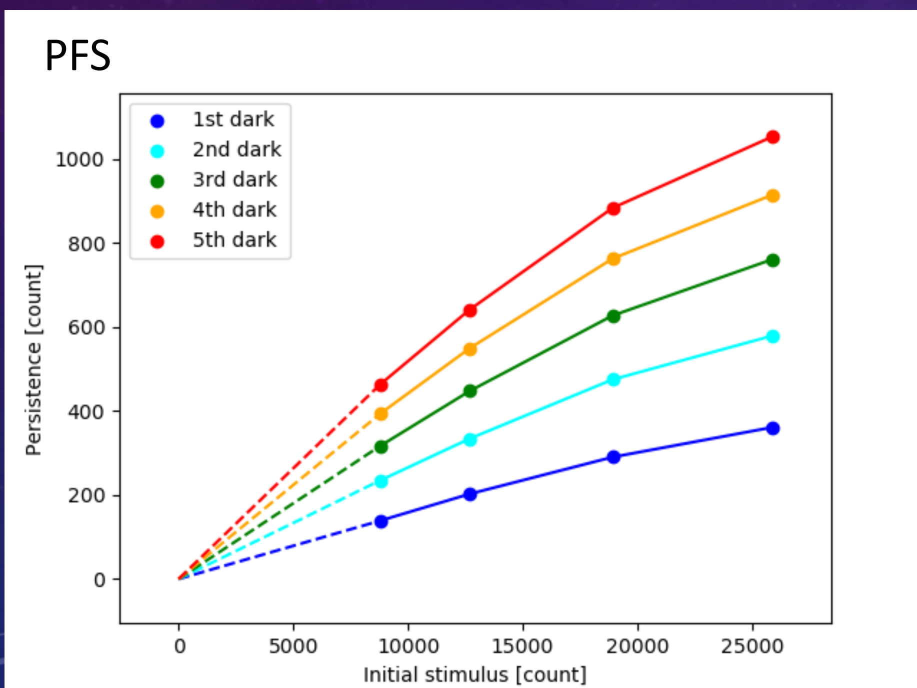
Toward the persistence correction of the PFS

- What was revealed about the PFS N1 H4RG persistence
  - The persistence decay curves can be fitted with the sum of >3 exponential functions with various timescales.
  - The persistence is likely to be proportional to the initial stimulus in a range of 10000~25000 counts.
  - Two or more distinct regions in the array have different persistence characteristics.
  - Extremely strong. (~10% of initial stimulus counts can be emitted as a persistence in total)
  - It takes a very long time (>5 hrs) to emit all the trapped electrons.
  - Variable time constants? Really?
  - $\tau 2$ in the 2 components fit depends on the initial stimulus? Really?
- What was not investigated at all
  - Dependence on the soak time.
  - How accurately can we remove the persistence image?
  - How accurately should we remove the persistence image?

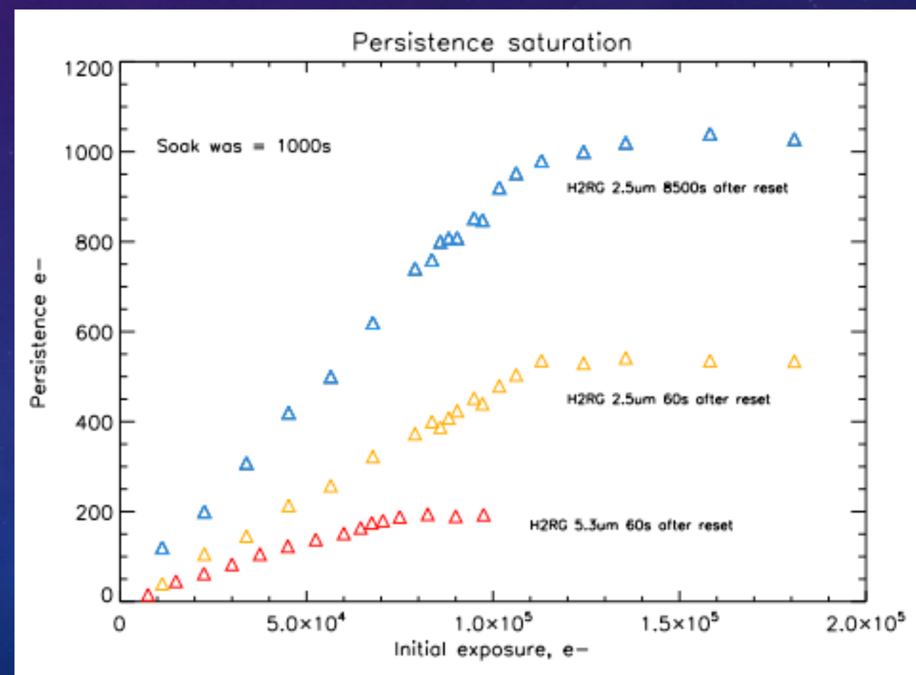
PFS array test plan

Dependence on the initial stimulus

- Do we need to know the relation between the persistence and initial stimulus at <10000 counts?
- Do we need to know the illumination level at which the persistence saturates?



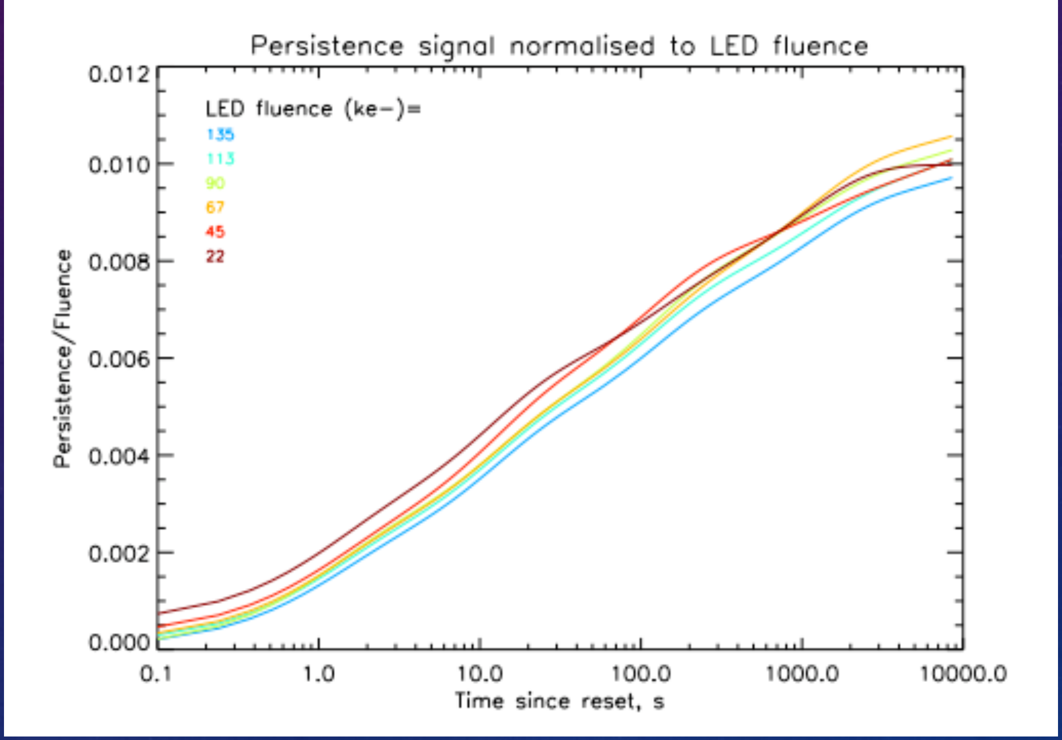
Tulloch & George 2019



PFS array test plan

Dependence on the initial stimulus

- Do we need to check whether the decaying time constants really depend on the initial stimulus?



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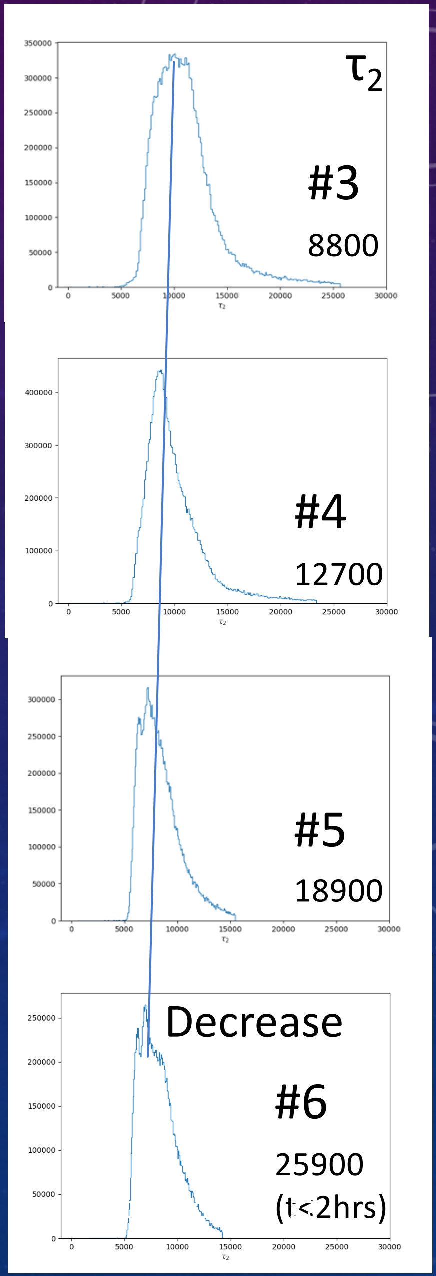
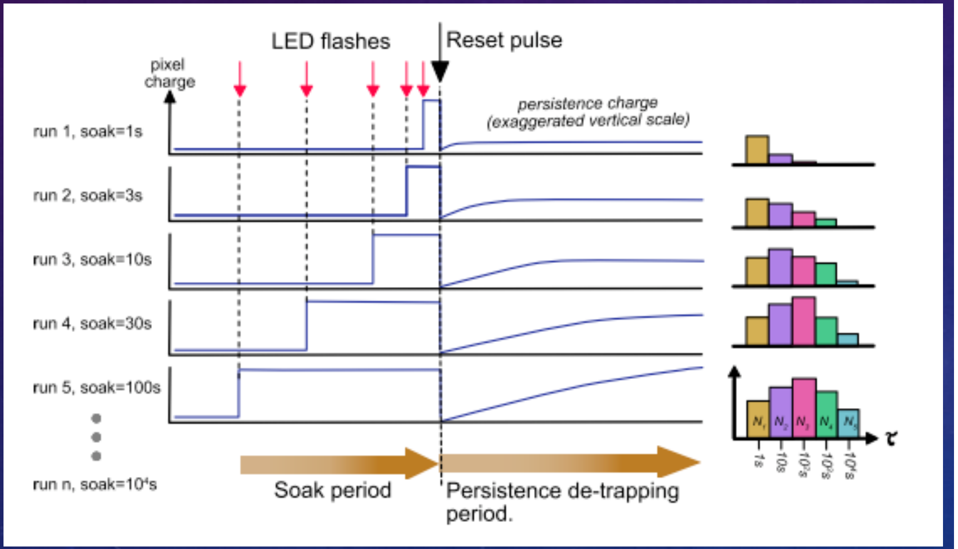
2 components fit



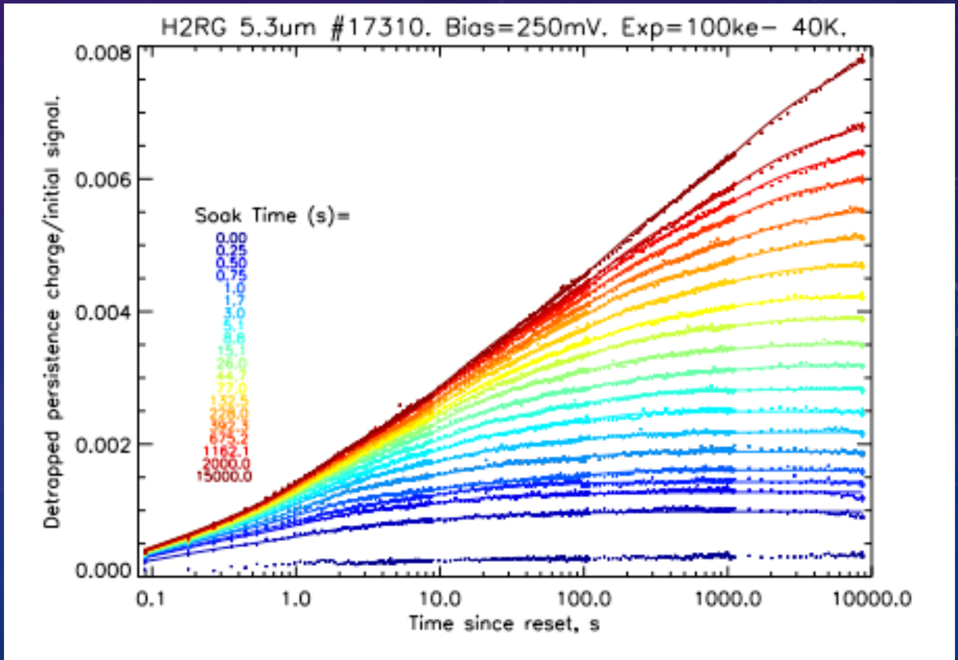
PFS array test plan

Dependence on the soak time

- The persistence dependence on the soak time should be examined.
  - In particular, it is important that the persistence data with the soak time that is similar to the planned exposure time of the PFS observations. (7.5 min/frame for astronomical observations? How about the calibration data, such as flat and comparison lamps?)



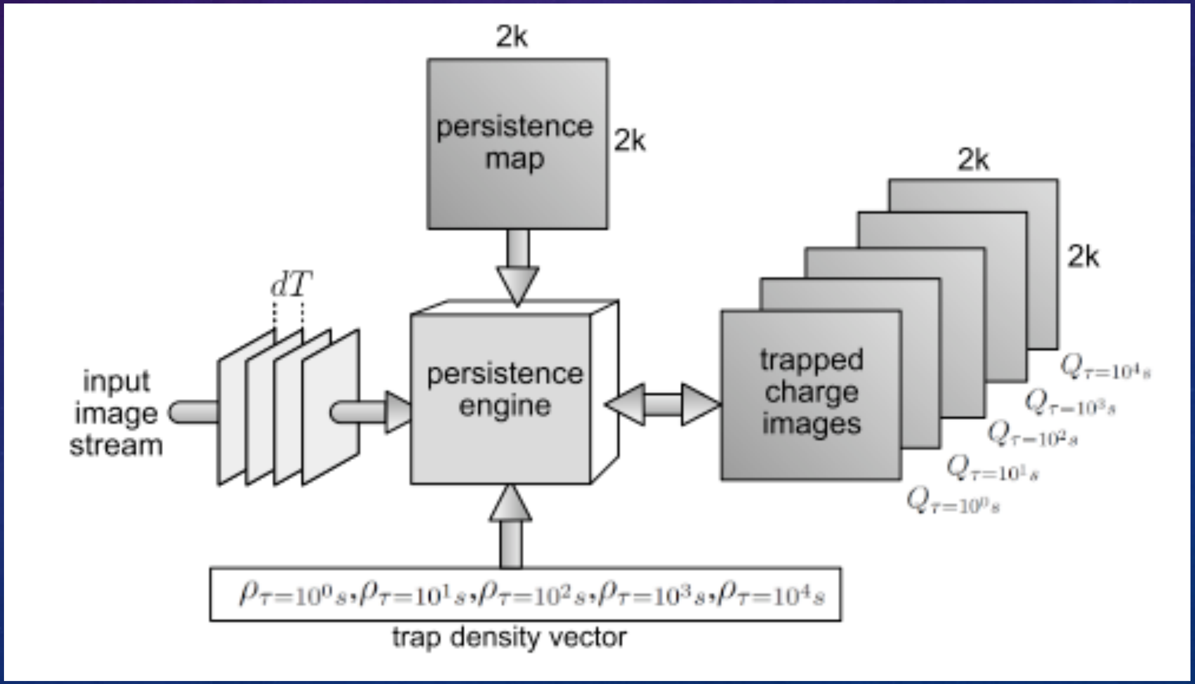
Tulloch & George 2019



PFS array test plan

Accuracy of the persistence model

- As far as I know, the previous models of the persistence assumes that the persistence of all pixels follows the same decaying curves for simplicity.
- How accurately can we remove the persistence with the simple model? Is it enough for our purpose?
- If we are not satisfied with the simple model, will we calibrate the persistence curves pixel by pixel? Then, how many cycles are needed to achieve the requirement to the accuracy?



PFS array test plan

- Dependence on the initial stimulus
  - Do we need to know the relation between the persistence and initial stimulus at <10000 counts?
  - Do we need to know the illumination level at which the persistence saturates?
  - Do we need to check whether the decaying time constants really depend on the initial stimulus?
- Dependence on the soak time
  - The persistence dependence on the soak time should be examined.
- Model accuracy
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These items can be examined partly with current experiment dataset.

PFS array test plan

New data is needed for these issues.

- Dependence on the initial stimulus
  - Do we need to know the relation between the persistence and initial stimulus at <10000 counts?
  - Do we need to know the illumination level at which the persistence saturates?
  - Do we need to check whether the decaying time constants depend on the initial stimulus?
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  - The persistence dependence on the soak time should be examined.
- Model accuracy
  - How accurately can we remove the persistence with the simple model? Is it enough for our purpose?
  - If we are not satisfied with the simple model, will we calibrate the persistence curves pixel by pixel? Then, how many cycles are needed to achieve the requirement to the accuracy?

These issues can be examined partly with the data of previous experiments.

PFS test

In any case, we need…

- Data without the USB noise.
- Data without overlaps of the persistence.