From ground characterization of the 16 H2RGs to the in-flight commissioning of the NISP* Instrument of Euclid**

SLAC, ISPA24

Rémi Barbier

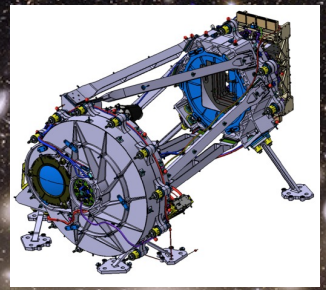
NISP Detector Scientist

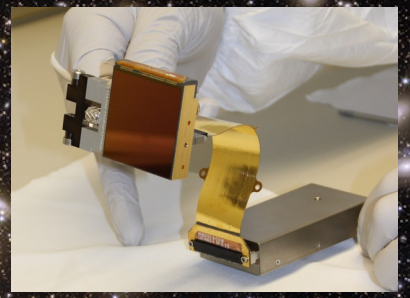
On behalf of NISP

Instrument Development Team

Euclid Consortium

*Near Infrared Spectrometer and Photometer





Detector Characterization Laboratory

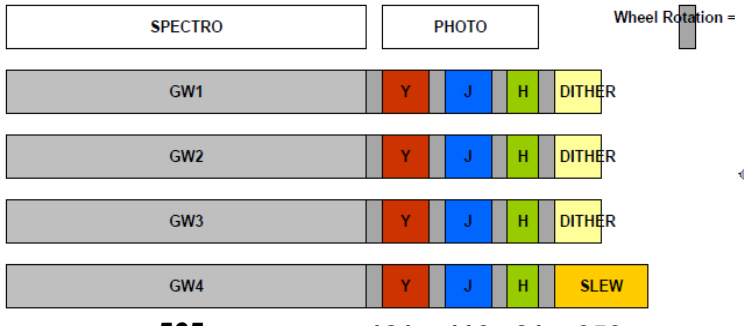
GSFC

** Disclaimer : every thing you will see in this presentation is obtained by the IDT and are not the results of the Euclid pipeline.

Near Infrared Spectrometer and Photometer

NISP Reference Observation Sequence [ROS]

- **Two RO modes**
- **4 dithers**



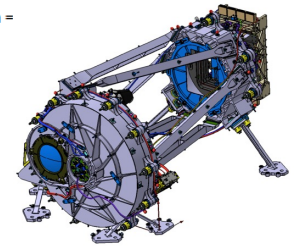
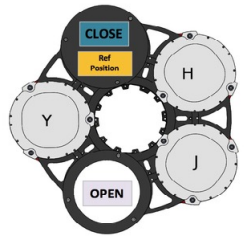


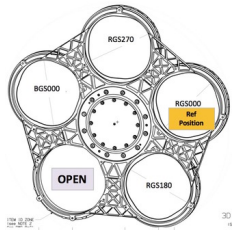
PHOTO mode

Filter Wheel

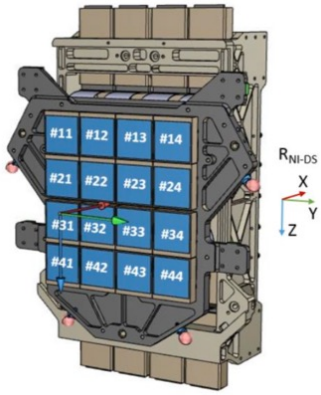


SPECTRO mode

Grism Wheel



4x4 H2RGs mosaic



The nominal MACC(G,F,D)

- **MACC(15,16,11) = Spectro Exp. Time ~576s**
- **MACC(4,16,4) = Photo Exp. Time ~116s**

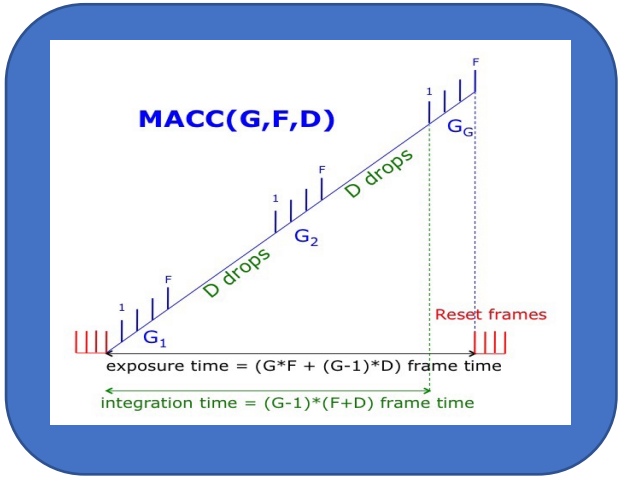
On Board Data Reduction:

- **1 ramp to one slope = flux = ADU/fr**

Conclusion :

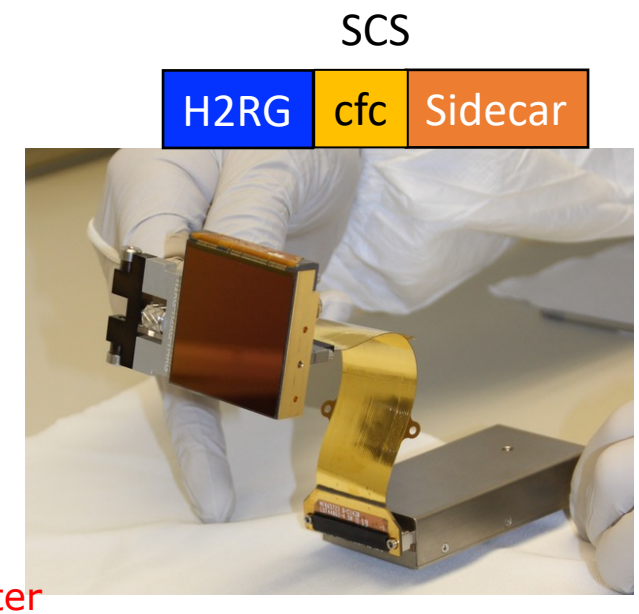
- **Accurate calibration of the pixel response only based on slope of the ramp is challenging**

Multi-Accumulation



16 H2RGs + Sidecars

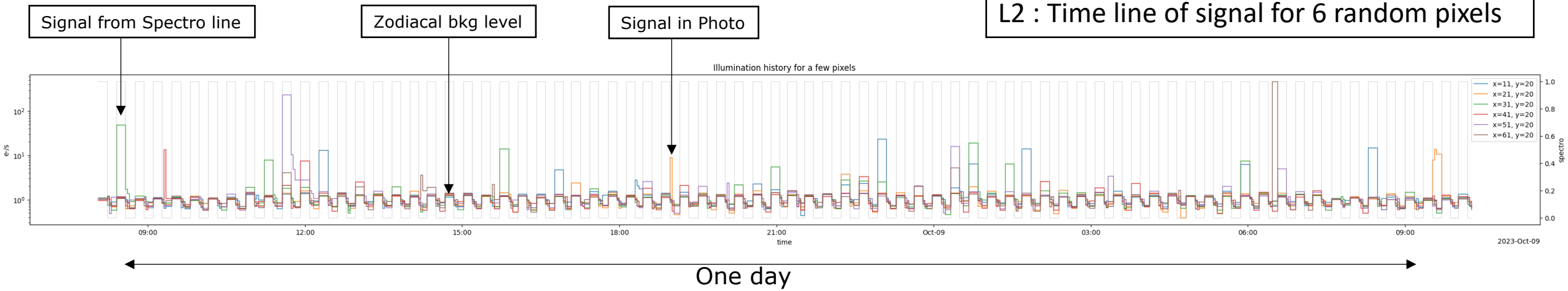
Configurations



- SCA: H2RG @ OT(L2) = 92K
  - Cut-off: 2.3um
  - Pixel clock: 100 kHz – slow readout mode
  - 32 channels in //
  - Frame time ~1.4548s
  - Buffered mode
  - Bias ~500mV, Diode FWC~120ke
- SCE : Sidecar @ OT = 136K
  - Single ended => baseline adjustment with tunable voltage register
  - Preamp Gain: 15dB (x ~5)
  - SAR ADC: Sat. ~ 85 ke- before the FW of the diode
  - Reference pixel subtraction : Mean of Top & Bottom + LR Sliding Window (5)Med – computed in the DCU
  - Euclid Firmware : SUTR and Single Pixel Reset (for IPC) Readout modes
- Downlink 5 raw pixel lines : all frames of MACC groups

Test as in flight !

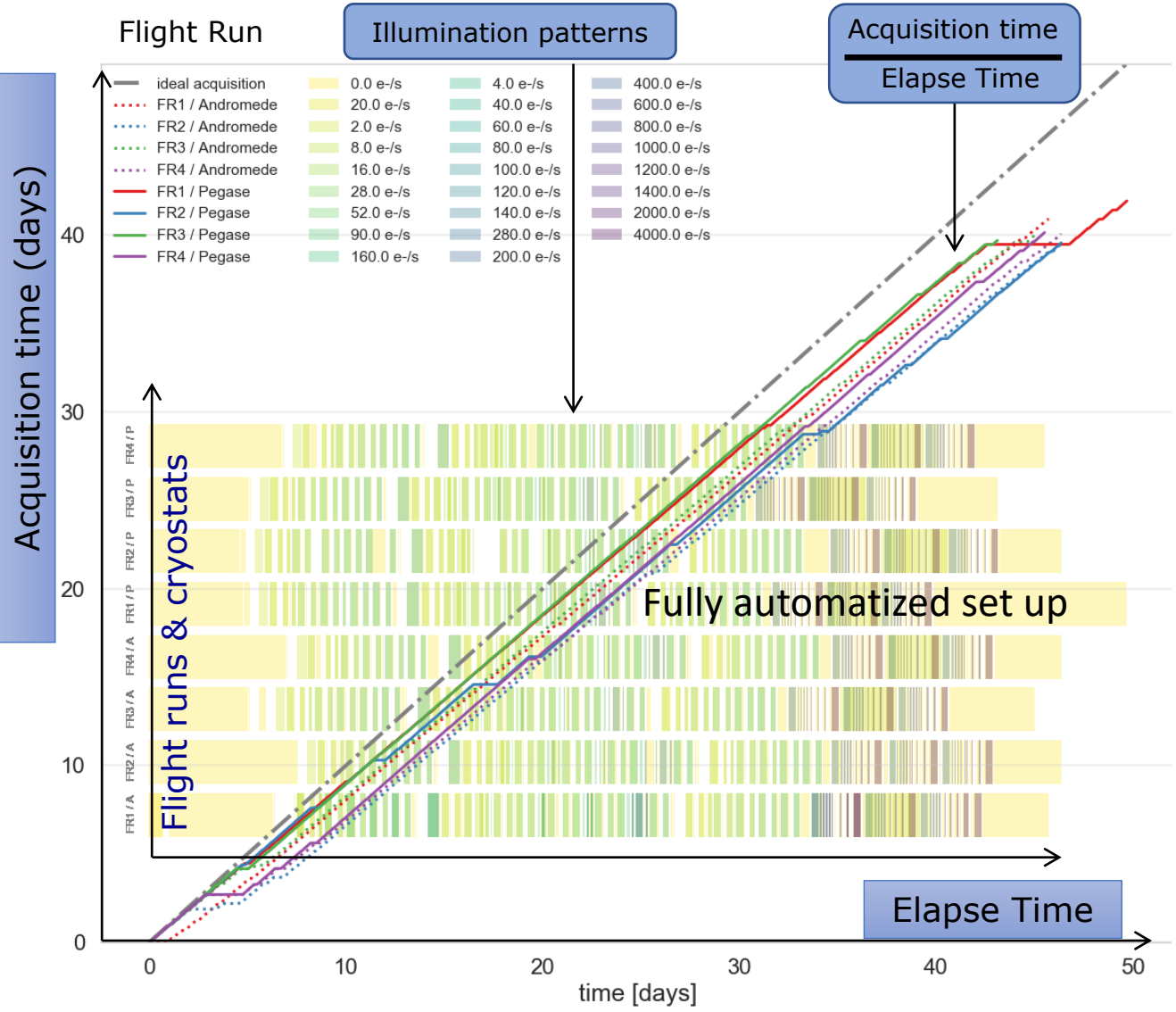
Reference Observation Sequence [ROS]
L2 : Time line of signal for 6 random pixels



- Most of the time the pixel “see” the zodiacal bkg
- What is the best test flow for this type of ROS ?

Test as in Flight ? complexity and efficiency

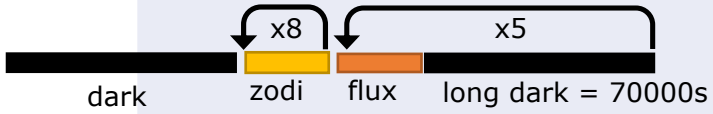
CPPM/IP2I Test flow



Test objective	Test configuration
IPC – SPR	Array: Rst — 16: dark — Grid 8x8: Rst — 16: dark -- x64 grids
Baseline, Rst Noise	16: dark -- 1000 ramps
Dark & Noise	396 (spe) or 76 (pho): darks -- 100 ramps
NL Calibration	396 or 76: flux flux -- flux 30-50 ramps
NL /w zodiacal bkg	396 or 76: flux Zodi bkg 2e-/s flux -- 30 seq. of 2 ramps
Persistence short NL w/ dark	396 or 76: flux — 800 (~20') dark — flux -- 30 seq of 2 ramps
Persistence long NL /w dark	396 or 76: flux — 8000 (~2h) dark — flux -- 20 seq. of..
ROS /w zodiacal bkg & /w flux in one seq.	GW1 Y J H DITHER / GW2 Y J H DITHER / GW3 Y J H DITHER / GW4 Y J H SLEW -- 5 seq.

Gnd test: dark or zodiacal level before illumination

Conversion factor : 1 ADU/fr ~ 1.4 e-/s	Workflow	Duration acq.+qc	Disk (GB)	Cycle	Iteration	Sequence	# Ramps	# Frames	flux (e/s)	
18280 FR4 : Run 59 : flux after zodi/dark	latency_90	15h00	290.7GiB	cycle_1	1	seq_1	1	5000	0	dark
						seq_2	8	400	2	Zodiacal emulation
				cycle_2	5	seq_1	1	400	90	flux
						seq_2	1	5000	0	dark

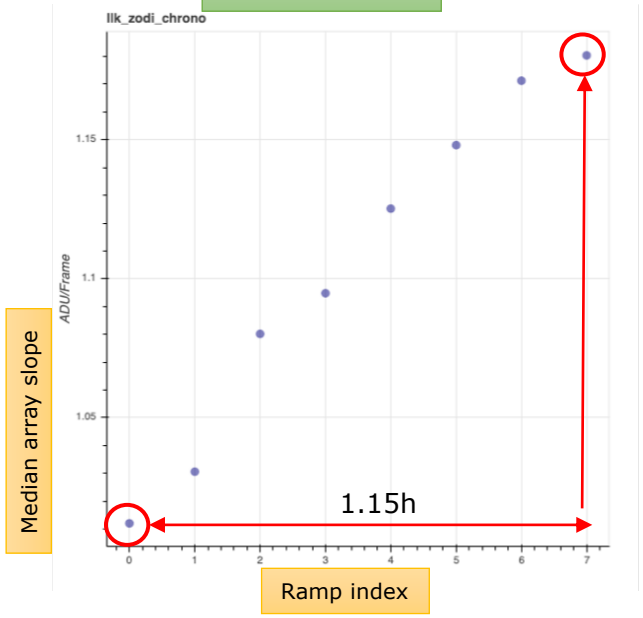


zodiacal emulation

Zodi
c_1_seq_2

+20% => persistence accum.
settling time > 1h

<zodi> ~ 1.75 e-/s



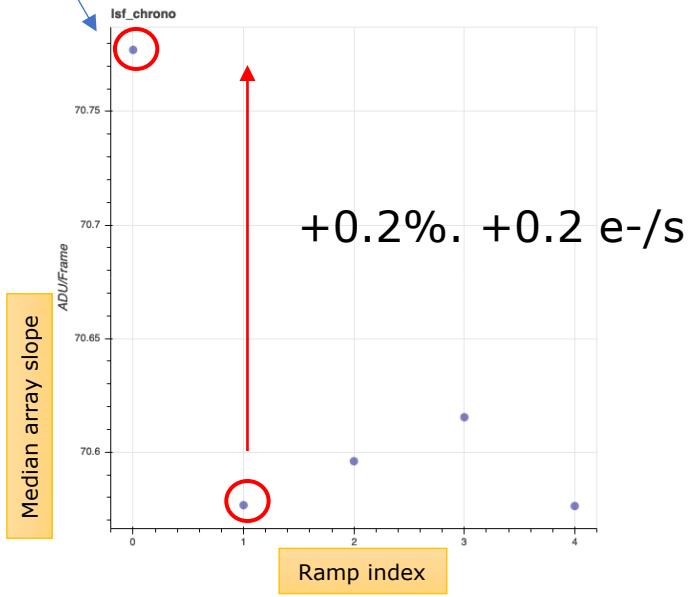
High flux

flux after zodi
c_2_seq_1_r=0

flux after dark
c_2_seq_1_r>0

+0.2% => persistence from zodiacal bkg

<flux> ~ 98 e-/s



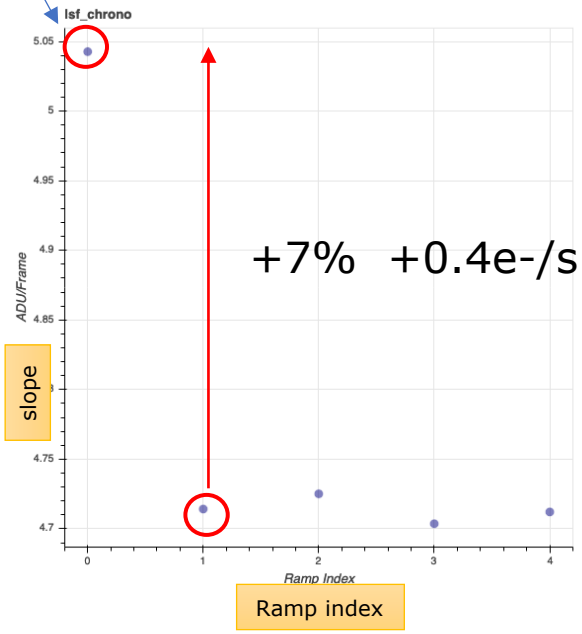
Low flux

Flux after Zodi
c_2_seq_1_r=0

flux after dark
c_2_seq_1_r>0

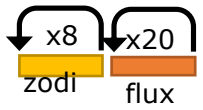
+7% => persistence from Zodiacal

<flux> ~ 6.6 e-/s

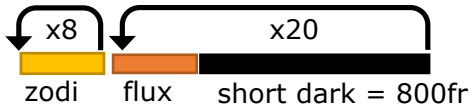


➢ Zodiacal persistence contribution to the signal is negligeable for high flux – not negligeable to low flux

flux /w & /wo dark interleaved



Same illumination level



flux after Zodi c_2_seq_1_r=0	flux after flux c_2_seq_1_r>0

+4.6% => due to persistence accumulation :"Self-persistence"

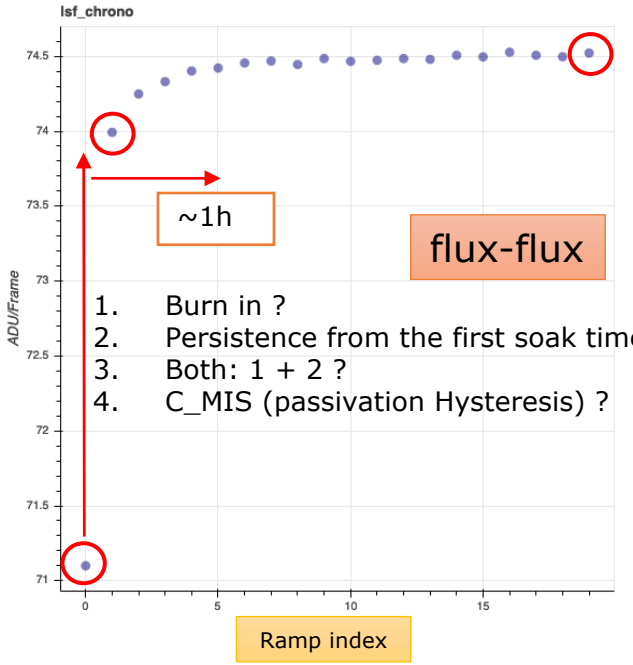
<flux> ~ 105 e-/s

Delta ~7 e-/s => 7 %

flux after Zodi c_2_seq_1_r=0	flux after dark c_2_seq_1_r>0

+1.25% => due to persistence acc.

<flux> ~ 98 e-/s

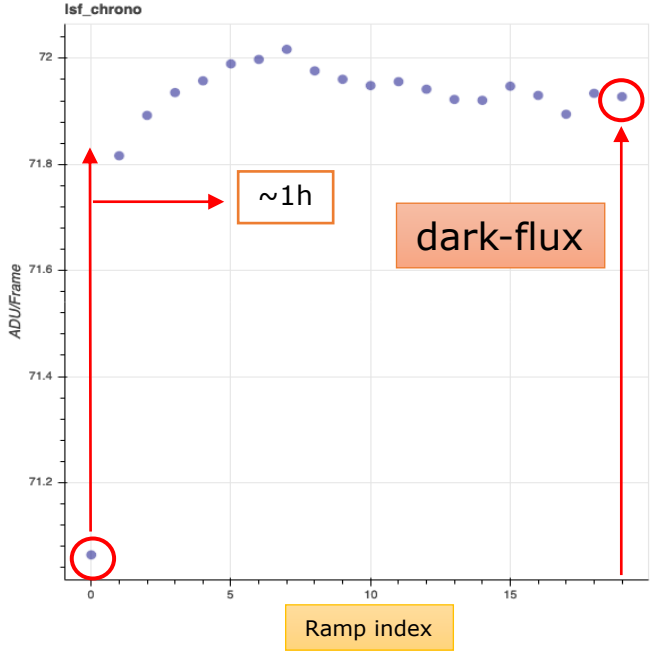


1. Burn in ?
2. Persistence from the first soak time ?
3. Both: 1 + 2 ?
4. C_MIS (passivation Hysteresis) ?

ROS = 4 dithers (spe + pho Y – J - H)

spectro photo

- "Self-persistence" => systematic errors for Y, J, H bands ?
- Spectro after slew in the dark ?



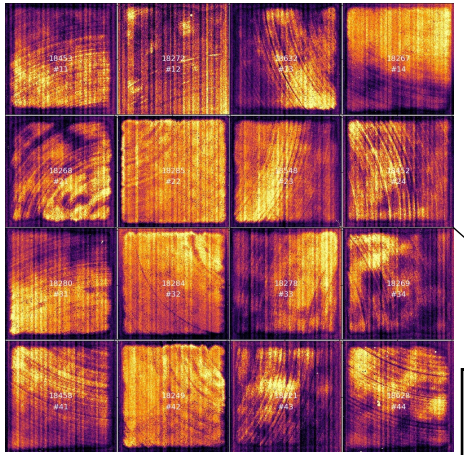
L2* vs Gnd

* Data from Commissioning and PV but not from the SGS pipeline

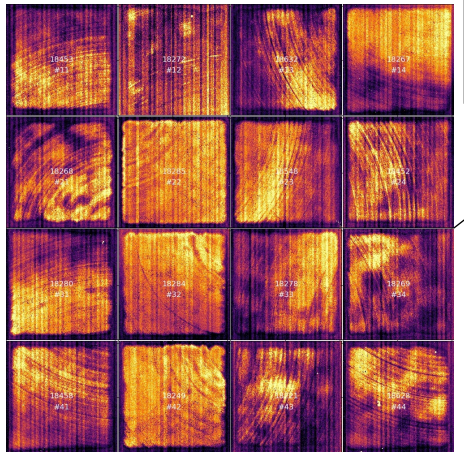
L2 : Baseline = first group (G1) after reset

- Different OT => baseline adjustment @ L2
- Verification on per pixel baseline shift = > Gnd-L2 shows some features on 4 detectors
- => Same feature on the Flat Field

Baseline in L2

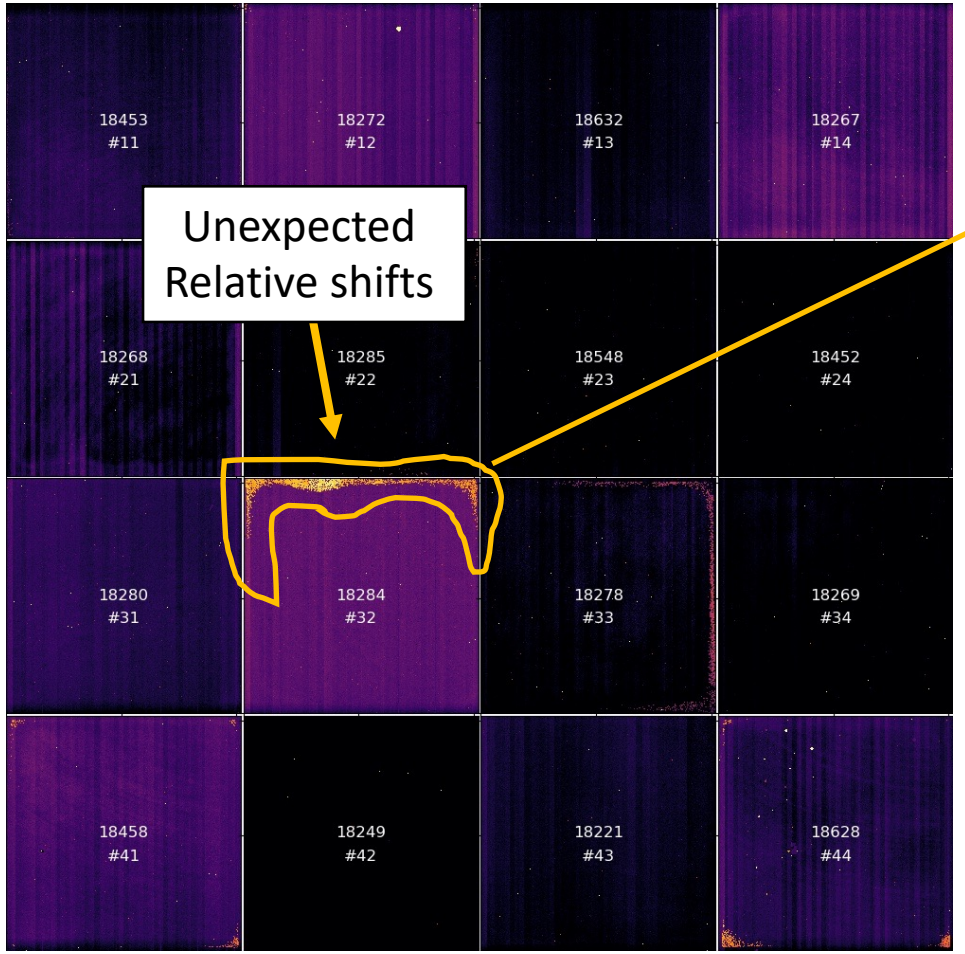


Baseline Gnd

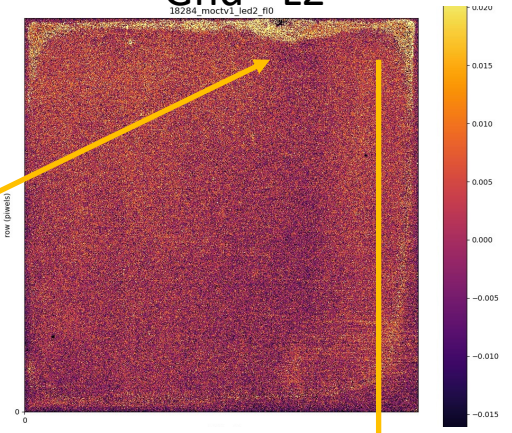


Per pixel difference => sanity check in L2

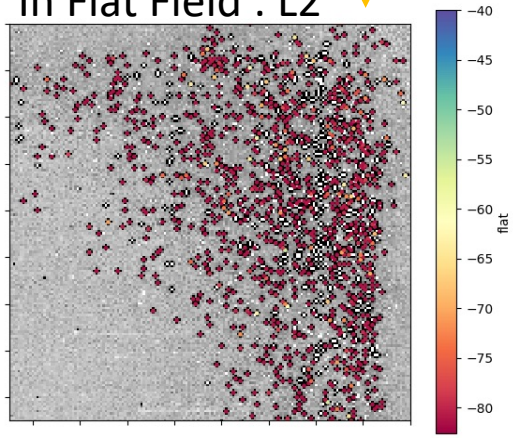
Baseline difference: Gnd –L2



Normalized FF difference
During CU commissioning
Gnd - L2

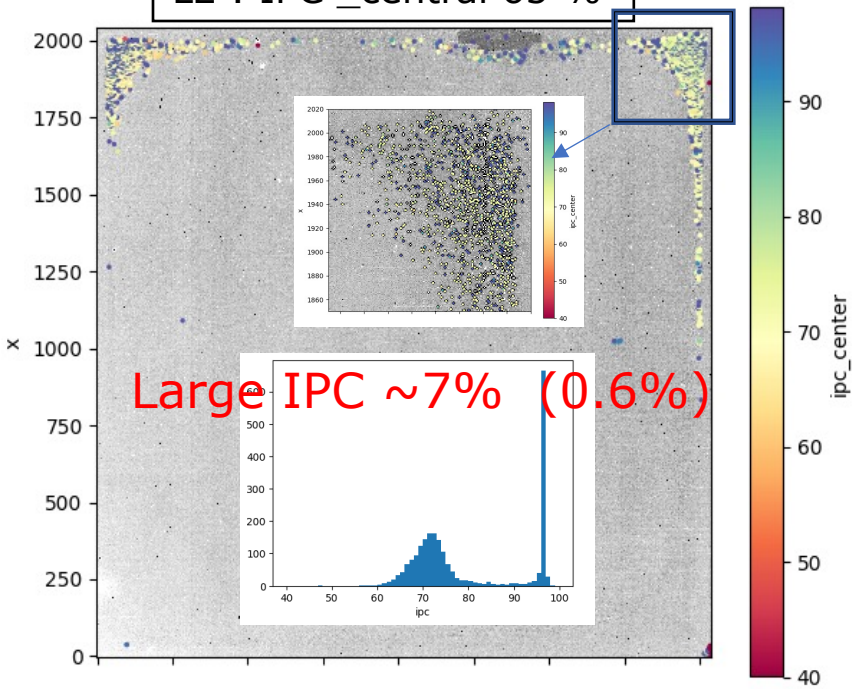


Selected features
In Flat Field : L2

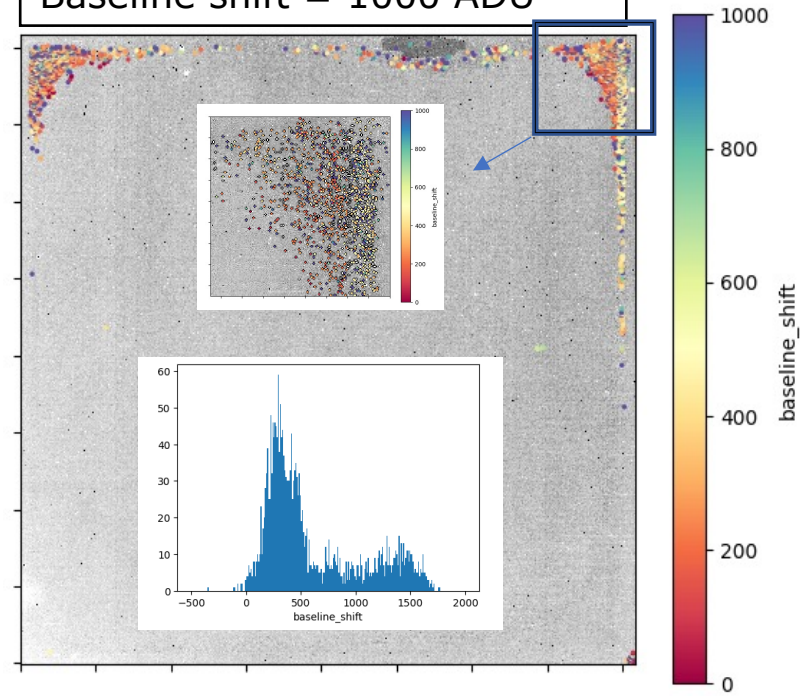


18284 Baseline shift & Flat field & IPC correlations

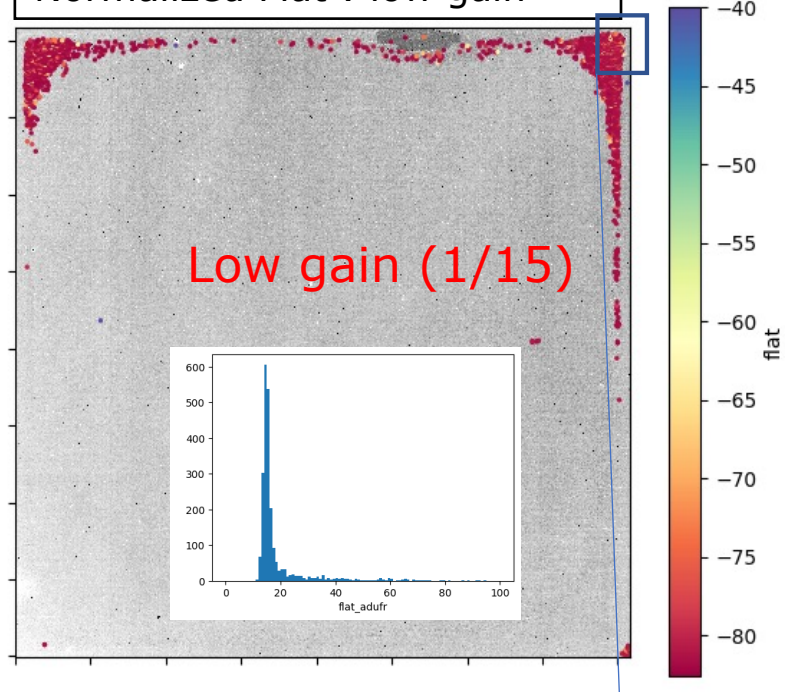
L2 : IPC _central 65 %



Baseline shift = 1000 ADU

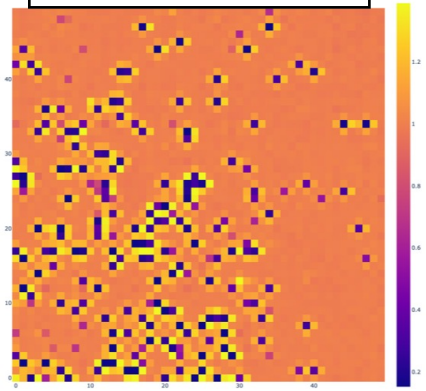


Normalized Flat : low gain



Curtosy of Simon Conseil

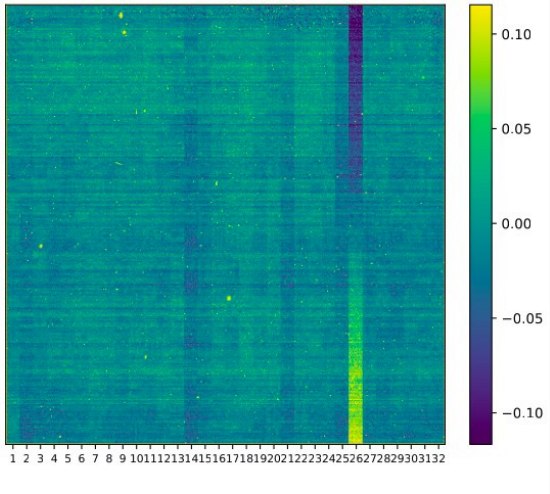
Zoom on FF



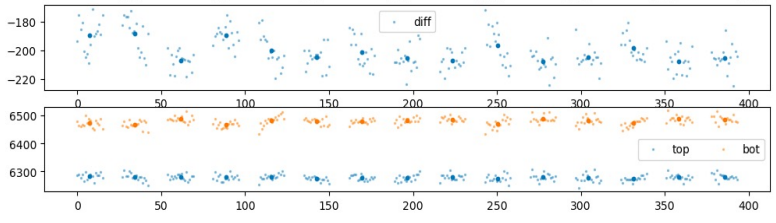
- **no** major impact on the Euclid survey (if the number of features remains as it is today)
- But the root cause is still unknown

L2 : “unstable” channels

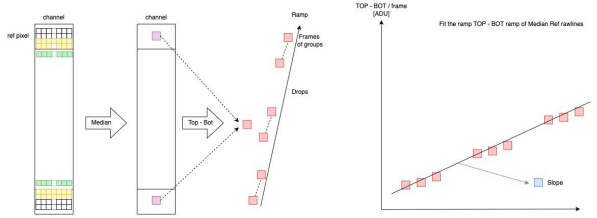
One noisy ramp image



Raw lines on reference pixels (2 Top- 2 Bottom)

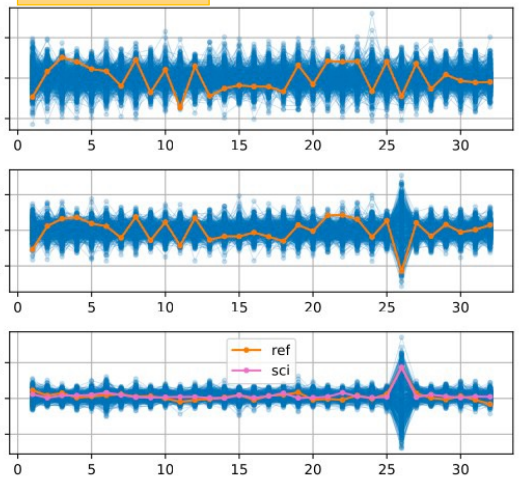


MACC 15,16,11

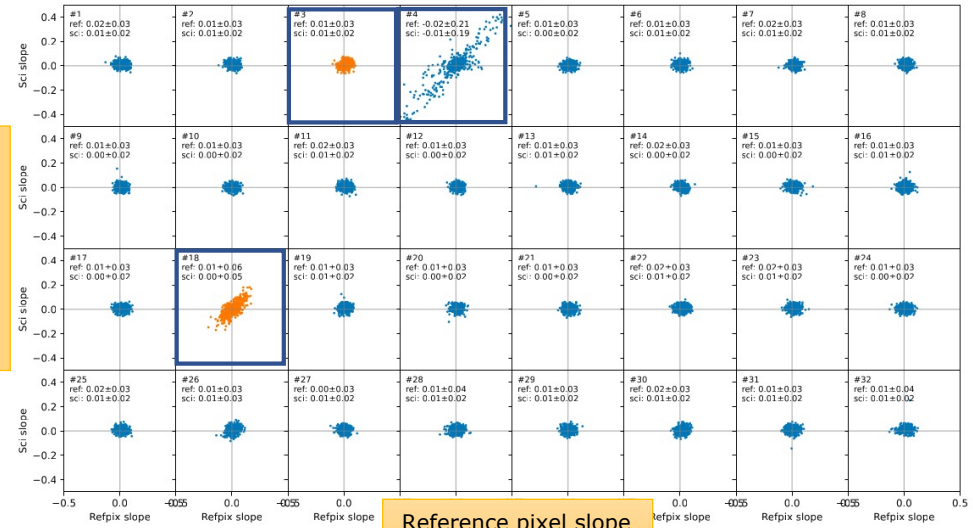


Ref pix :
Ramp of the
Top – Bot

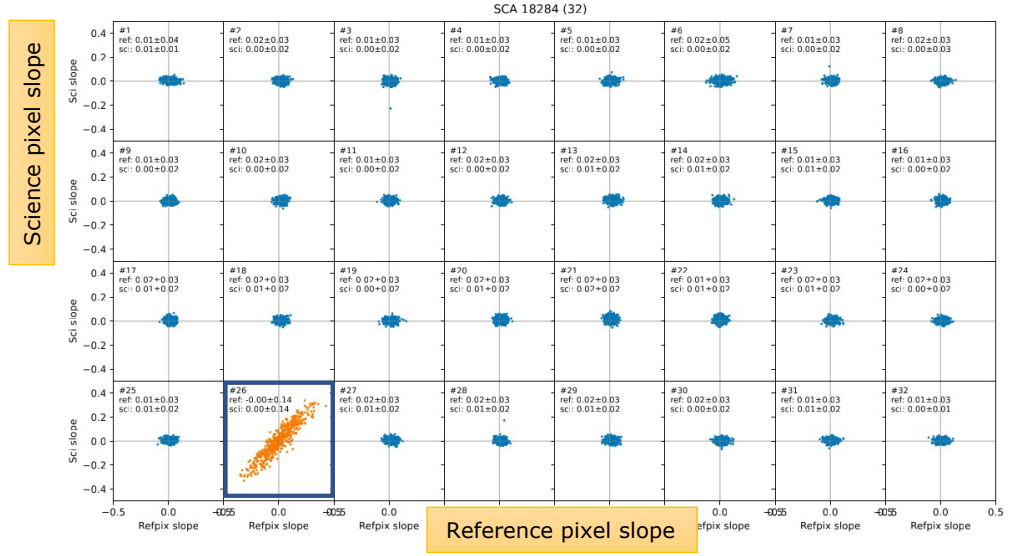
100 ramps



100 dark ramps in photo mode / 32 channels



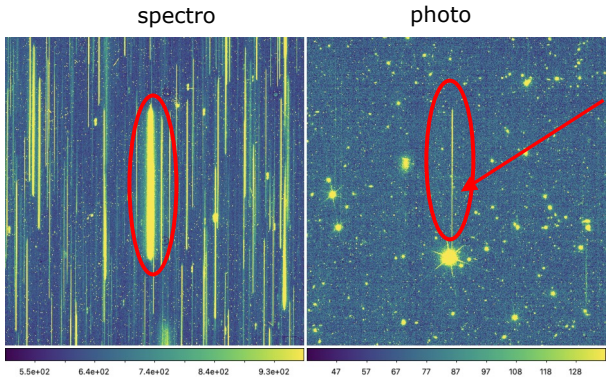
seen as unstable on Gnd



- SGS correction implemented :thanks to the RAW lines on Ref pixels
- Channel instabilities can be thermal cycling dependent

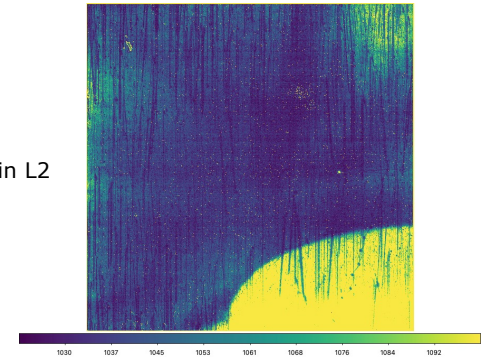
Curtesy of Simon Conseil

L2 Persistence is as expected : L2 vs Gnd



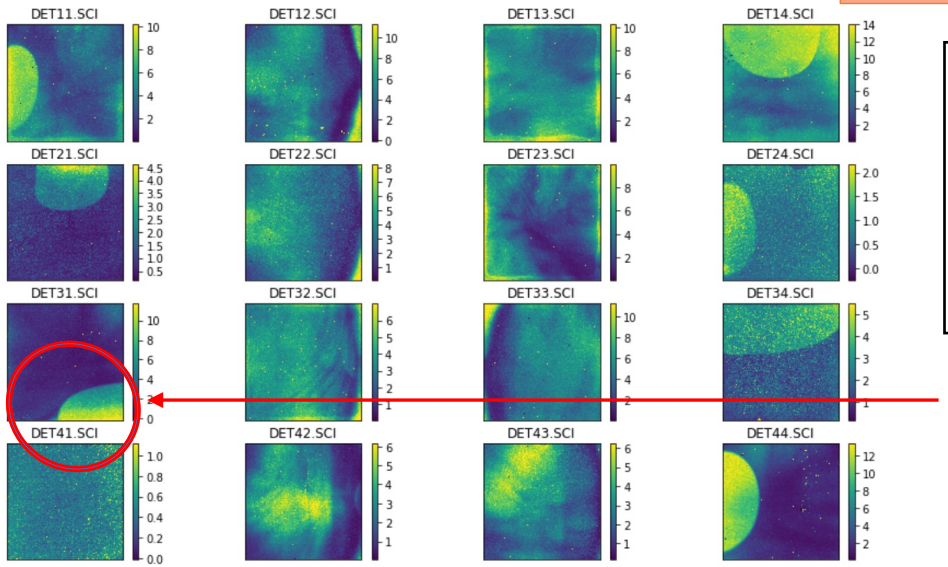
Persistence from spectro line

Persistence image after illumination in L2

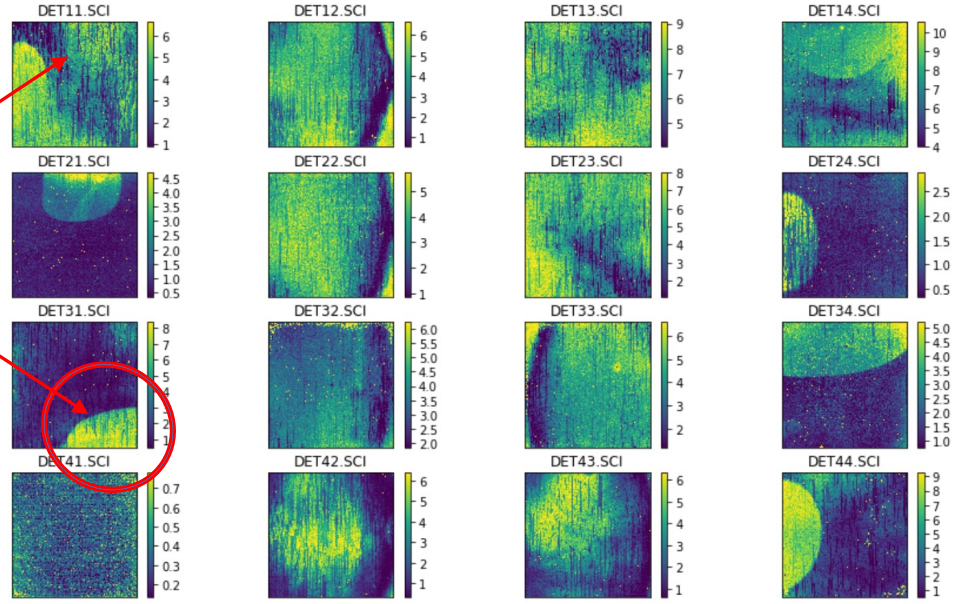


Persistence images in the dark after illumination

GnD



L2



- Spectro lines from previous illuminations give less persistence in the Cal Block Persistence !

Curtesy of Bogna KubiK

- L2 Persistence level and time constants are similar to Gnd values
- Today Euclid SGS applies mask on pixels with high persistence but persistence correction is planed

Non linearity correction

Systematics ?

Non Linearity polynomial correction Method

- $y(x_i)$ signal ramp in ADU from MACC
- $x_i = G_i$ => 15 or 4 (spe or pho)

- $P(x_i)$ Orthogonal polynomials computed for each basis
- Alpha = Y(x) projected on P(x)

- beta_1 as the "linear" flux

$$y(x) = \beta_0 + \beta_1 x + \cdots + \beta_N x^N = \sum_{i=0}^{N} \beta_i x^i$$

$$P_i(x) = a_{i0} + a_{i1}x + \cdots + a_{ii}x^i = \sum_{i=0}^{i} a_{ij}x^i$$

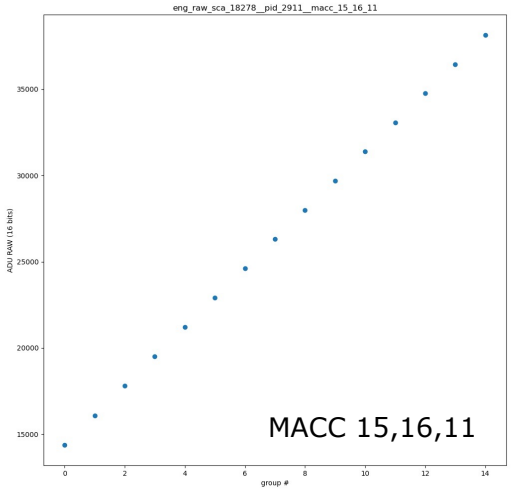
$$\beta_j = \sum_{i=j}^{N} \alpha_i a_{ij}$$

$$y(x) = \alpha_0 P_0(x) + \alpha_1 P_1(x) + \cdots + \alpha_N P_N(x) = \sum_{i=0}^{N} \alpha_i P_i(x)$$

$$\alpha_m = \langle y, P_m \rangle = \sum_{i=1}^{D} y_i P_m(x_i) = \sum_{i=1}^{D} y_i \sum_{j=0}^{m} a_{mj} x_i^j$$

15 groups of the spectro ramp MACC(15,16,11)

Raw Eng Mode
=> 15 groups sent to GnD

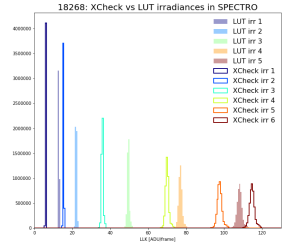


- **beta_1** : "linear" reference flux
- **Phi** = On board flux

NL correction

polynomial Fit (deg 3 or 4)

beta_1 = P_4(Phi)

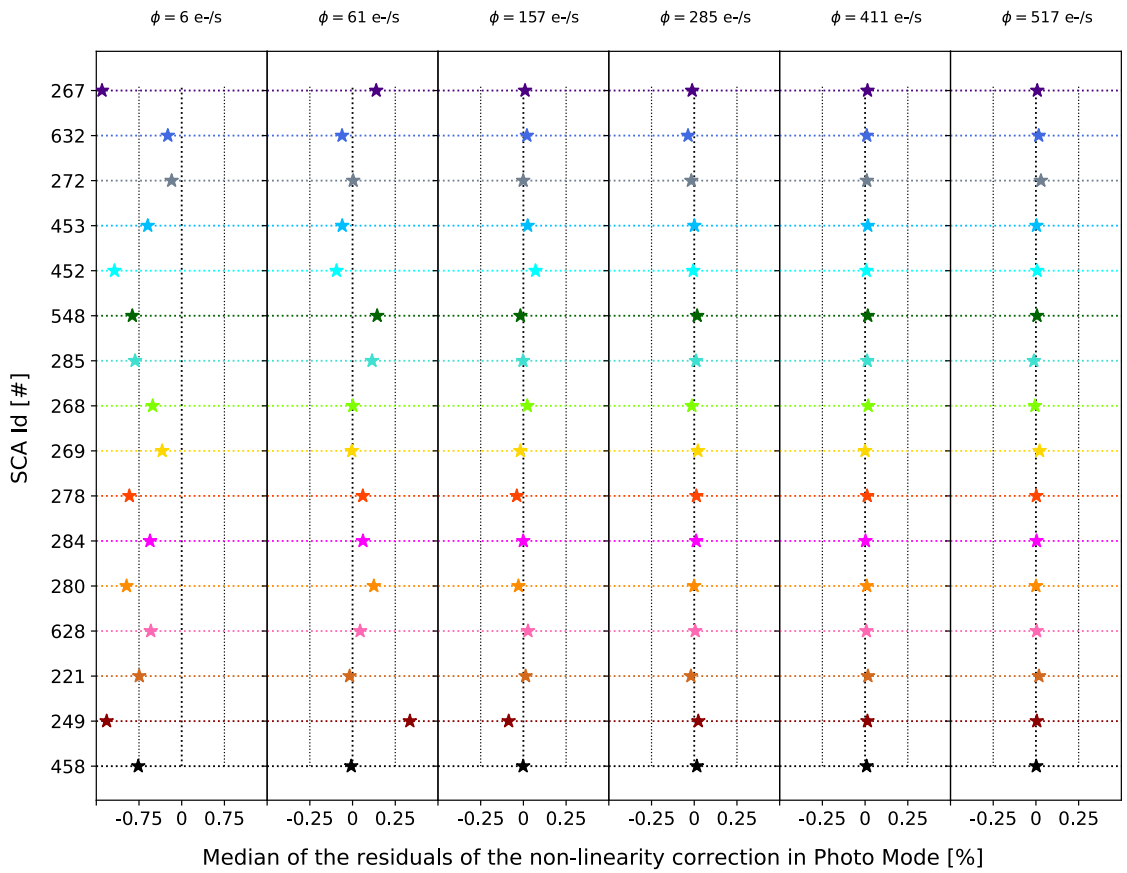


- The non linearity on sequences of fluxes in a row : no dark no zodi interleaved
- Polynomial correction is valid only **inside** the range of the tested flux available during calibration => issues when extrapolated

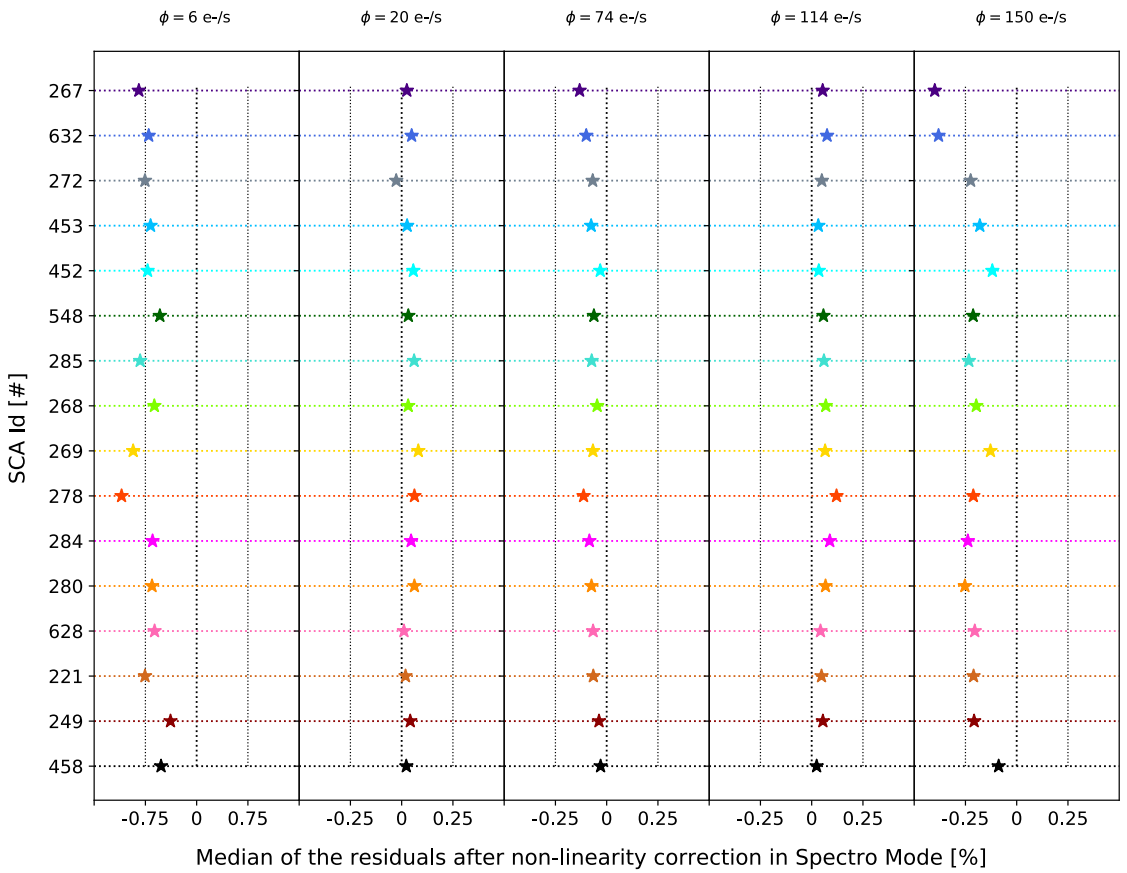
Non Linearity Performances : Gnd residuals 16 flight
NL Spec +/-1%

Systematic error on NL correction : Residual [%] = (beta_1 - P_4(Phi)) / beta_1 x 100

Photo

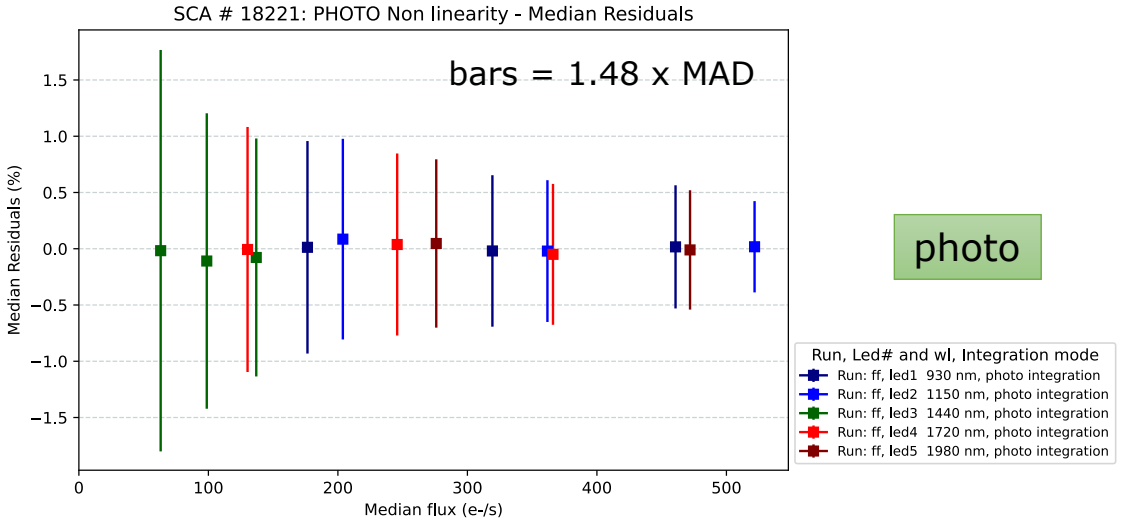


Spectro



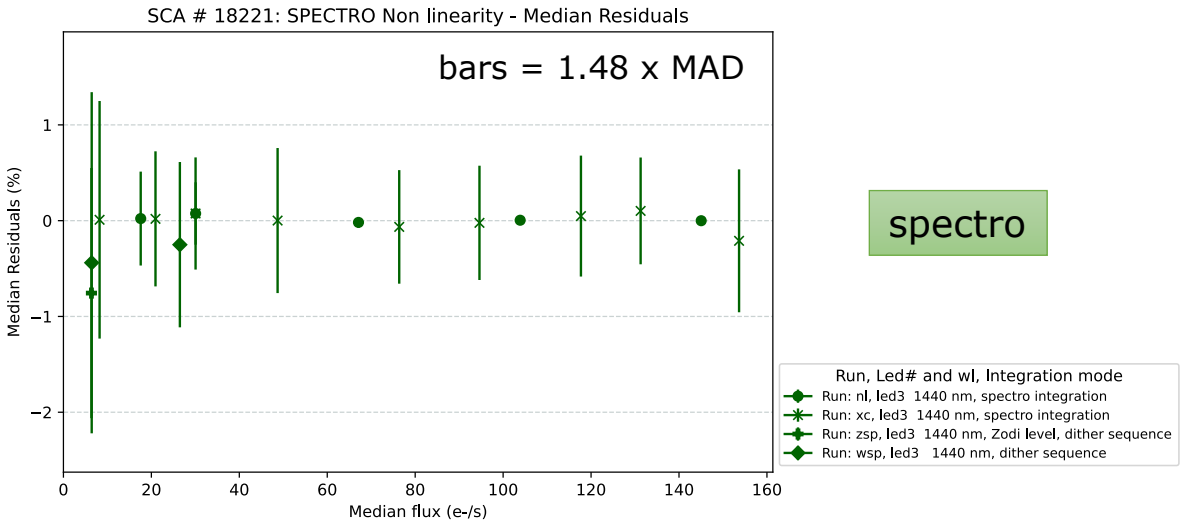
Non linearity corrections: residuals

Median Residual + scaled MAD

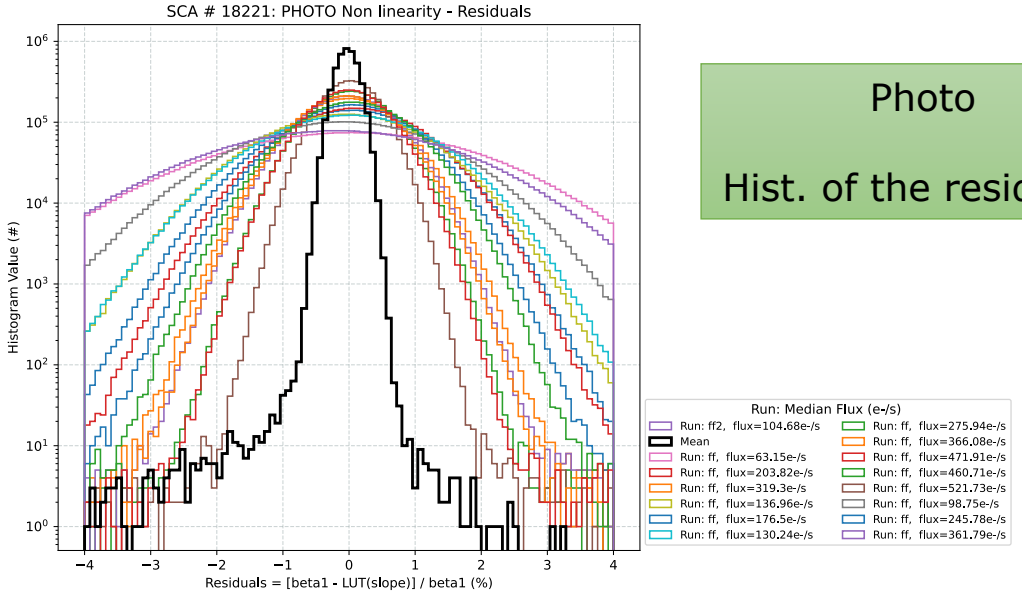


photo

bars = 1.48 x MAD



spectro



Photo

Hist. of the residuals

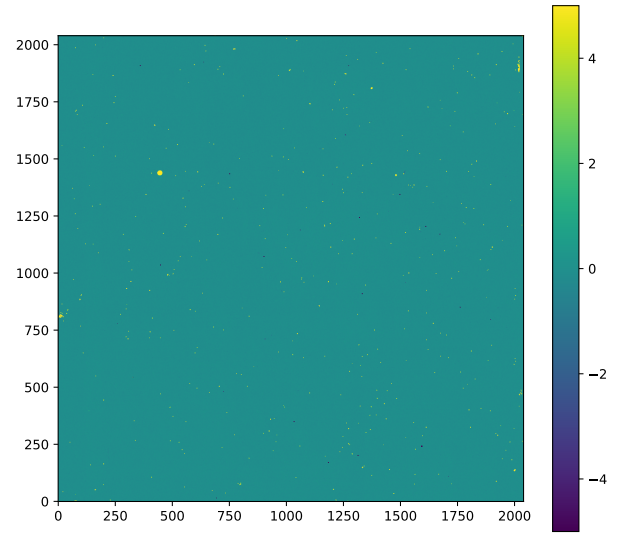
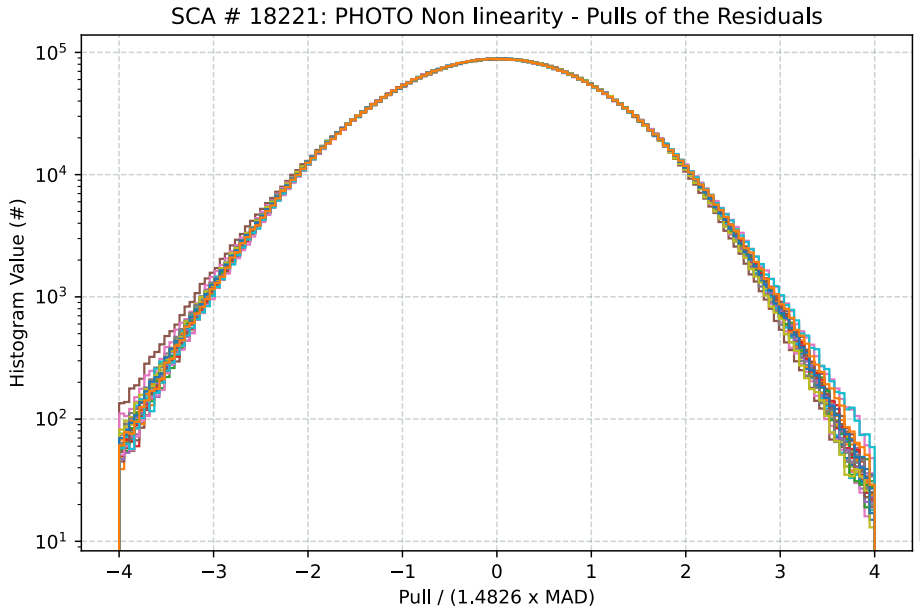


Photo
Image of the
Mean residual
over fluxes

No spatial features

Statistics or systematics ? Pull analysis

photo

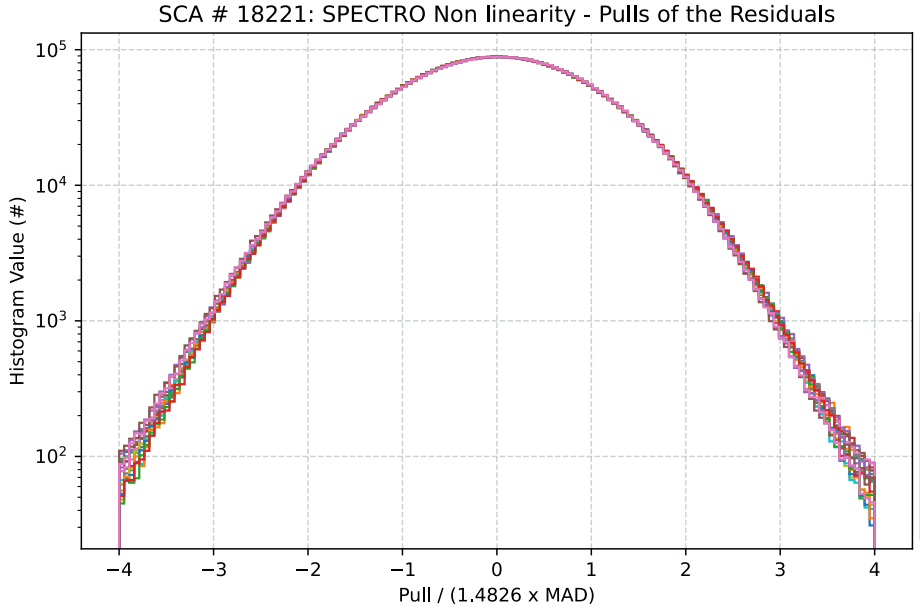


➢ sigma of the pull ~1

Run: flux & Pull mean, sigma

Run: la, flux=156 e-/s, mean=0.11 sigma=0.96
Run: la, flux=432 e-/s, mean=0.07 sigma=0.99
Run: la, flux=48 e-/s, mean=0.16 sigma=0.99
Run: ff, flux=472 e-/s, mean=0.04 sigma=1.06
Run: ff, flux=176 e-/s, mean=0.09 sigma=1.05
Run: la, flux=313 e-/s, mean=0.13 sigma=0.95
Run: la, flux=607 e-/s, mean=0.19 sigma=0.92
Run: ff, flux=461 e-/s, mean=-0.0 sigma=0.93
Run: ff, flux=130 e-/s, mean=-0.11 sigma=1.03
Run: ff, flux=362 e-/s, mean=-0.06 sigma=0.97
Run: ff, flux=246 e-/s, mean=0.08 sigma=0.96
Run: la, flux=550 e-/s, mean=0.14 sigma=0.98
Run: nl, flux=149 e-/s, mean=-0.29 sigma=0.92
Run: nl, flux=68 e-/s, mean=-0.02 sigma=0.98
Run: ff, flux=319 e-/s, mean=-0.1 sigma=0.97
Run: zph, flux=6 e-/s, mean=0.21 sigma=0.97
Run: la, flux=86 e-/s, mean=-0.02 sigma=1.0
Run: ff, flux=137 e-/s, mean=0.02 sigma=0.99
Run: ff, flux=276 e-/s, mean=0.09 sigma=0.98
Run: nl, flux=30 e-/s, mean=0.03 sigma=0.98
Run: nl, flux=18 e-/s, mean=0.06 sigma=0.99
Run: la, flux=853 e-/s, mean=0.0 sigma=1.04
Run: la, flux=665 e-/s, mean=0.11 sigma=1.01
Run: nl, flux=106 e-/s, mean=-0.17 sigma=0.97
Run: ff, flux=204 e-/s, mean=0.02 sigma=0.99
Run: ff, flux=99 e-/s, mean=-0.09 sigma=1.0
Run: la, flux=209 e-/s, mean=0.2 sigma=0.97
Run: ff, flux=63 e-/s, mean=-0.0 sigma=1.0
Run: ff, flux=366 e-/s, mean=-0.04 sigma=1.02
Run: ff, flux=522 e-/s, mean=0.02 sigma=1.0
Run: ff2, flux=105 e-/s, mean=-0.03 sigma=0.95
Run: la, flux=104 e-/s, mean=0.0 sigma=0.97

spectro



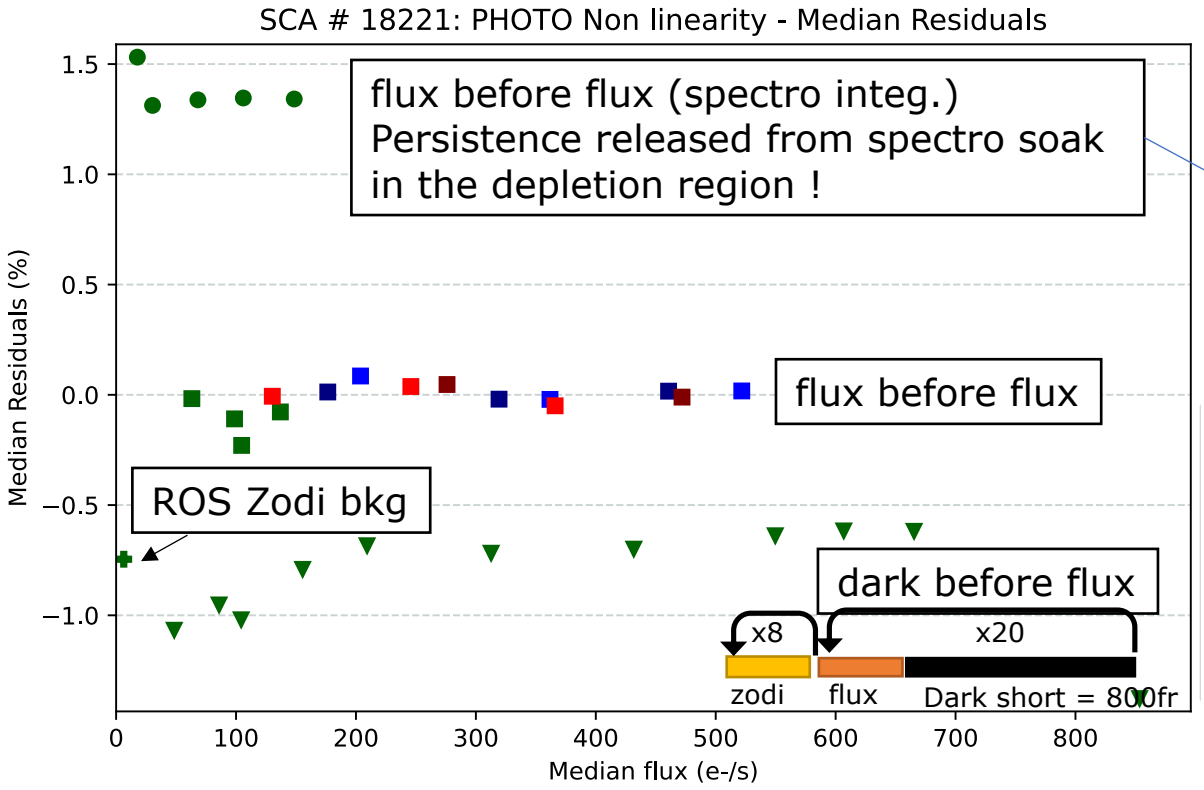
➢ No systematics observed with flux in a row runs
➢ Traps in steady state

➢ sigma of the pull ~1

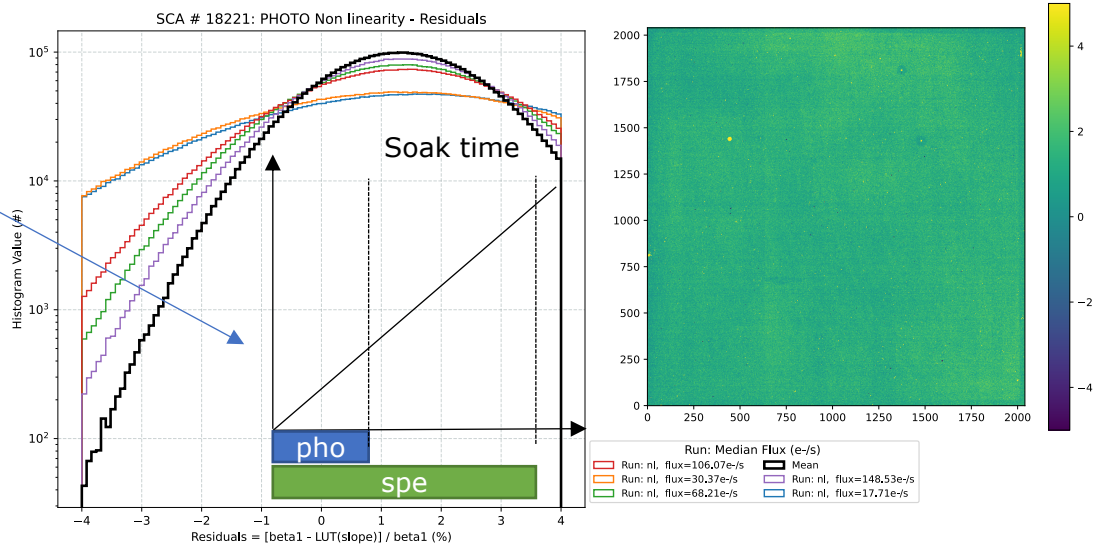
Run: flux & Pull mean, sigma

Run: nl, flux=18 e-/s, mean=-0.06 sigma=1.01
Run: wsp, flux=6 e-/s, mean=0.07 sigma=0.94
Run: xc, flux=95 e-/s, mean=0.04 sigma=0.98
Run: nl, flux=145 e-/s, mean=0.02 sigma=1.06
Run: xc, flux=49 e-/s, mean=0.07 sigma=0.99
Run: xc, flux=118 e-/s, mean=-0.02 sigma=0.97
Run: wsp, flux=26 e-/s, mean=0.35 sigma=0.96
Run: zsp, flux=6 e-/s, mean=0.15 sigma=1.01
Run: xc, flux=21 e-/s, mean=-0.07 sigma=1.0
Run: xc, flux=154 e-/s, mean=0.01 sigma=0.97
Run: xc, flux=131 e-/s, mean=-0.03 sigma=0.94
Run: xc, flux=8 e-/s, mean=-0.0 sigma=1.0
Run: nl, flux=30 e-/s, mean=0.03 sigma=1.02
Run: nl, flux=104 e-/s, mean=-0.02 sigma=1.04
Run: xc, flux=30 e-/s, mean=-0.06 sigma=0.94
Run: nl, flux=67 e-/s, mean=0.02 sigma=1.04
Run: xc, flux=76 e-/s, mean=0.07 sigma=0.96

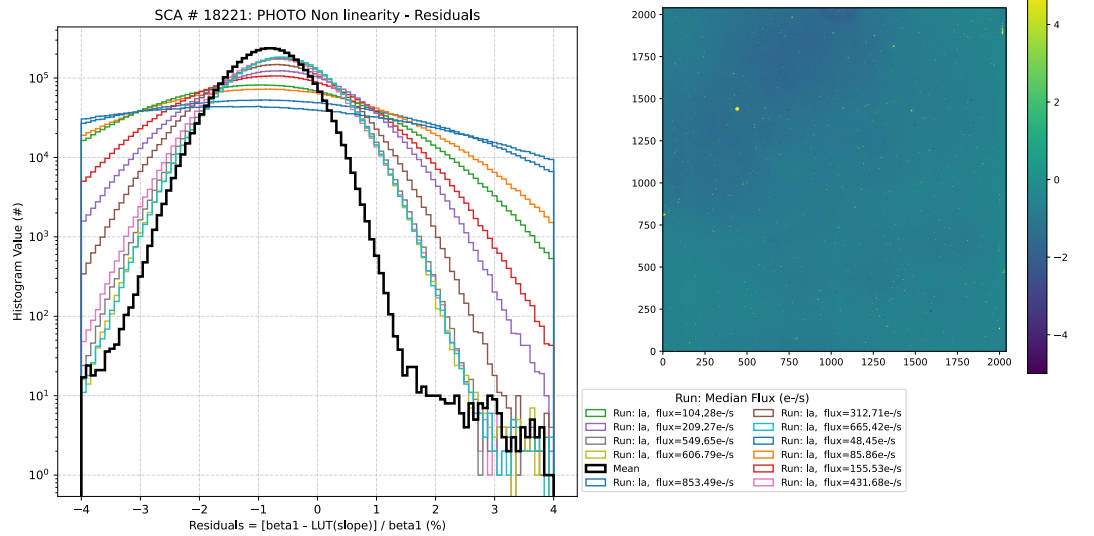
18221 : LUT applied on flux+dark sequences
a low persistence SCA 18221



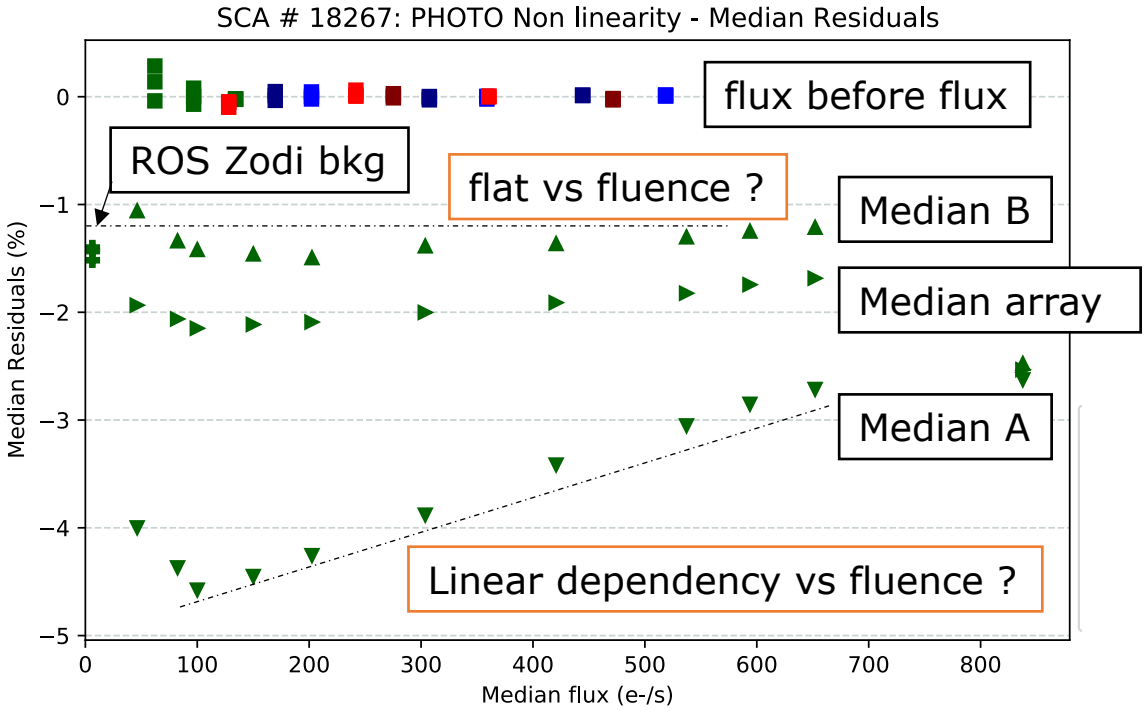
Spectro ramp used with photo LUT. +1.4%



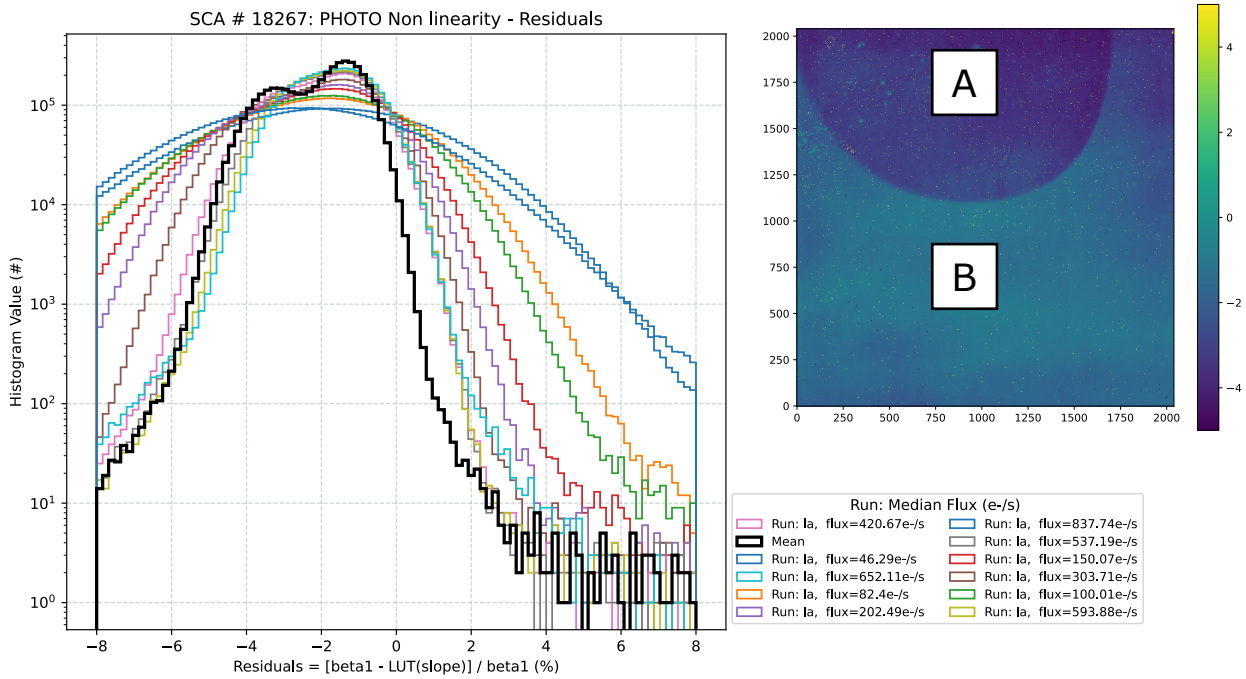
Flux + Dark => - 0.5%

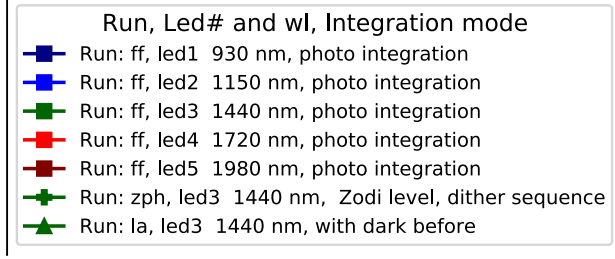


18267 : LUT applied on flux+dark patterns a high persistence SCA 18267



Bimodal distribution





Systematic error with dark before flux:

- -4% for high persistence region A /w positive slope vs flux ?
- -1% for regular persistence region B /w flat offset vs flux ?

Lesson Learned

- The 16 Euclid H2RGs work as expected in-flight
- Better to optimize the MACC mode on NL and Persistence correction than on Single SNR foM
- Test as in flight is a very challenging task for the Test flow with 2 possible strategies
  - Emulate the ROS with a all possible combination of illumination scenario and learn the response with a Big Data approach
  - Generate the "good" Cal blocks for pixel response modelling with V/V, e/V NL and Persistence ?
- Even with a low persistence H2RG, to reduce systematics below 1% can be challenging
  - The effect is not negligeable but the effect is "clean"


Thank you