Focal plane commissioning: bias frame corrections

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LSST-France meeting

Annecy

May 17, 2022

Outline

- 5-min crash course:

- Focal plane
- Bias correction

- PCA studies on bias frames

- Dark runs

- Prescan pixels

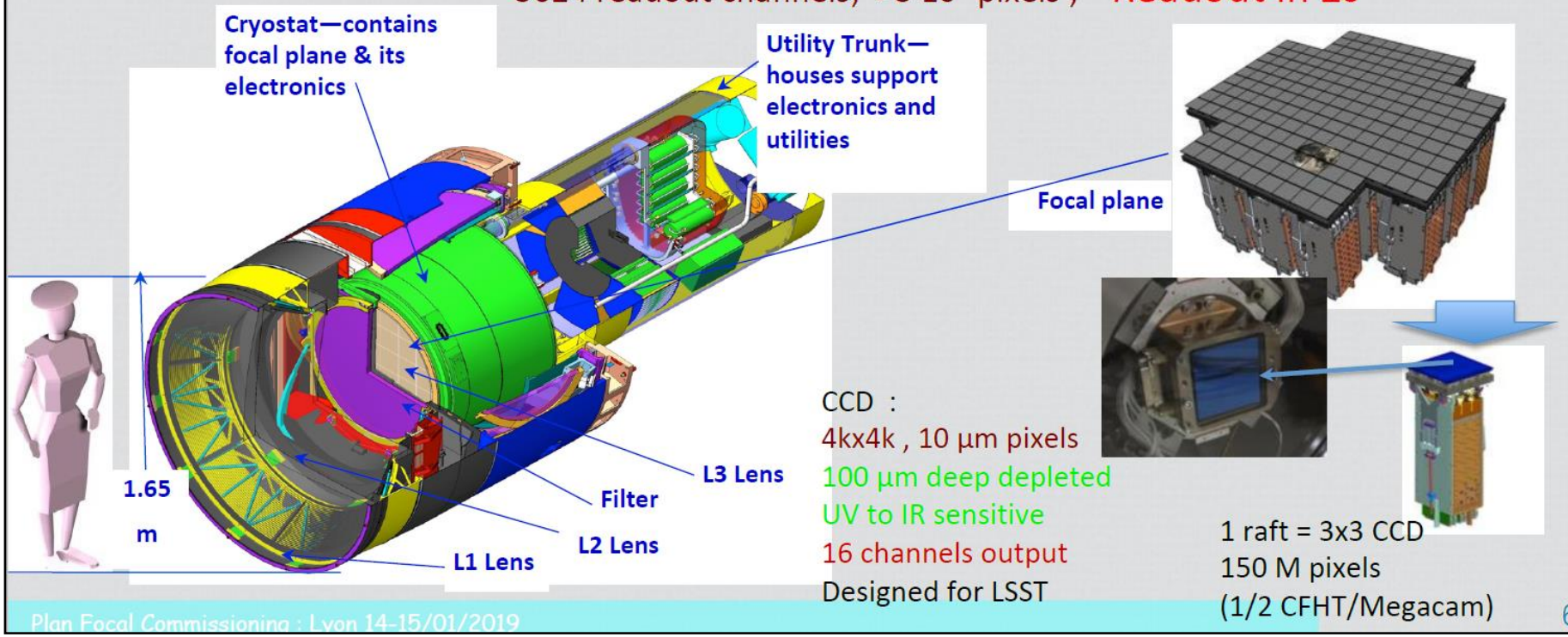
Rubin optical system

LSST : Wide , Deep and Fast

Field of view : 3.5 deg (9.6 deg^2 =.023% sky sphere)

Focal plane diameter : 64 cm ; 189 science CCD (21 rafts)

3024 readout channels; >3 10^9 pixels ; Readout in 2s



CCD :
4kx4k , 10 µm pixels
100 µm deep depleted
UV to IR sensitive
16 channels output
Designed for LSST

1 raft = 3x3 CCD
150 M pixels
(1/2 CFHT/Megacam)

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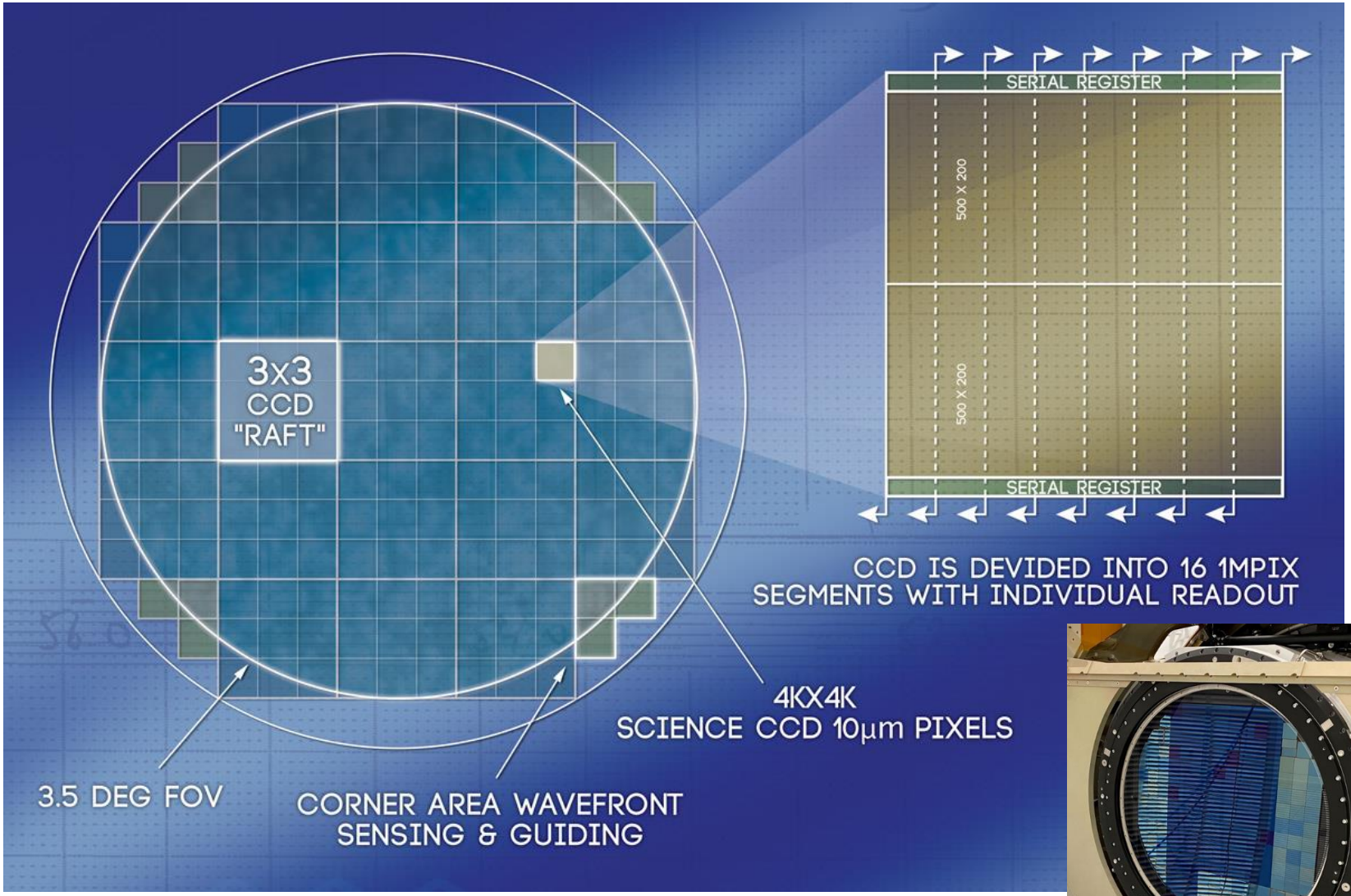
From P. Antilogus

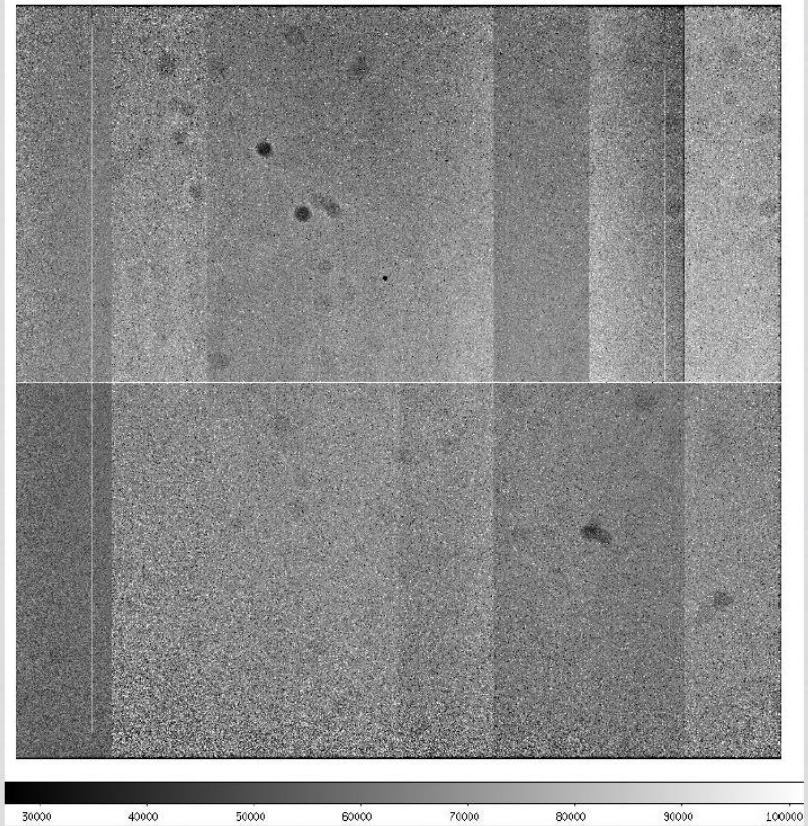
Focal plane layout



21 science rafts / 1 raft = 9 CCD / 1 CCD = 16 amplifiers

CCD-level image

1 CCD = 16 amplis = une image brute/raw non-uniforme



Pour multiplexer la lecture les CCD LSST sont segmentés en 16 Amplis .

Chaque ampli a son propre :

- Niveau de biais (~ 25000 counts ou ADU)
- Gain (e2v ~ 0.75 ADU = 1 e- , itl ~0.9 ADU=1e-)
- Bruit (e2v ~ 5 e- , itl ~ 8 e-)
- Charge transfert ineficiencies (~ 1 e-6 / transfer)
- …

C'est presque comme si on avait 16 CCD d'un point de vue lecture…

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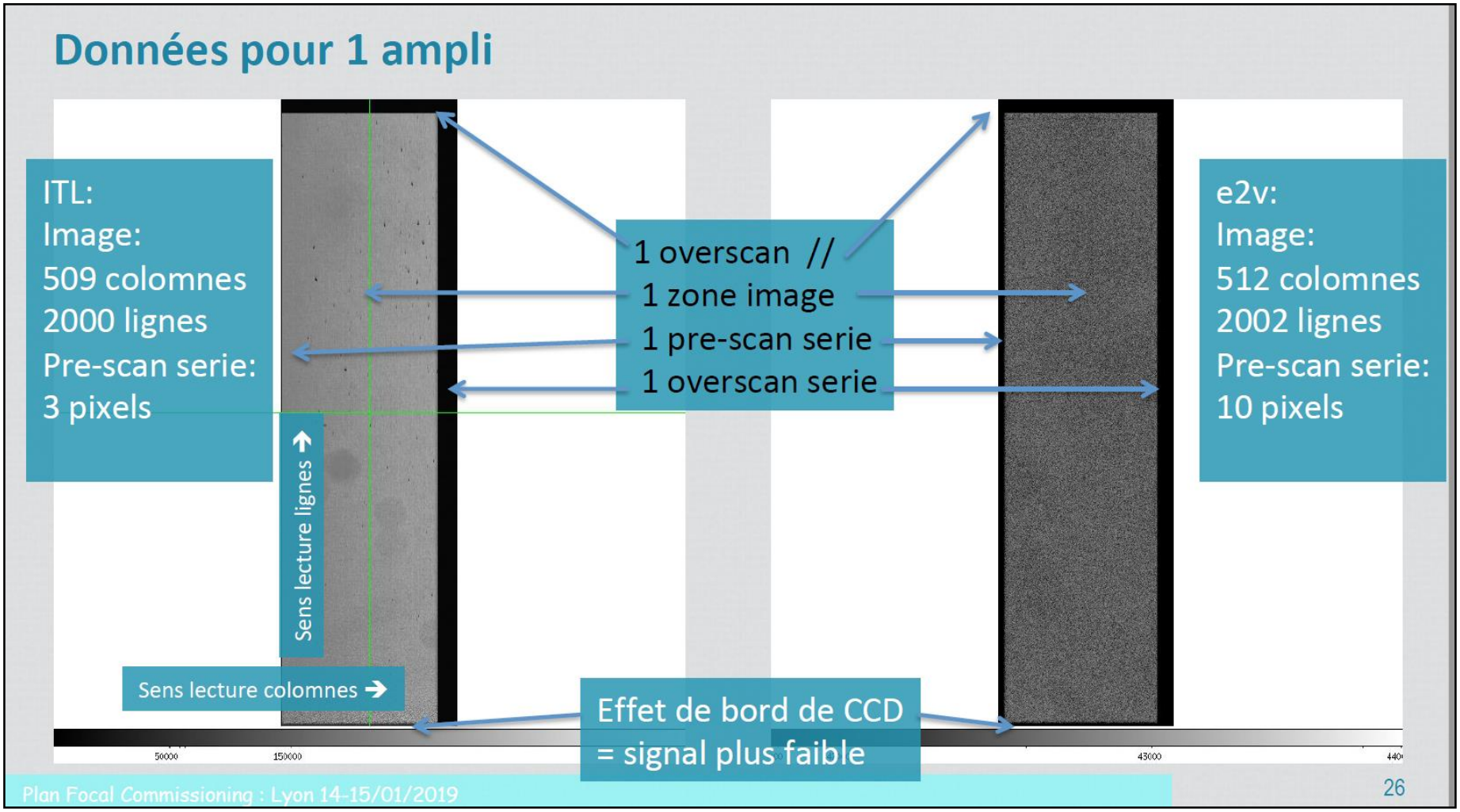
From P. Antilogus

Bias image = image taken with the shutter closed and zero exposure time

Overscan

From P. Antilogus



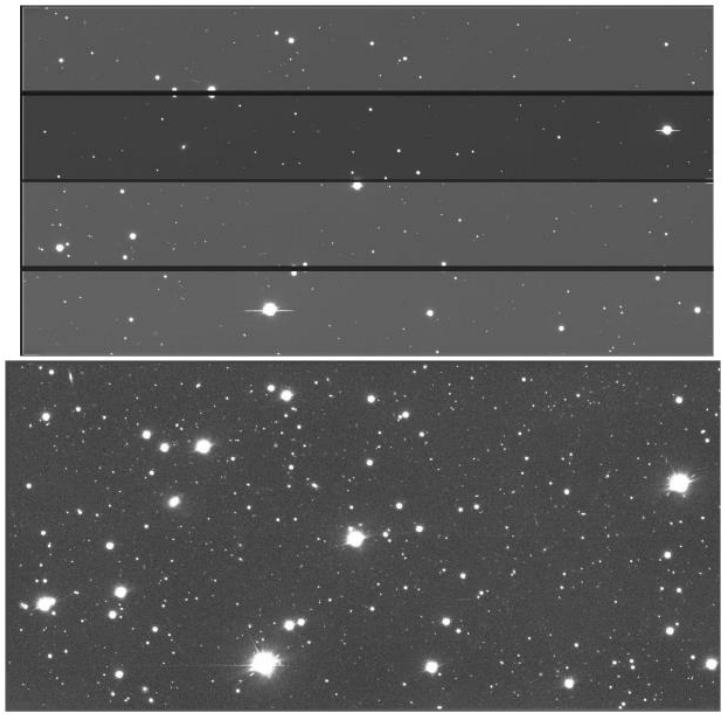
Overscan pixel: 'virtual pixel' corresponding to an actual clock cycle

Instrument Signature Removal steps in DM Stack

- ISR steps in DM as of July 2020
  - integer-to-float conversion
  - saturation and suspect pixel masking
  - overscan subtraction
    - Optional: Apply crosstalk correction here before CCD assembly, and before trimming
  - CCD assembly of individual amplifiers
  - bias subtraction
    - Note: Calibration products construction (master bias, master dark, master flat).
  - variance image construction
  - linearization of nonlinear response
  - crosstalk correction
  - mask defects, edges, nan's, etc.
  - brighter-fatter correction
  - dark subtraction
  - fringe correction
  - stray light subtraction
  - flat correction
  - apply gains
    - Optional: Fringe Correction after flat
  - vignette calculation
  - attach transmission curve
  - illumination correction

Overscan substraction (lines)

Master bias substraction (mean over n bias images)



HSC image before/after stack

From arXiv:1704.05858

Bias structure and variability

- Bias frame corrections

- 2D shape (partial) correction from overscan pixels
- residual effect from master bias (but imperfect as not fully stable over time)

- Bias frame corrections studies by A. Bradshaw

"Fitting bias frames" CVT meeting 02/09/2021 (link)

➔ Development of PCA correction from serial and parallel overscan pixels

Implemented in eotest package (not in DM stack)

- Today: PCA-related studies on BOT data at CC-IN2P3

Effect	Description	Links	Additional Data, Study or Code Needed
Bias Structure & Bias Variability	1. Bias shows rapid changes in value in either serial or parallel directions, making spline fitting difficult/impossible 2. Bias level and shape varies from image to image in both Serial & Parallel directions		1. PCA-based Serial+Parallel overscan correction method works, but probably could use refinement and needs implementation in DM 2. S+P overscan correction works well for most channels, but a number of e2v channel have remaining 2-D bias variability, for which only pre-scan pixels have relevant information RHL: both easy enough to implement, although we'll have to determine the proper lookup for PCA functions (e.g. are they fixed? Are they a function of other parameters which we'd need to include?)

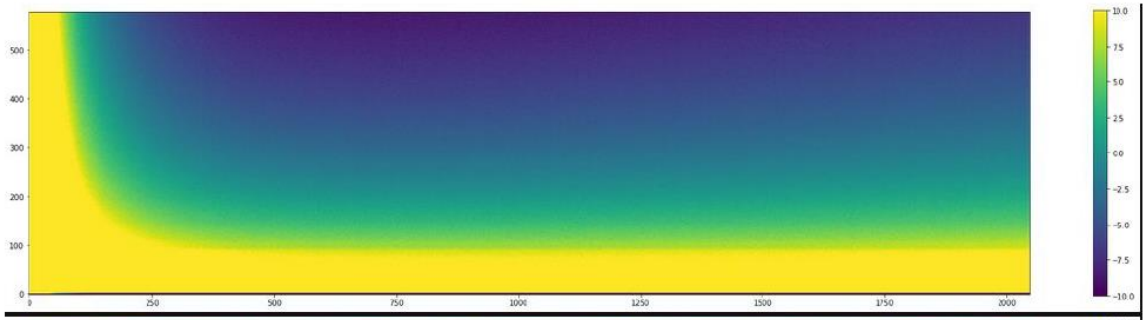
From confluence page (link)

PCA recap (1/3)

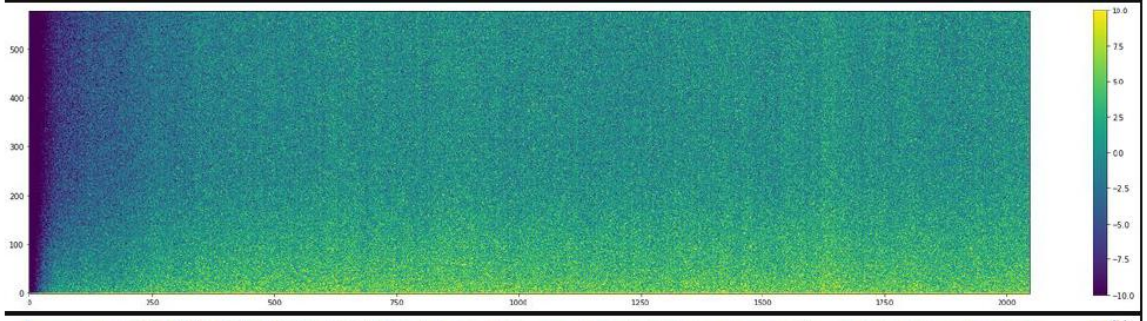
Bias instability in master bias subtracted images

(Example: R22_S22_amp4)

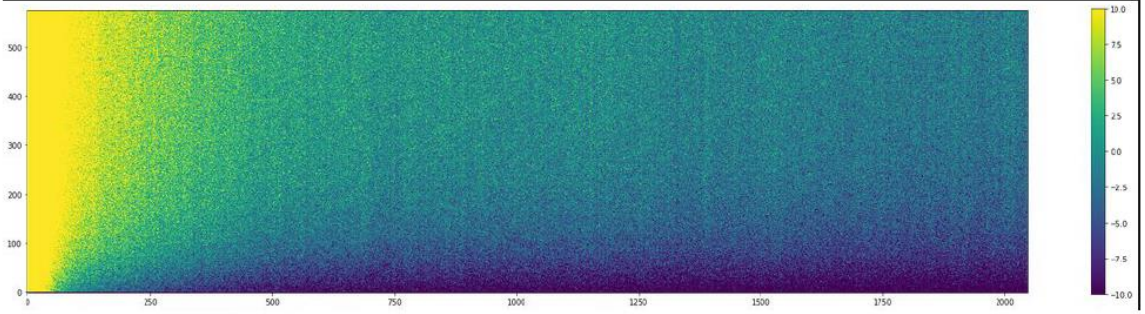
Mean of 81 biases from a run



First bias minus mean bias



Last bias minus mean bias



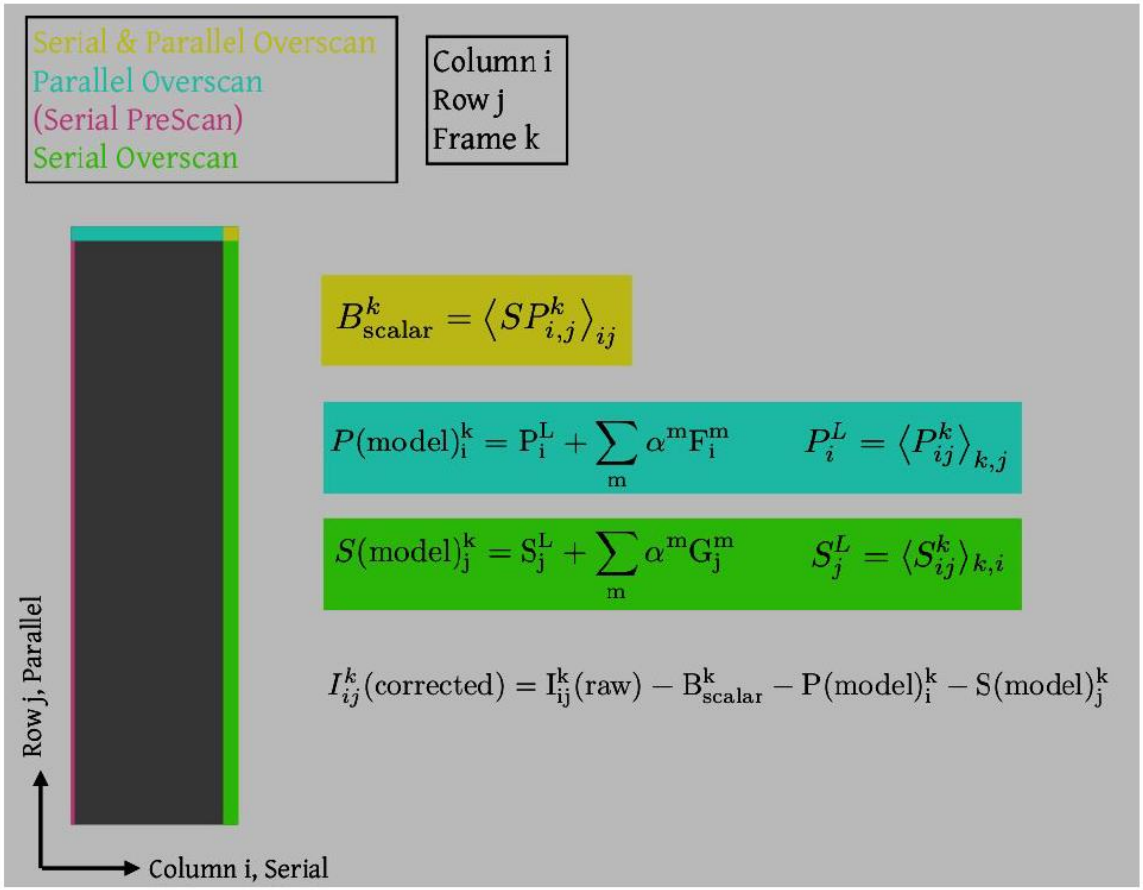
PCA recap (2/3)

Removing bias instability with **Principal Component Analysis (PCA)**

Use the bias data itself to "learn" about instability in a given amplifier

Maximizes the statistical power of overscan region by using just a few degrees of freedom (eigenvectors), each weighted by their variance

Remains agnostic to the form of variation in amplifiers



Credit: Aaron Roodman

PCA recap (3/3)

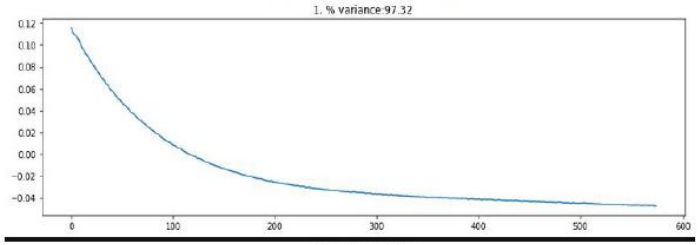
November 2020 data

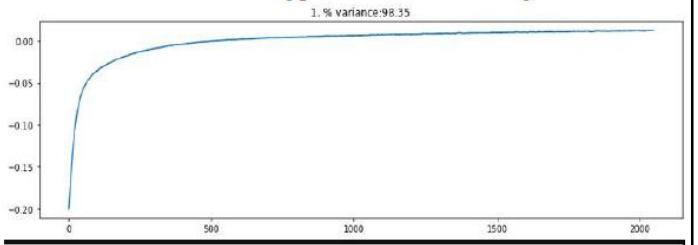
Eigenvectors in X (serial) and Y (parallel)

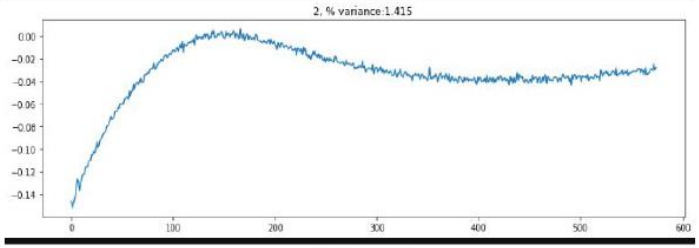
Trained using the run stack of bias images, after subtraction of the mean bias frame and mean of the joint X/Y overscan region

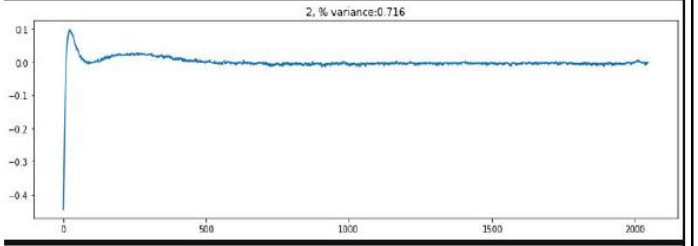
Captures >99% of the variance in first 4 components

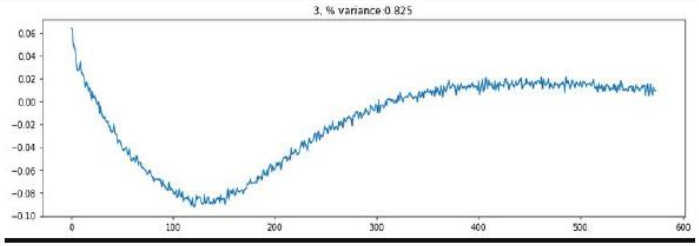
Fairly smooth, could be smoother with more training data!

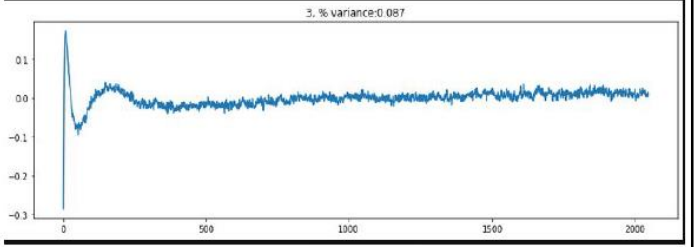


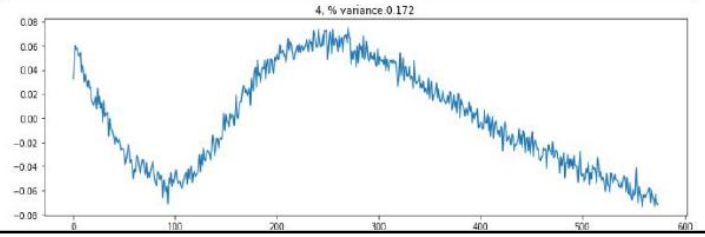


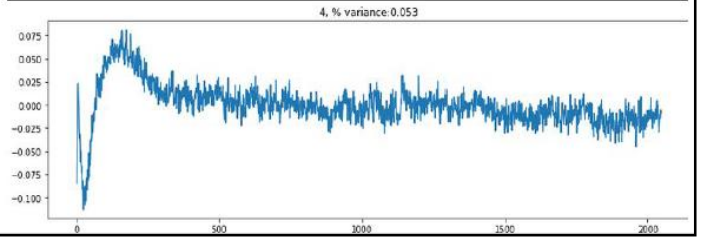








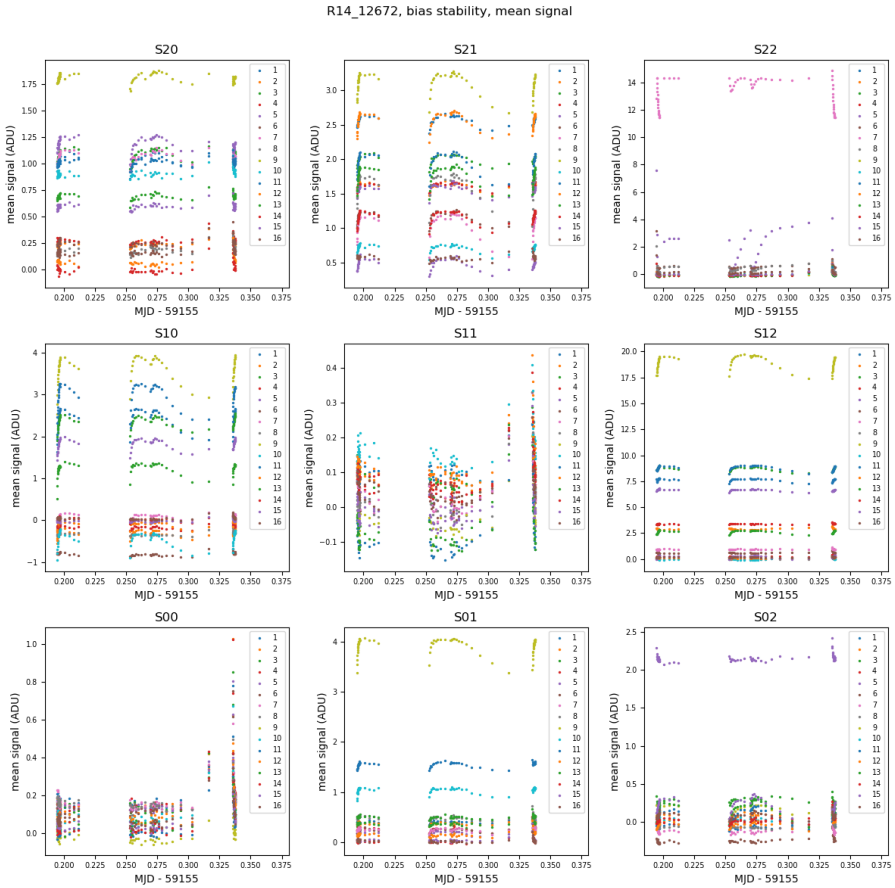




Bias frame stability from BOT data

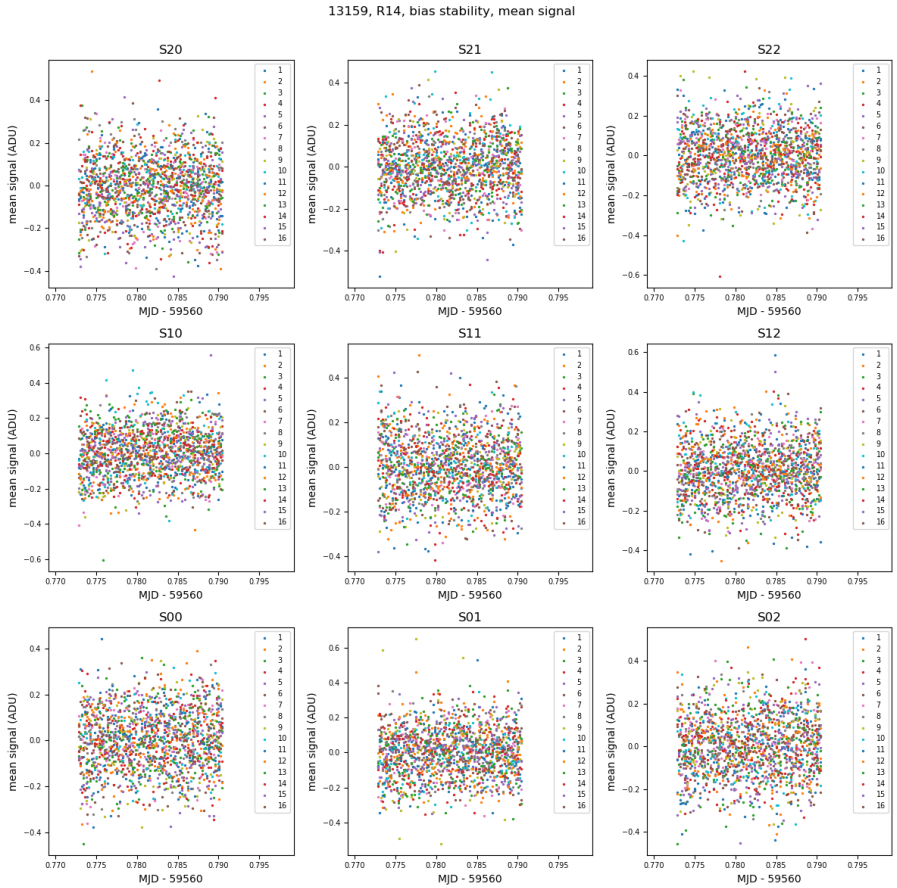
Raft R14

November 2020



ADU variations ~10-20

December 2021 (Run 5)



ADU variations ~0.3

BOT Run 5 data analysis at CC-IN2P3

- BOT Run 5 data copied at CC-IN2P3

(most of the runs from 13005 to 13282)

- Made eotest package work (thanks to Jim Chiang)

➔ Can use the implemented PCA tools

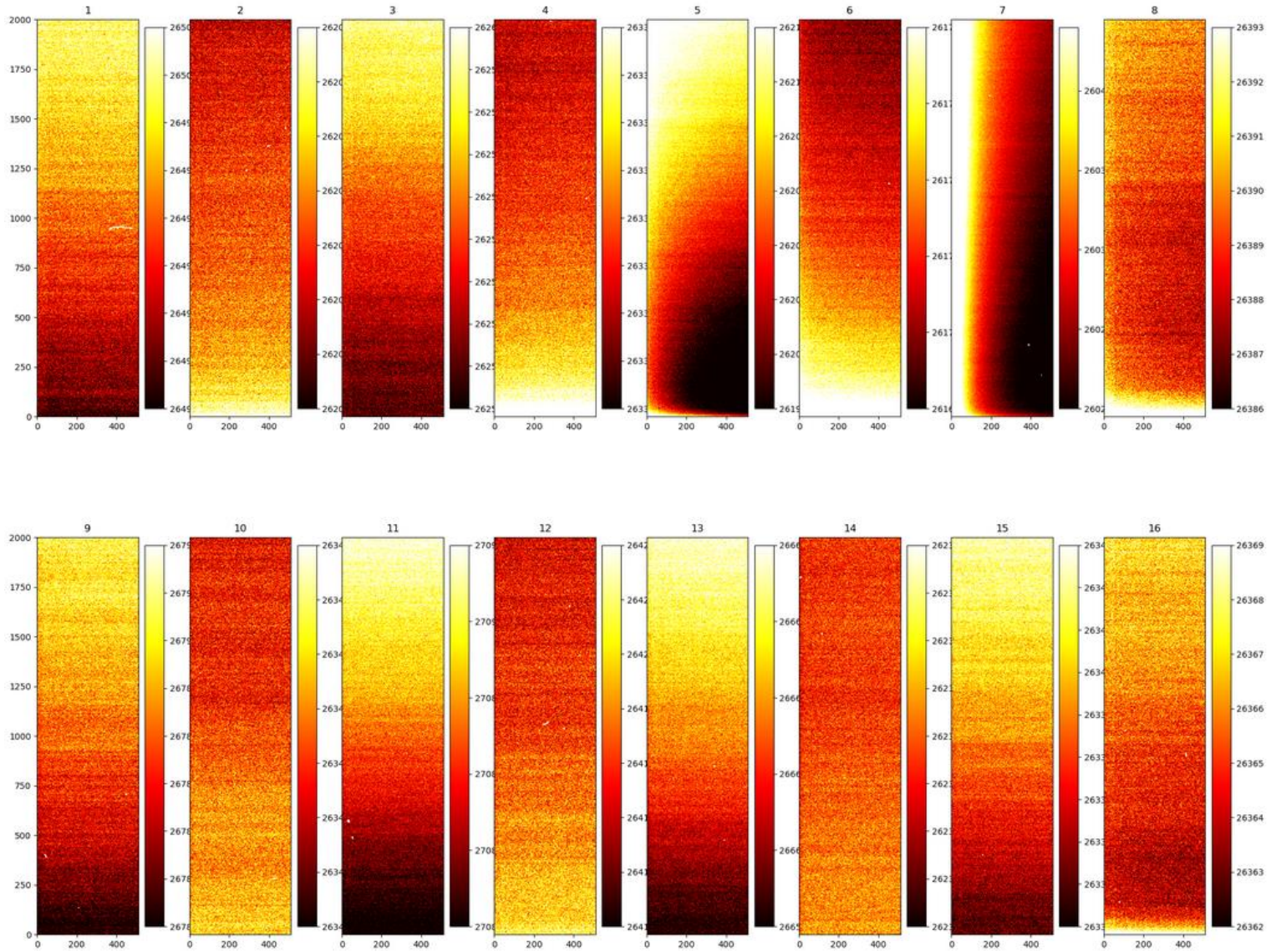
- Runs considered

- 13159: bias (97 exposures, used for PCA)

- 13161: dark

Master bias of Run 13159

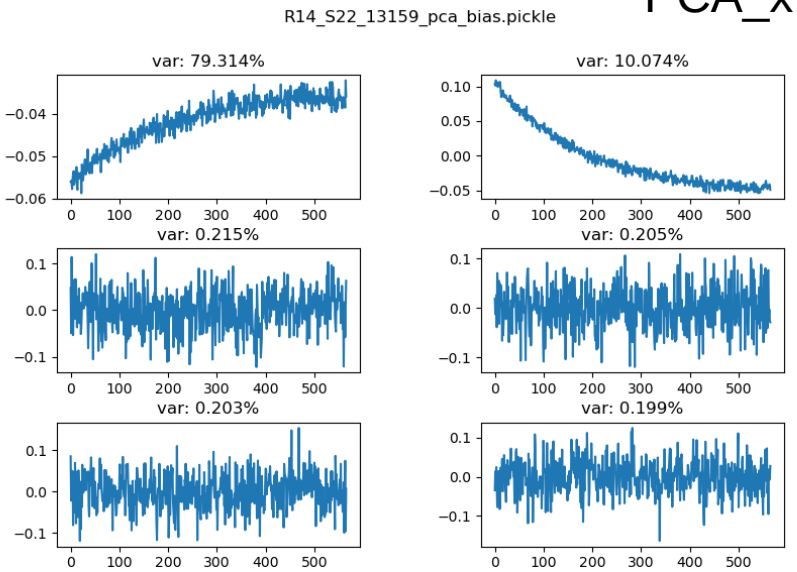
R14 S22



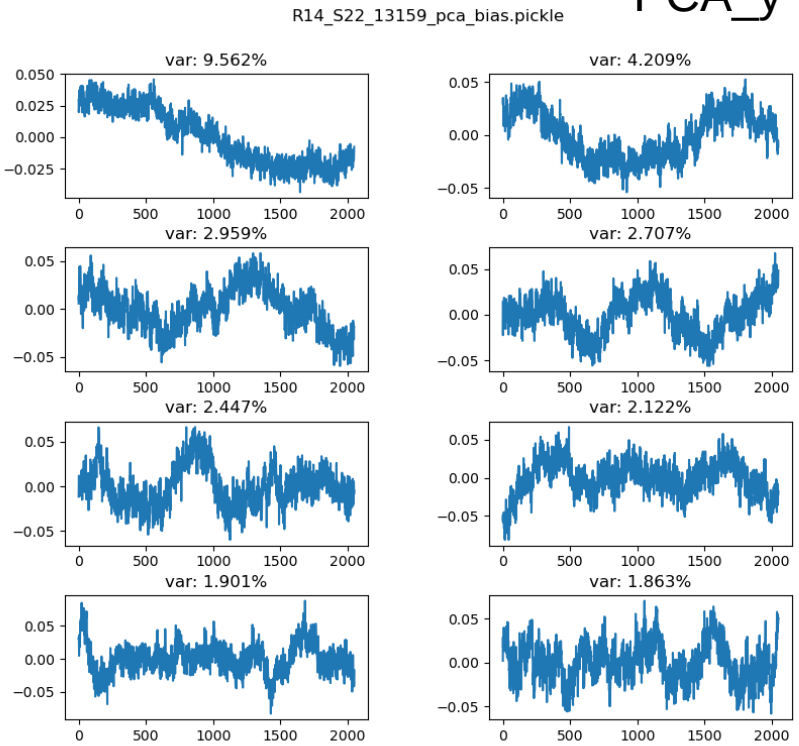
PCA components

PCA correction computed from 97 bias of Run 13159
➔ Overscan pixels corrected by the master bias
Example: R14 S22 amp 7

PCA_x



PCA_y

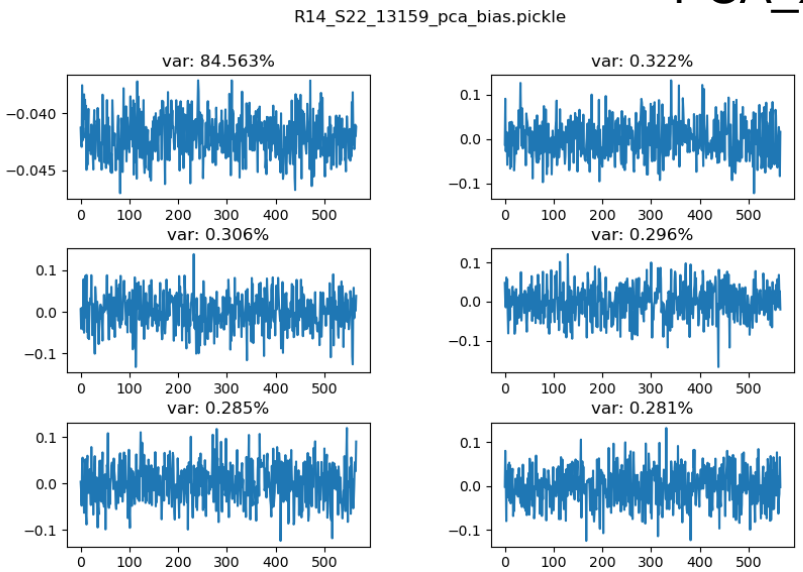


Variable: explained_variance_ratio
All amplifiers here: link

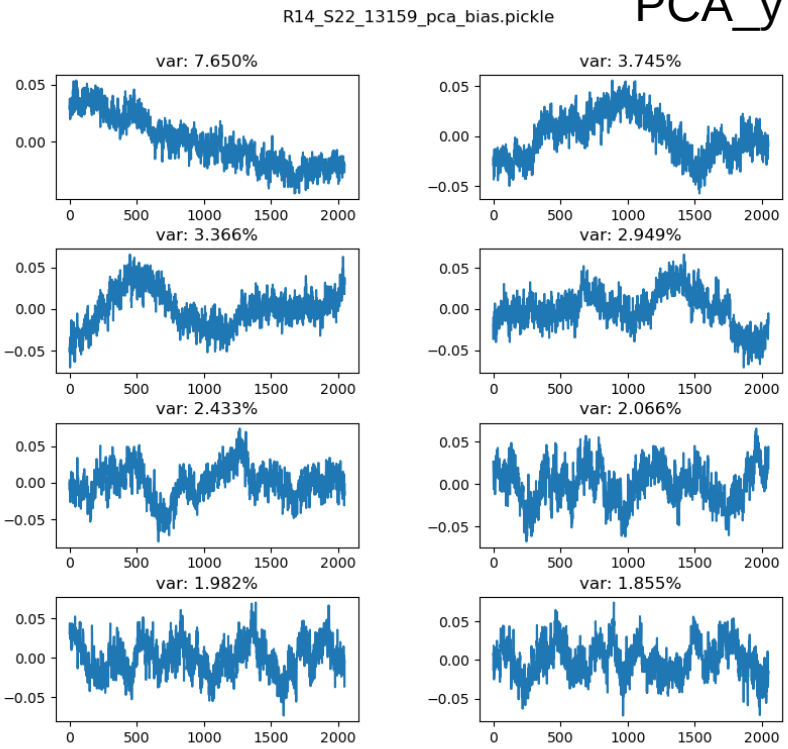
PCA components

PCA correction computed from 97 bias of Run 13159
Example: R14 S22 amp 16

PCA_x



PCA_y

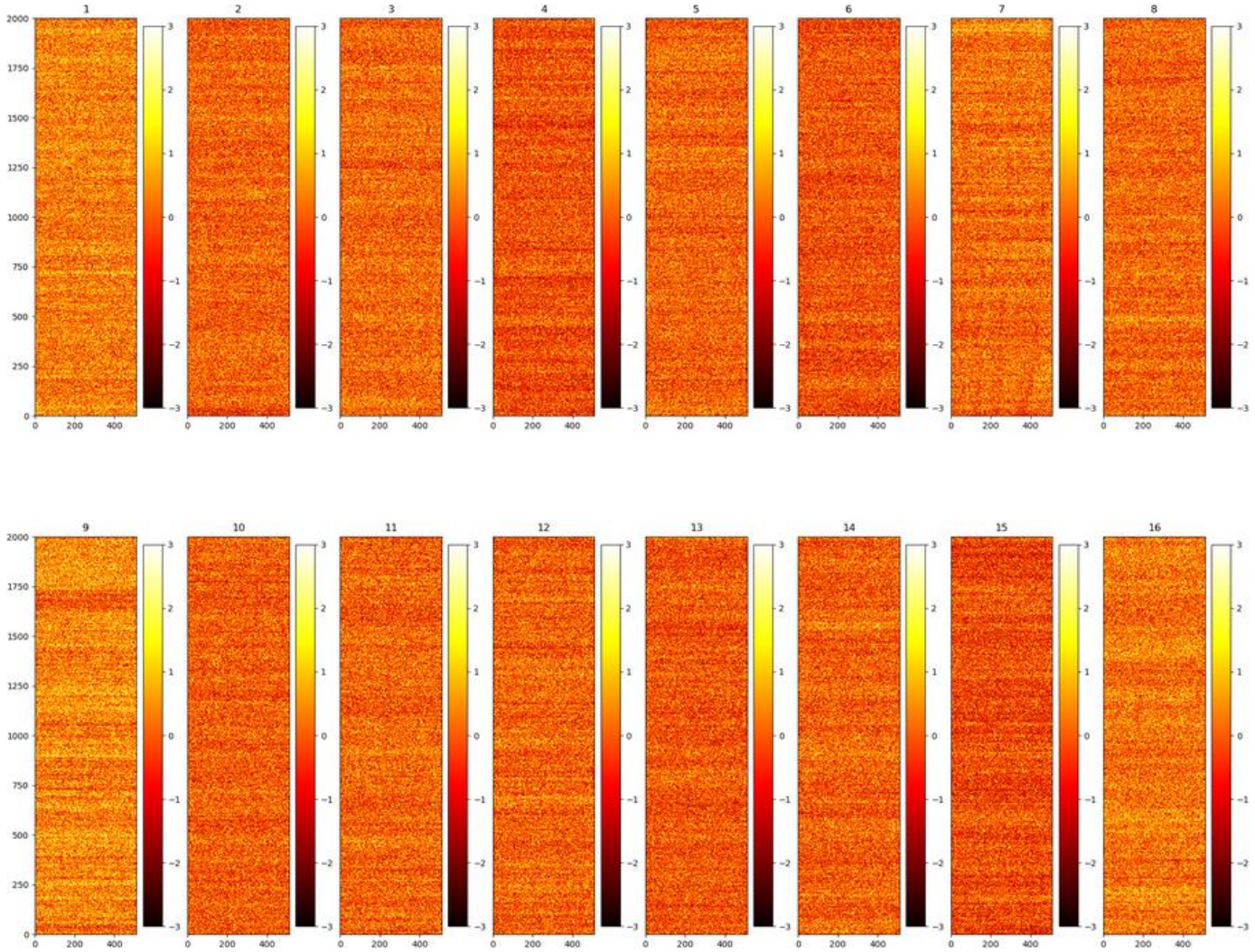


8 components really needed for y?
PCA for x needed only for some amplifiers (variance>threshold)?

Applying the PCA correction to the same run

Same set of bias frames (closure test)
Master bias subtraction + PCA

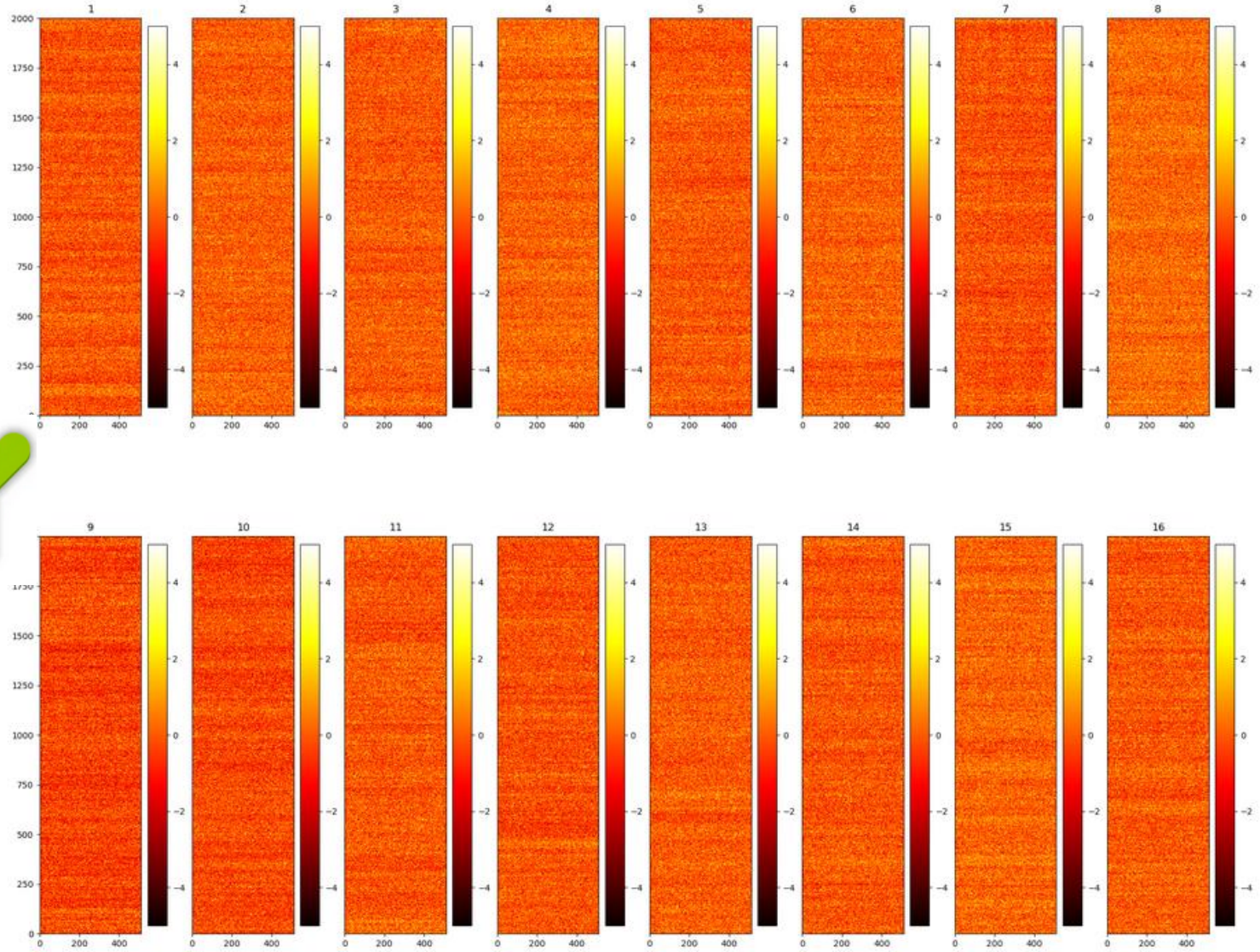
Run 13159, bias_074



Applying the PCA correction to a dark run

Master bias subtraction + PCA

Run 13161, bias_007



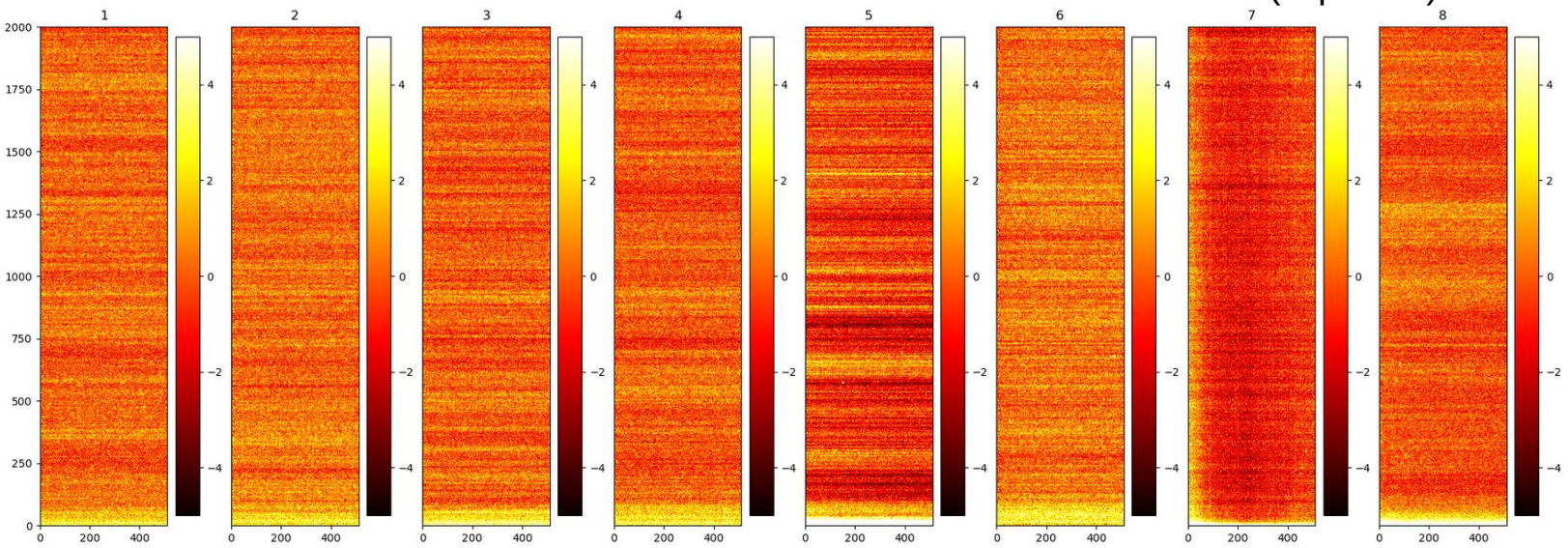
Applying the PCA correction to a dark run

Procedure for science images in the survey:
a visit is defined as a pair of 15-second exposures, performed back-to-back in a given filter, and separated by a four-second interval for readout and opening and closing of the shutter

Run 13161, dark_023

(exp. 30 s)

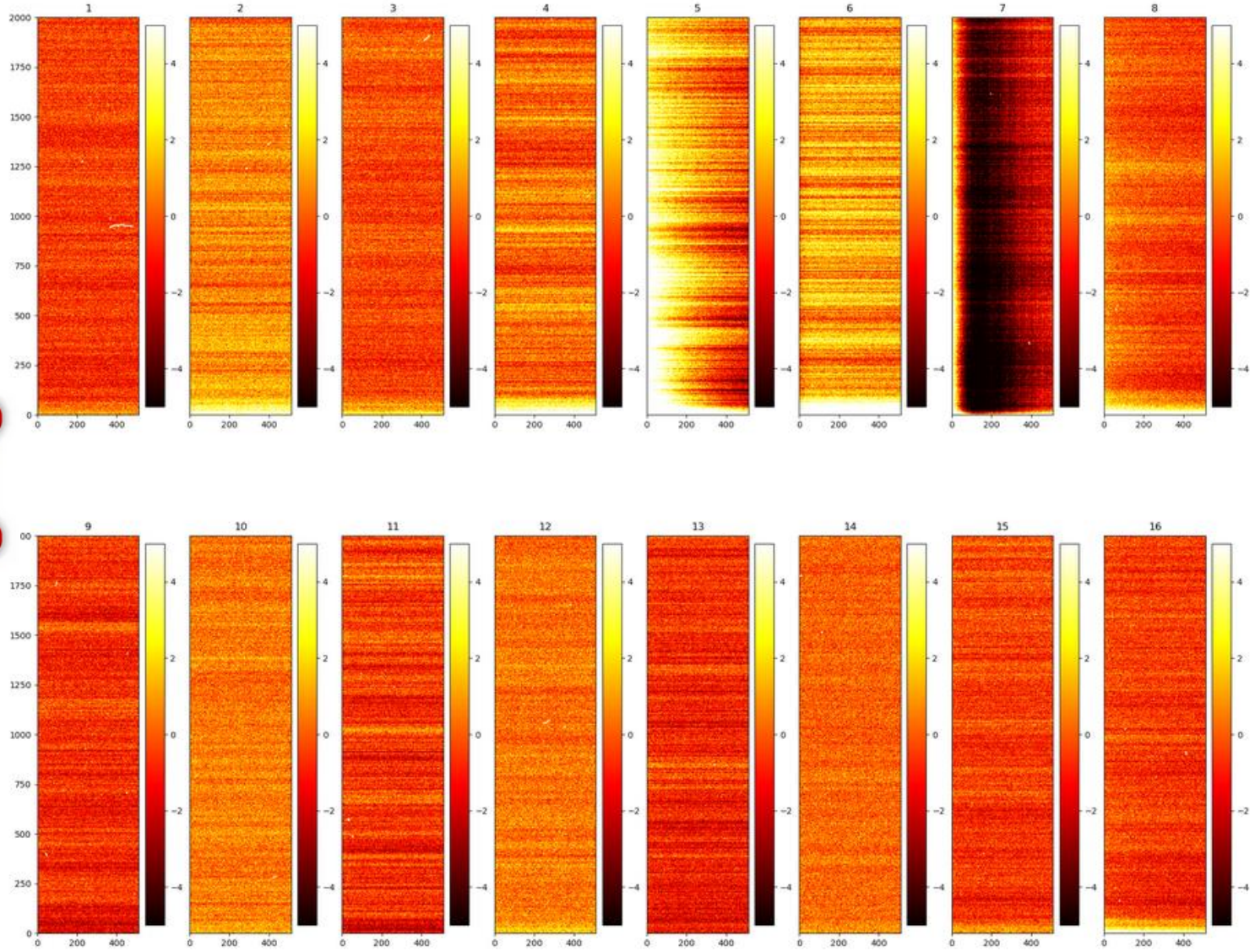
Master bias subtraction + PCA



Applying the PCA correction to a dark run

Master bias subtraction + PCA

Run 13161, dark_032 (exp. 120 s)



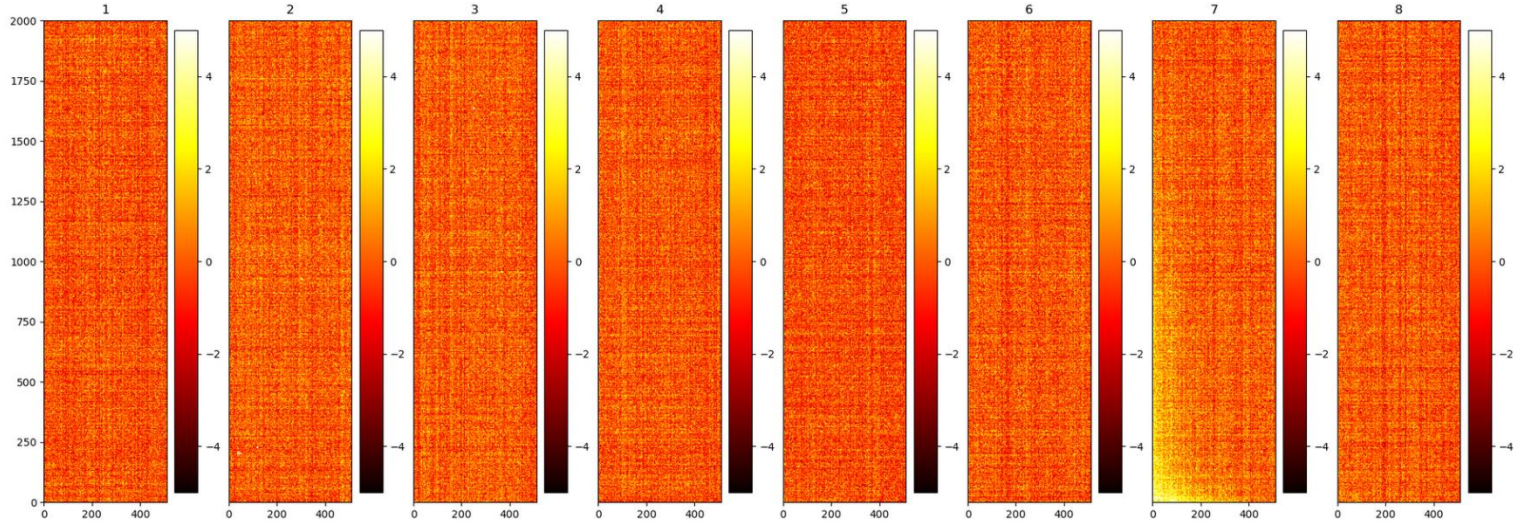
Impact of exposure time

Direct 2D correction (no master bias subtraction)
amp 1-8

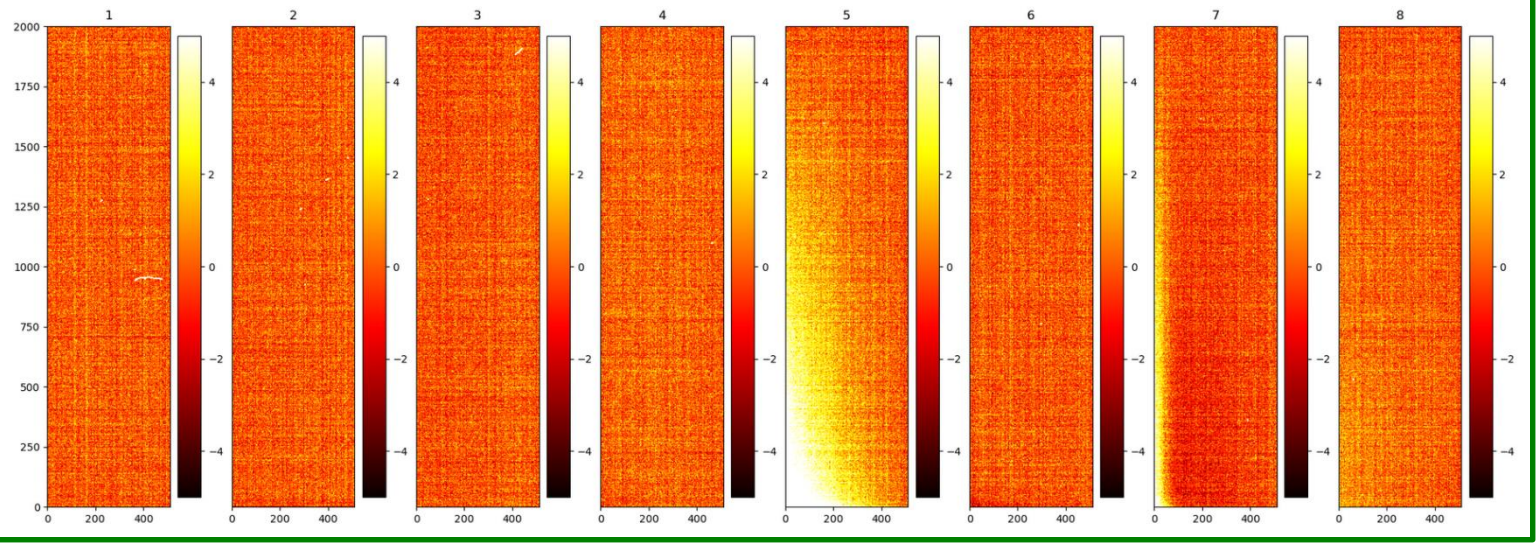
Run 13161

dark_020
exp. 30 s

Animated gif



dark_032
exp. 120 s

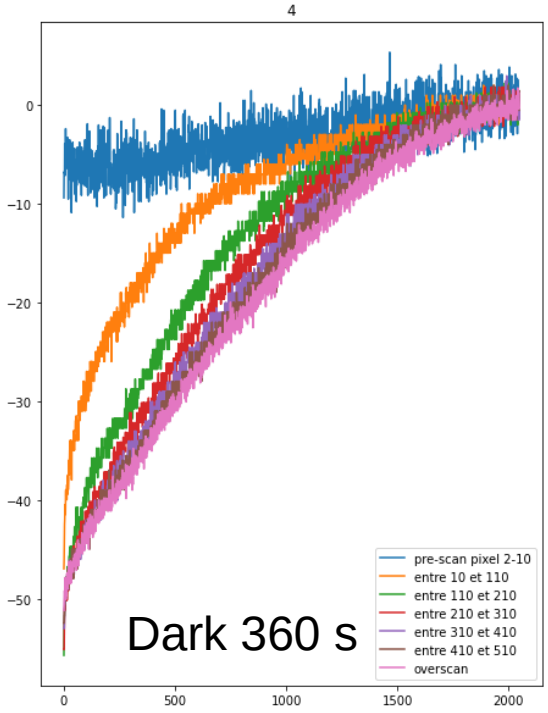


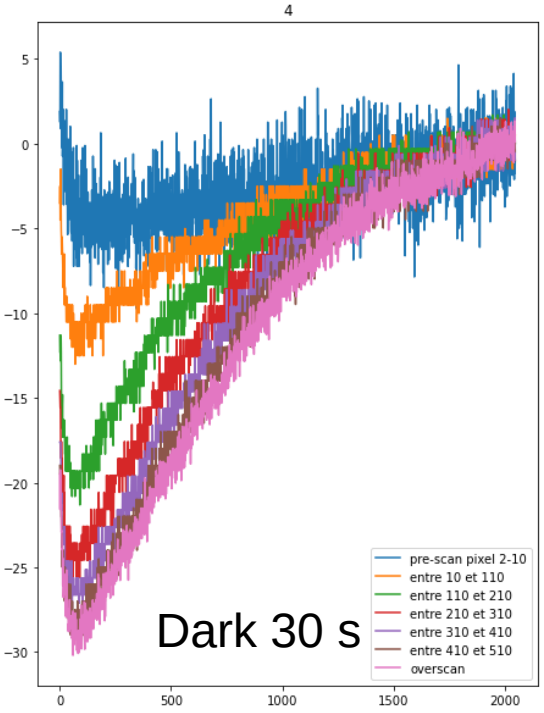
Prescan pixels

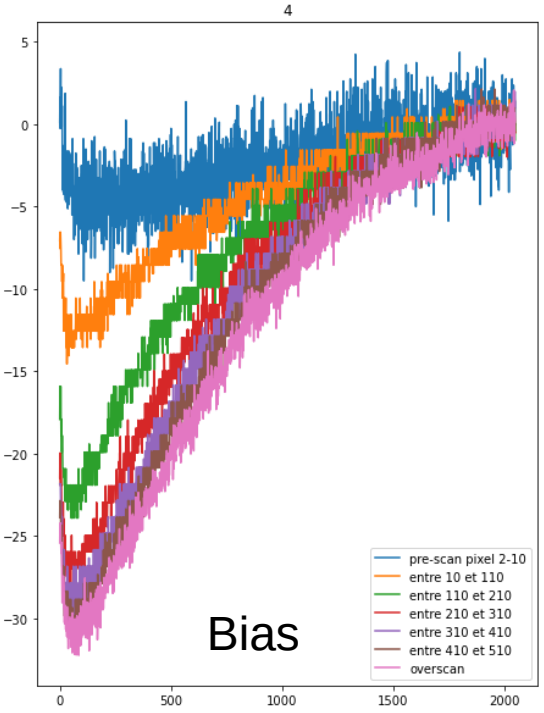
Can we use the prescan pixels to correct/reduce the yellow corners?

Stage de Bruno Longo (M1) en cours au LPNHE

Run 13034 / R12 / S22







- Some useful information in the prescan (‘orange closer to blue than pink’)
- Dependency on the exposure time

Conclusion

- The study of dark runs shows that the currently planned PCA approach (extracted from bias images and applied to science images) does not work, because of the impact of the exposure time on the bias level.
- Will we need to use master dark corrections (exposure time = 15 s)?
- Use of the prescan pixels to correct/reduce the yellow corners: some hope, quantitative studies needed.
- We should push to take data at SLAC in conditions as close as possible to the survey.