Payload on-ground calibration

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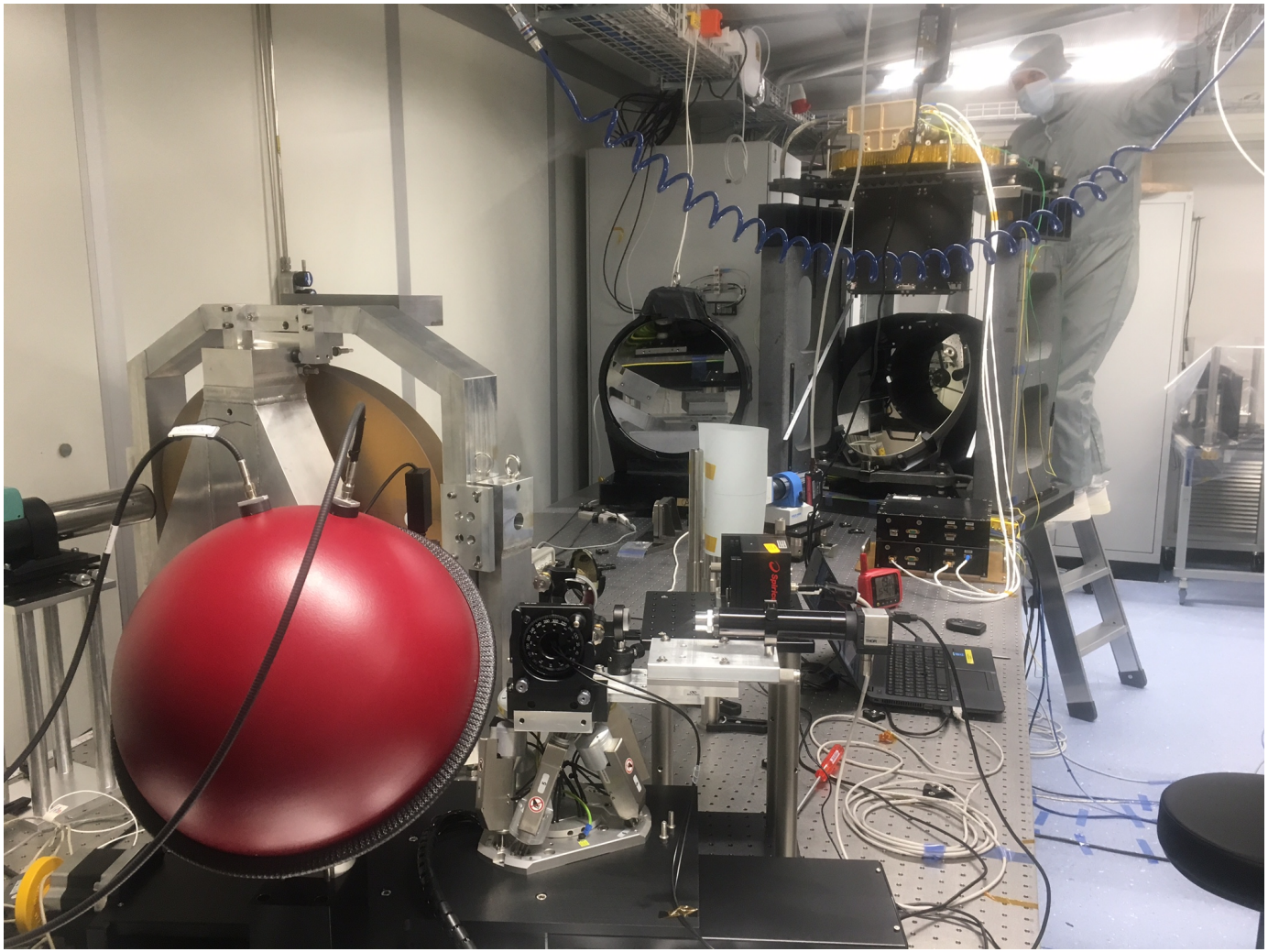
cheops

Overall approach

Test campaign	Institute	Date
CCD tests	e2v	2014
CCD characterization	Geneva	2015-2016
FPM calibration	Bern	Q2-Q3 2017
Payload calibration	Geneva/Bern	Q4 2017

*FPM : Focal plane module

Calibration bench @ UNIBE

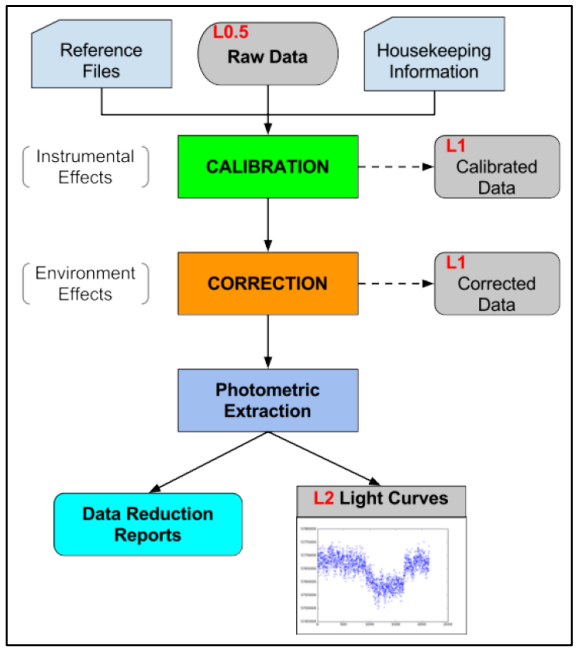


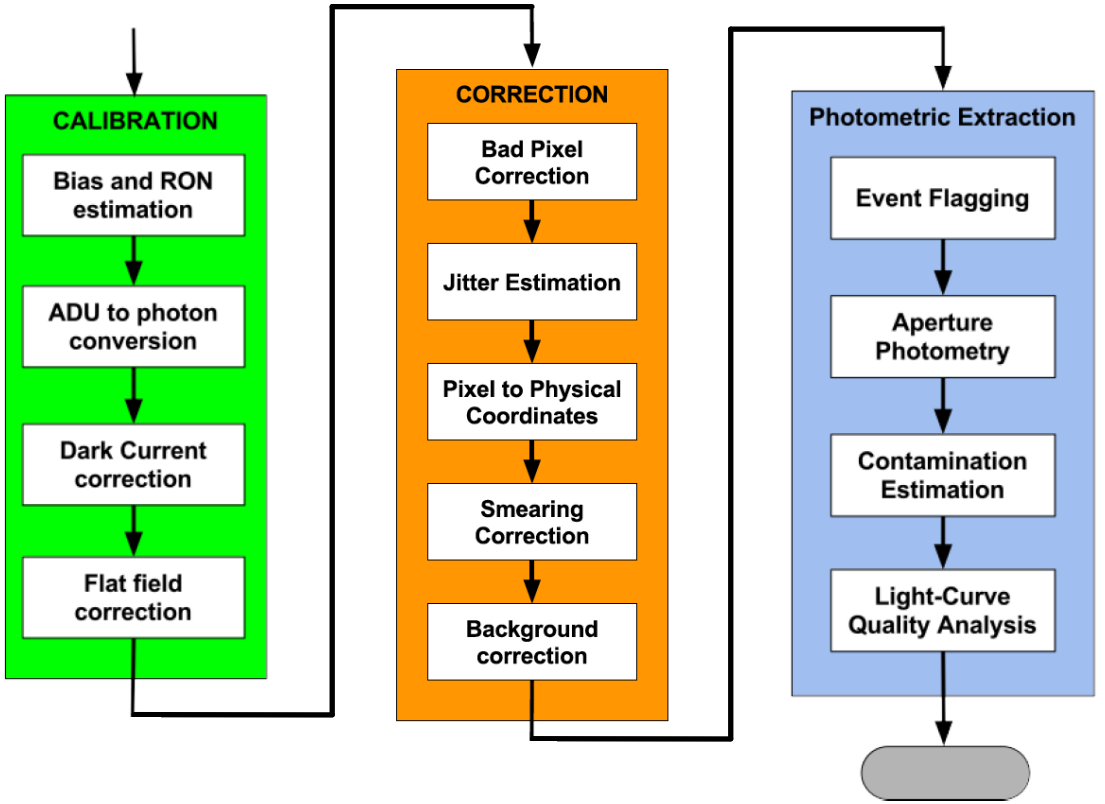
Context

- CHEOPS does not have an on-board calibration source nor a shutter
- All the key measurements already done during CCD characterization campaign
- Most of these results have to be measured again during payload calibration
  - change of electronics
  - payload optics
  - but gain sensitivities are measured for good
- Some of these results will be updated in-flight during the Monitoring & Characterization phase (M&C)

See R. Alonso's talk *(talk n°6.2)*

Inputs for DRP





See S. Hoyer's talk
(talk n°8)

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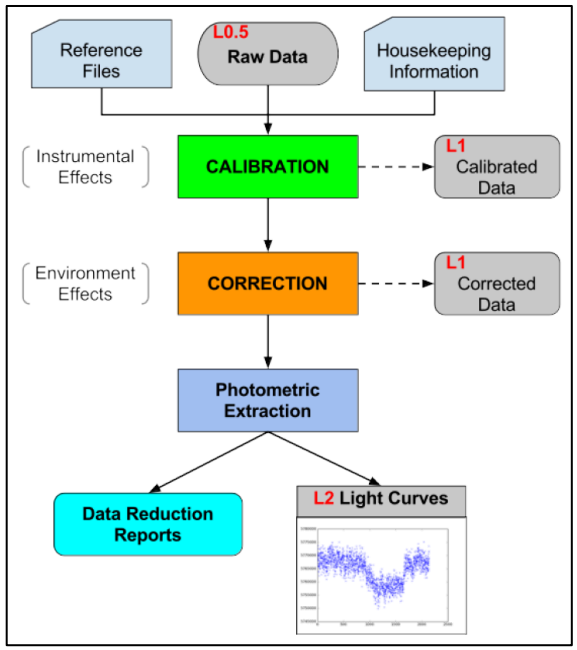

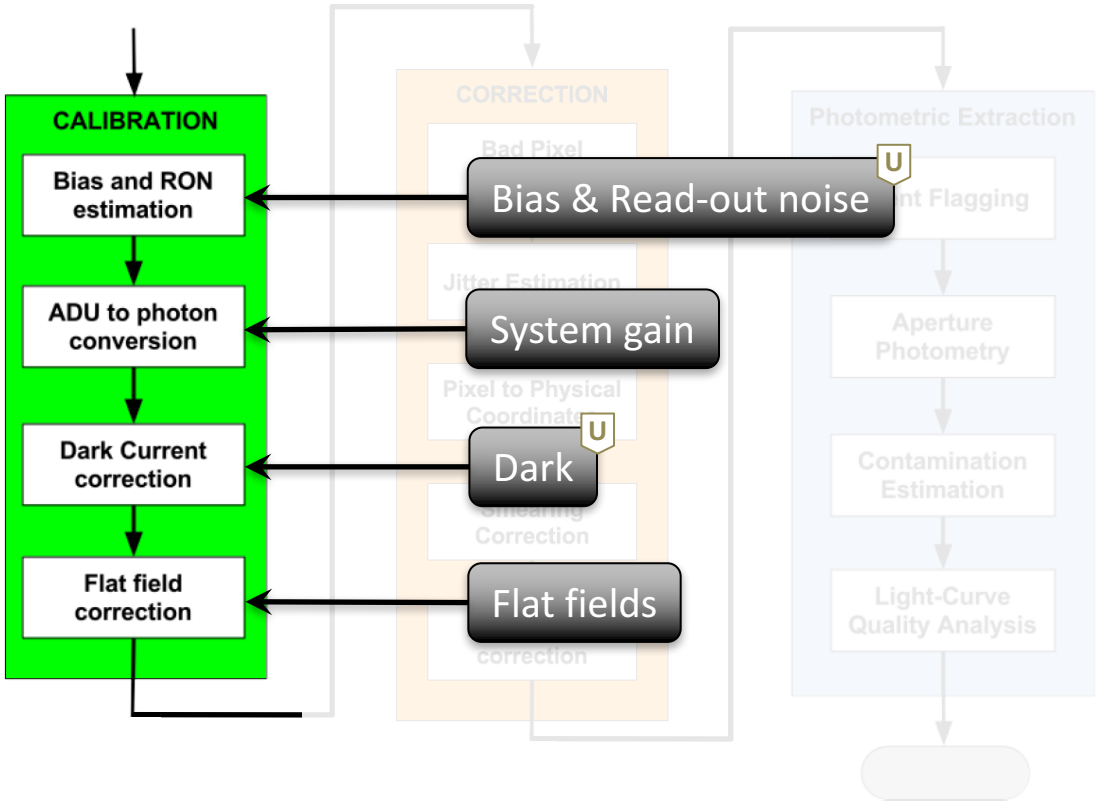

U will be updated during in-flight M&C

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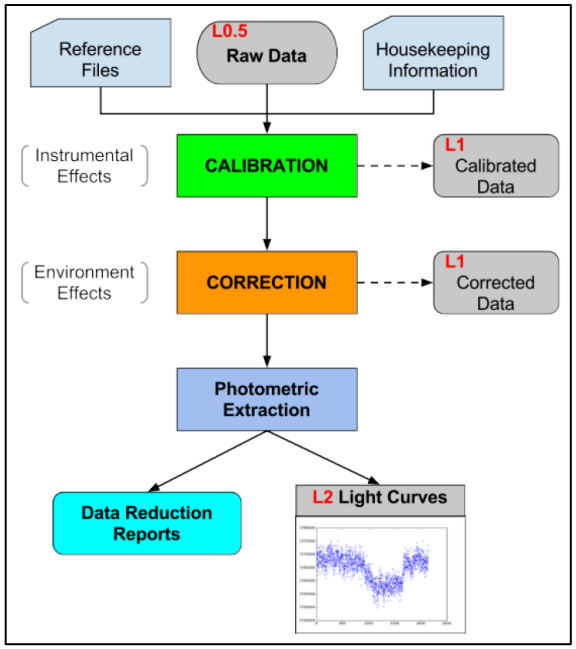

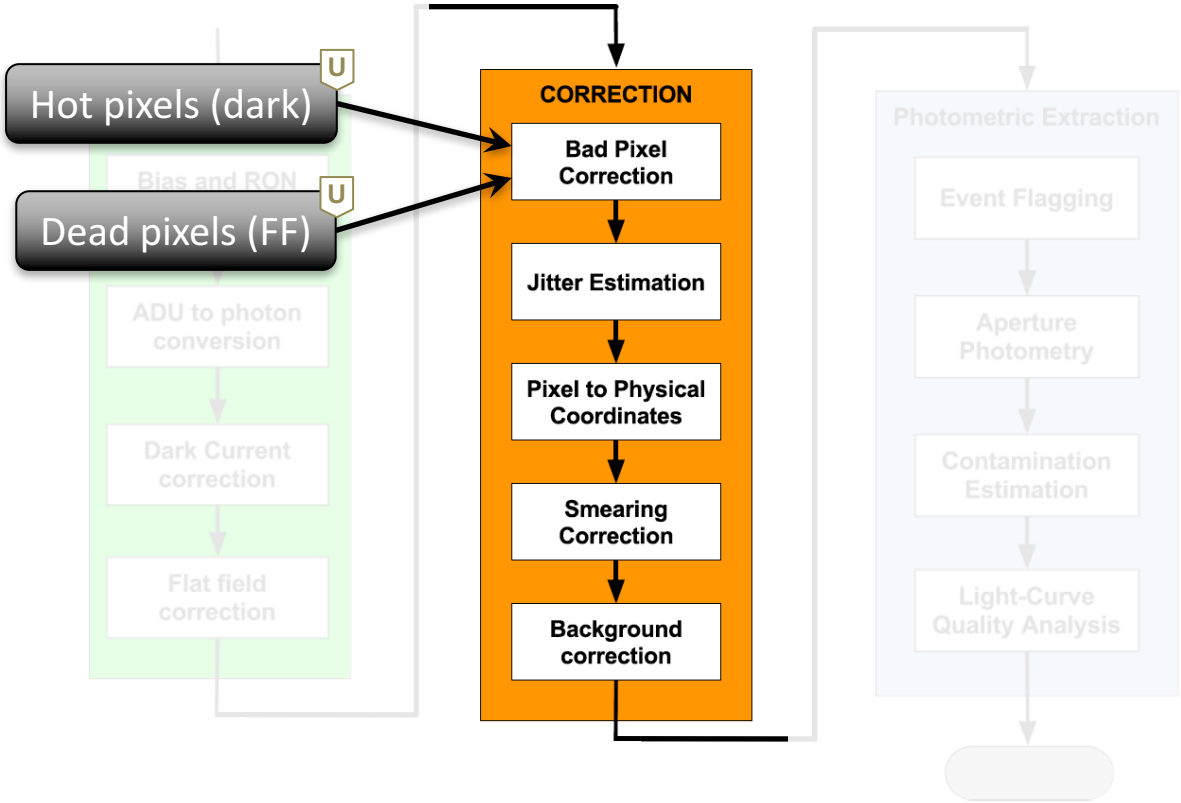

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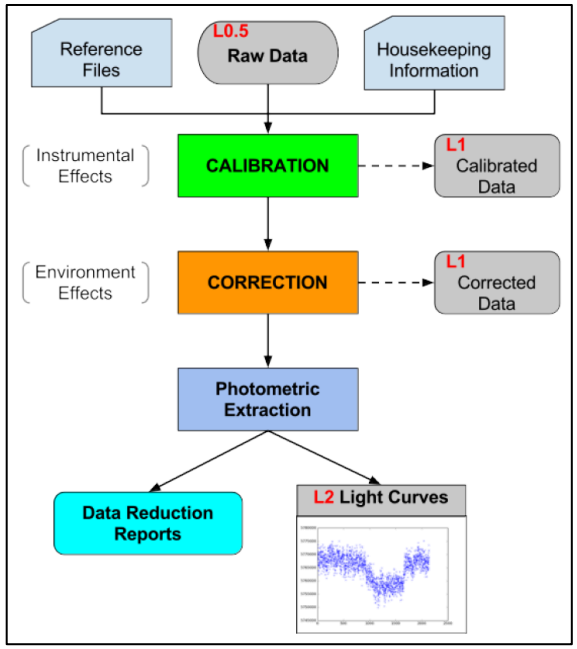

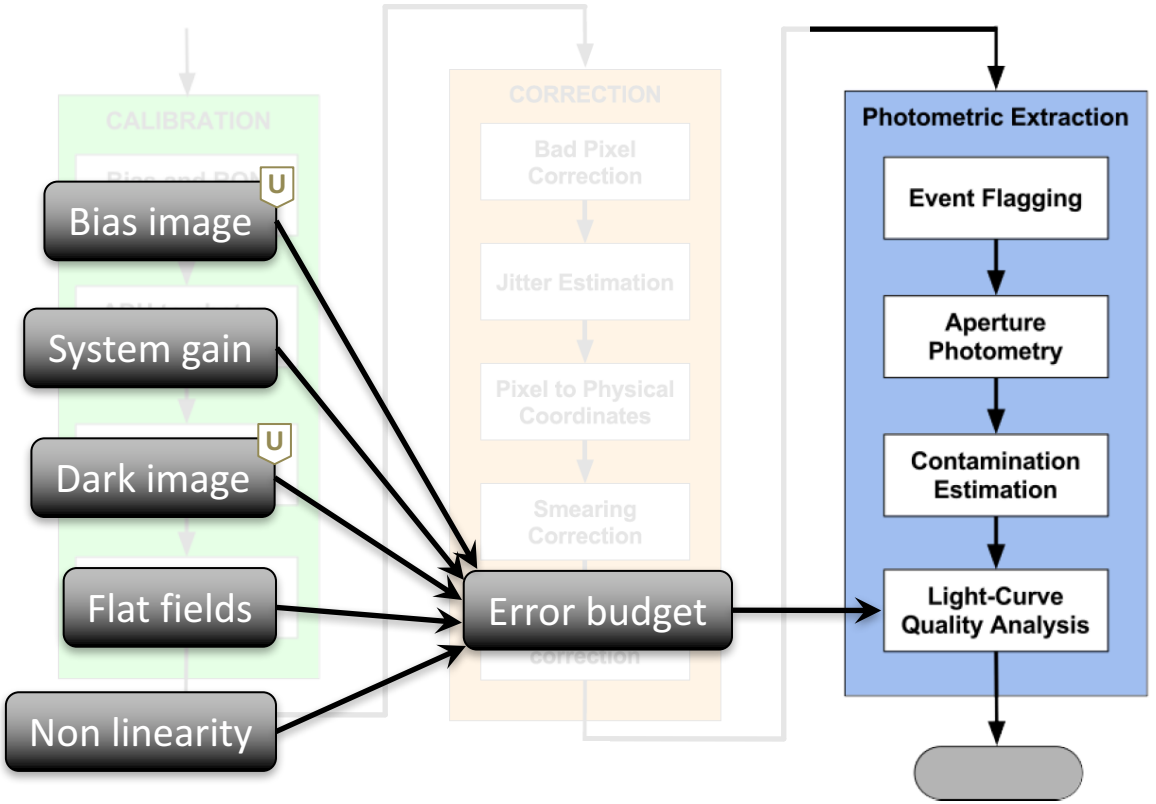

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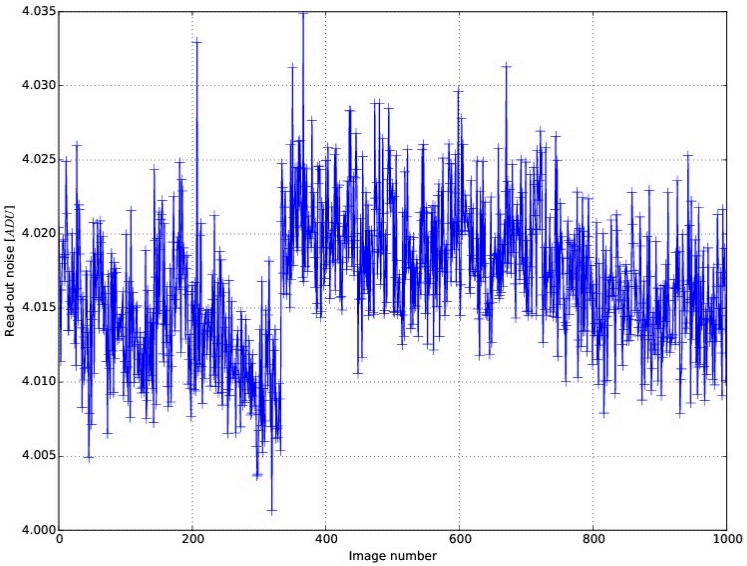
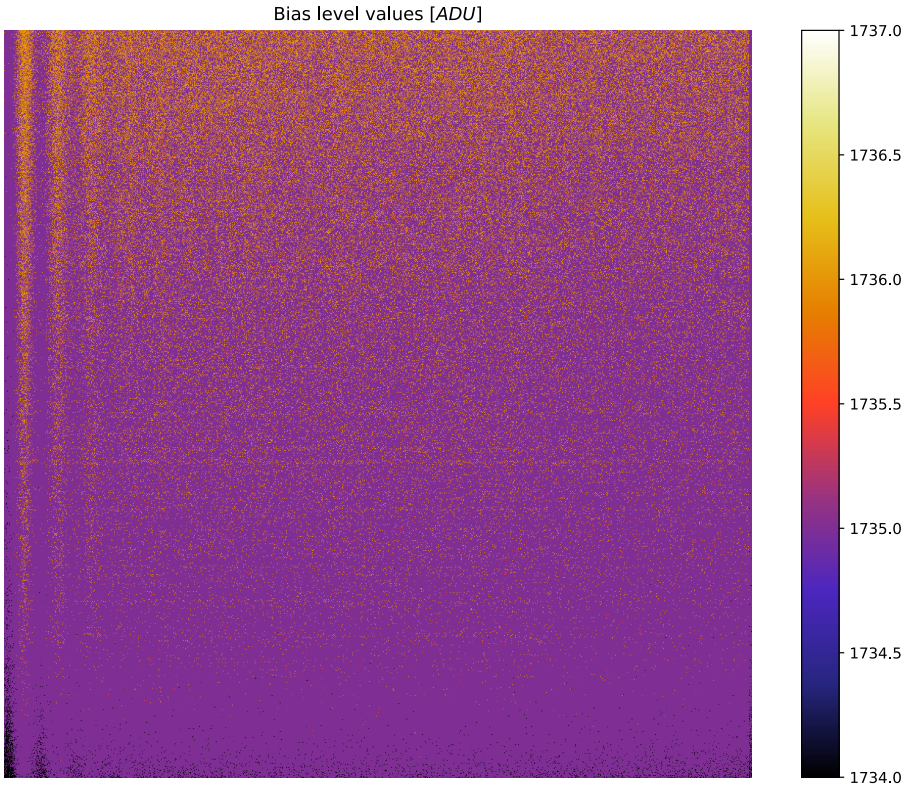
Bias & Read-out noise

- CCD characterization :
  - 0s exposures in the dark
  - Bias level = 1735 ± 1 ADU
  - RON = 4.02 ± 0.01 ADU





from FM2 test report
(CHEOPS-UGE-SYS-120_1.2)

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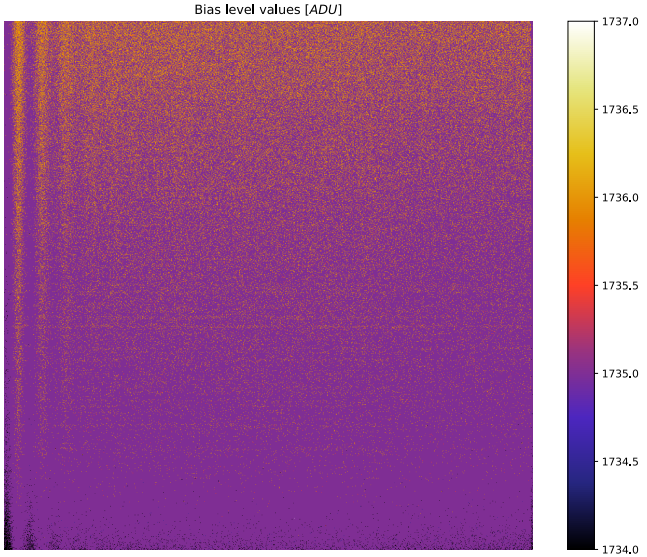
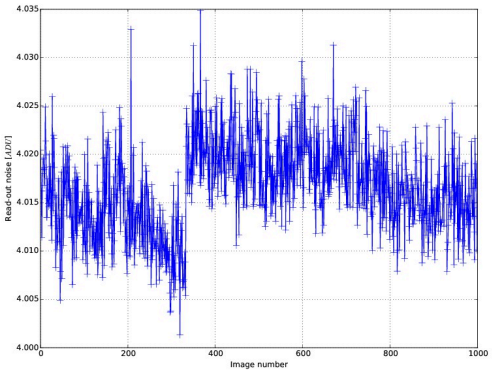


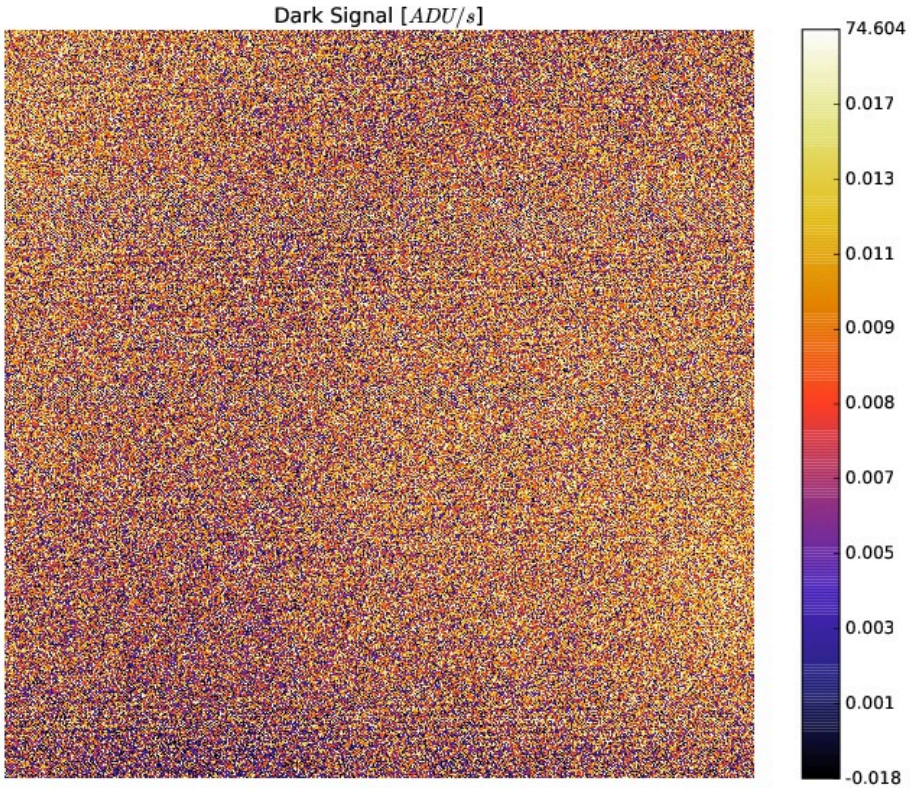
- Measurements during payload calibration
  - dependence on electronic chain
  - small RON variations with V_{bias}
    (less than 0.2 ADU/V, from CCD characterization)



Dark current

- CCD characterization :
  - Various exposures in the dark at different temperature (-40..20 °C)
  - Dark @ -40°C = 0.0016 ADU/s (10 times better than specs)
  - Hot pixels coordinates

from FM2 test report
(CHEOPS-UGE-SYS-120_1.2)



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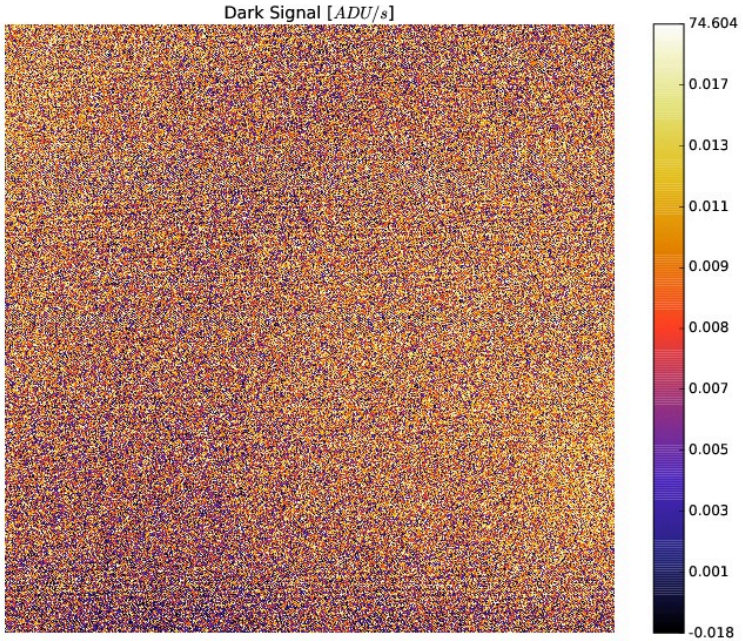

- Measurements during payload calibration
  - only at 0°C and 10°C to identify/locate hot pixels

System gain

- CCD characterization :
  - Different exposures in white light up to saturation
  - Slope at (0,0) of a 2D-polynomial fit
  - Gain = 0.4410 ADU/e^-

from FM2 test report
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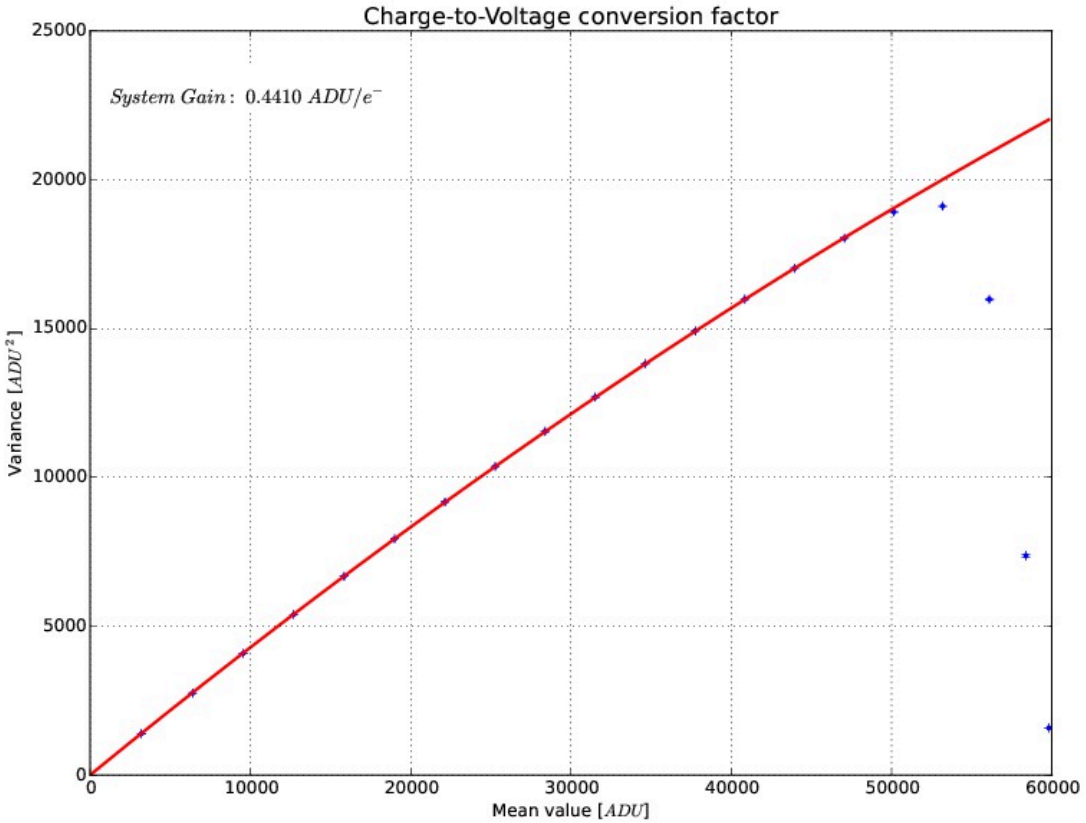

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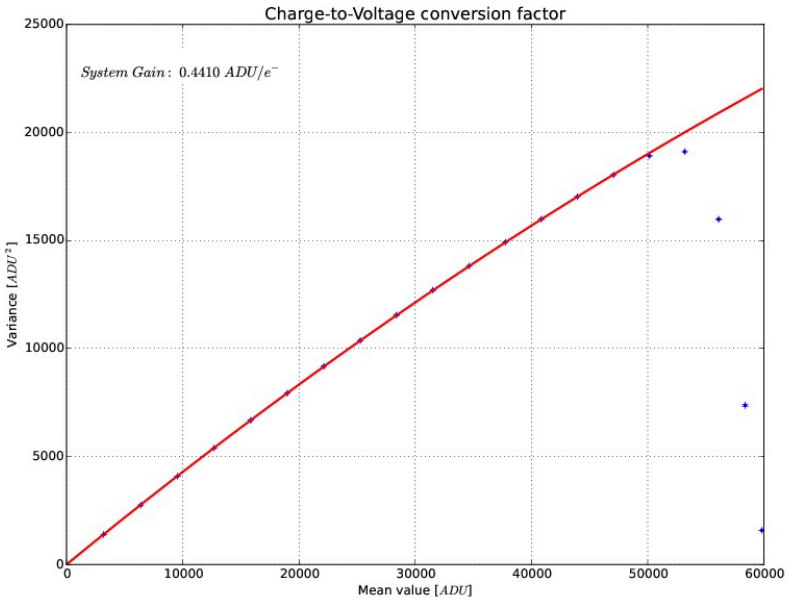
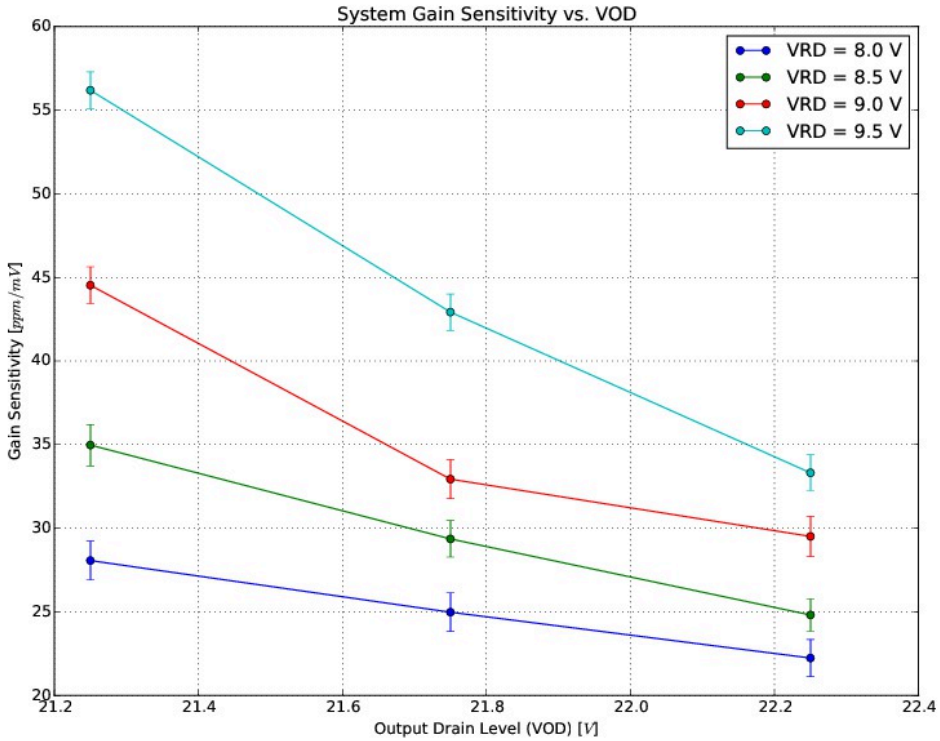


- Measurements during payload calibration
  - dependence on electronic chain
  - gain variations with respect to V_{bias} will be extrapolated from CCD characterization measurements

System gain

- Gain sensitivity
  from CCD characterization
  (not repeated during payload calibration campaign)



- Voltages stability from DLR (nov. 2016)
  - Very high V_{bias} stability
    (less than 1 mV over tens of hours)

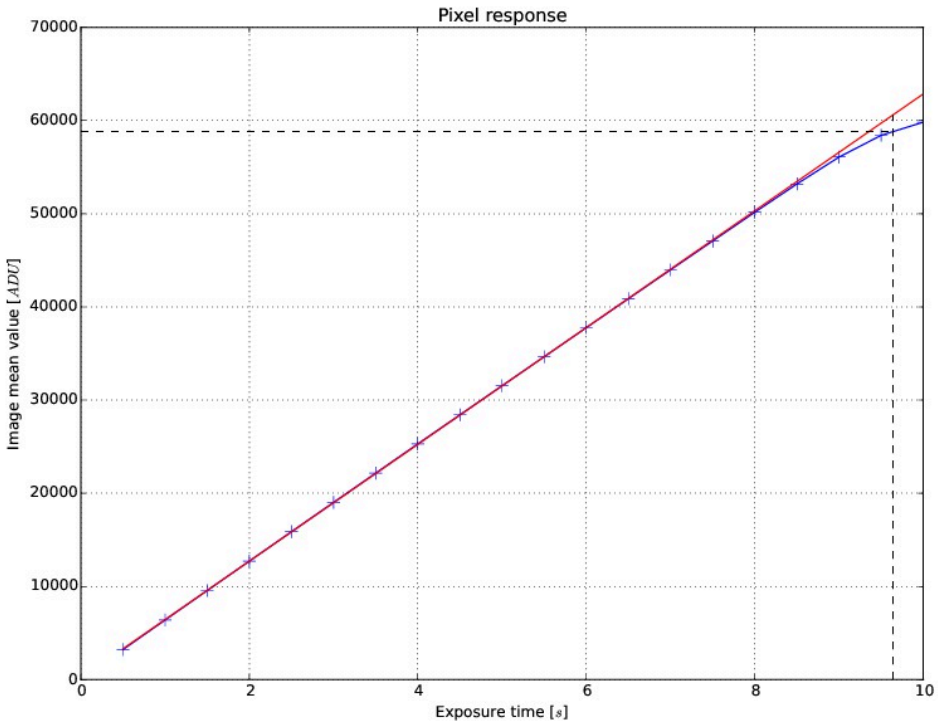
from FM2 test report
(CHEOPS-UGE-SYS-120_1.2)

Full-well capacity

- CCD characterization :
  - Different exposures in white light up to saturation
  - Full-well capacity is defined as the point where CCD response is 3% away from linear fit
  - FWC = 58823 ADU

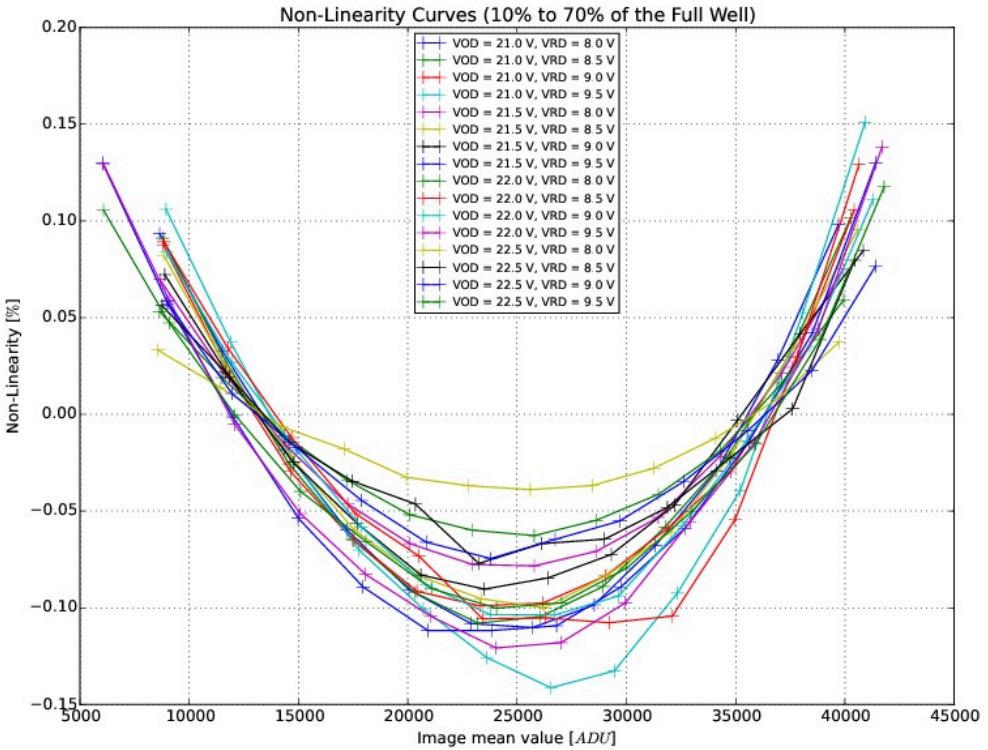
- Conservative definition
  - when reaching FWC, the CCD is not fully saturated (still signal beyond FW)

from FM2 test report
(CHEOPS-UGE-SYS-120_1.2)



Non-linearity

- CCD characterization :
  - Different exposures in white light up to saturation
  - Non-linearity is the difference between CCD response and a linear fit
  - Nominal non-lin. ≤ 0.088 % in the 10-to-70%$_{FWC}$ range



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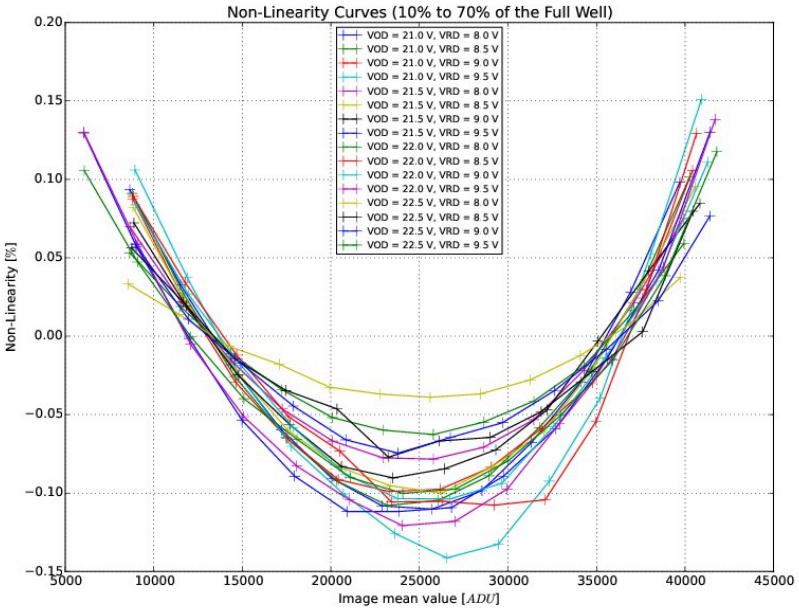
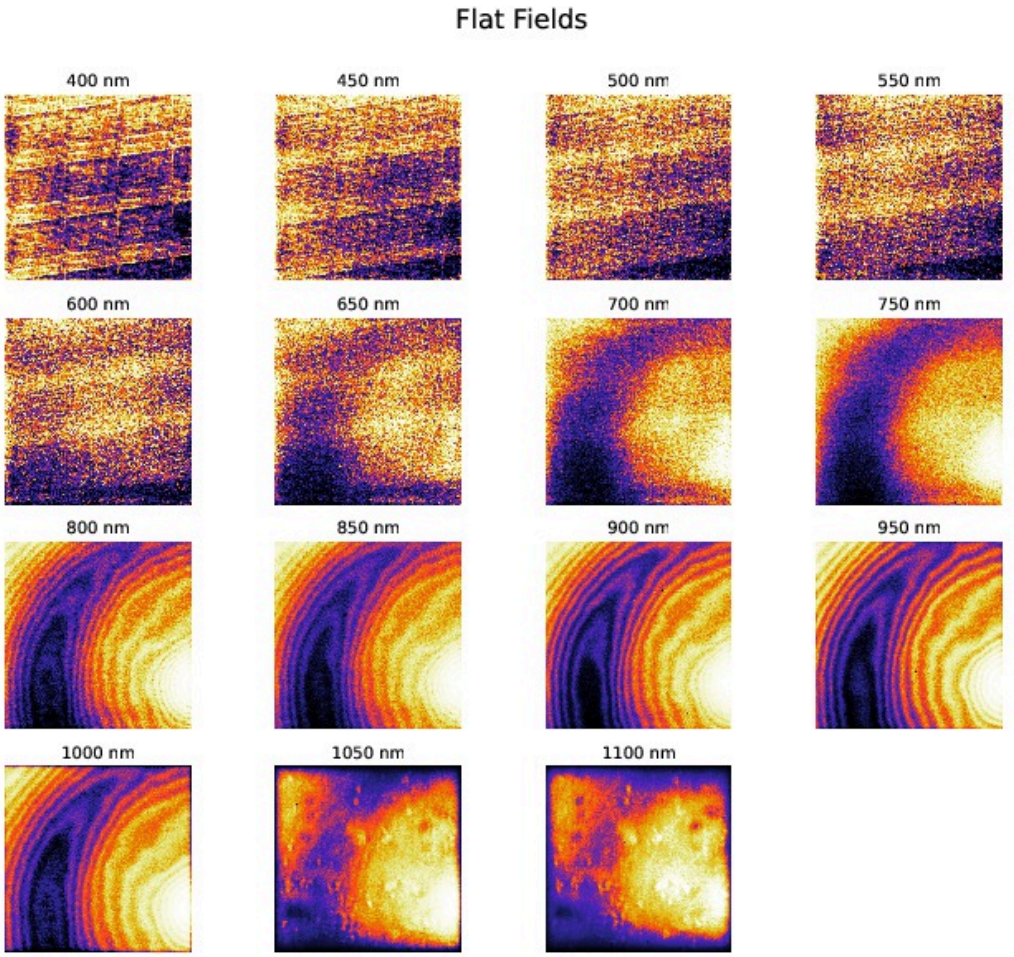


- Measurements during payload calibration
  - should show no dependence on electronic chain (dominated by CCD)
  - nominal case only (expect very small V_{bias} variations during mission compared to the range explored)

Flat fields

- CCD characterization :
  - Various exposures in monochromatic light at different λ
  - Wavelength bands of 30 nm
  - Blue diamond and "tree-ring" effects



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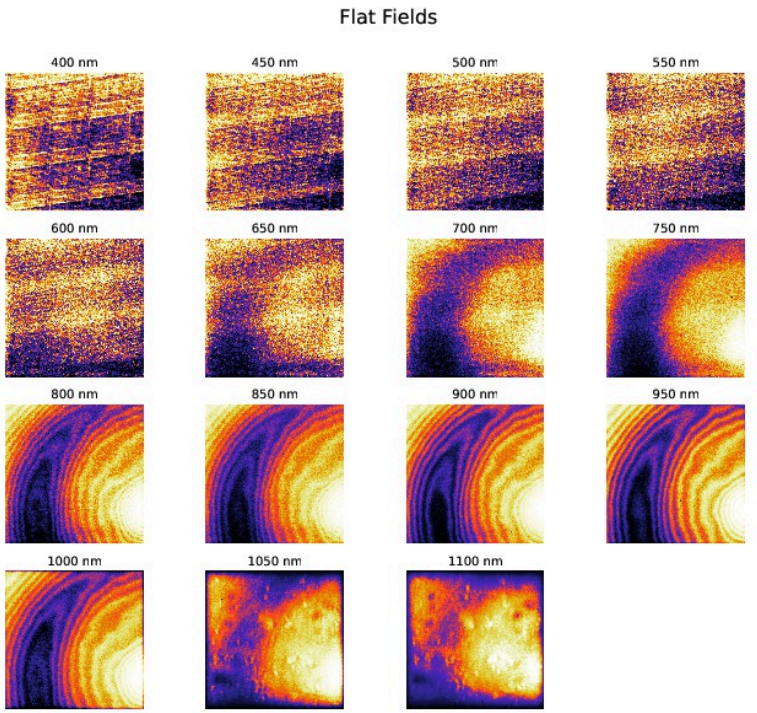
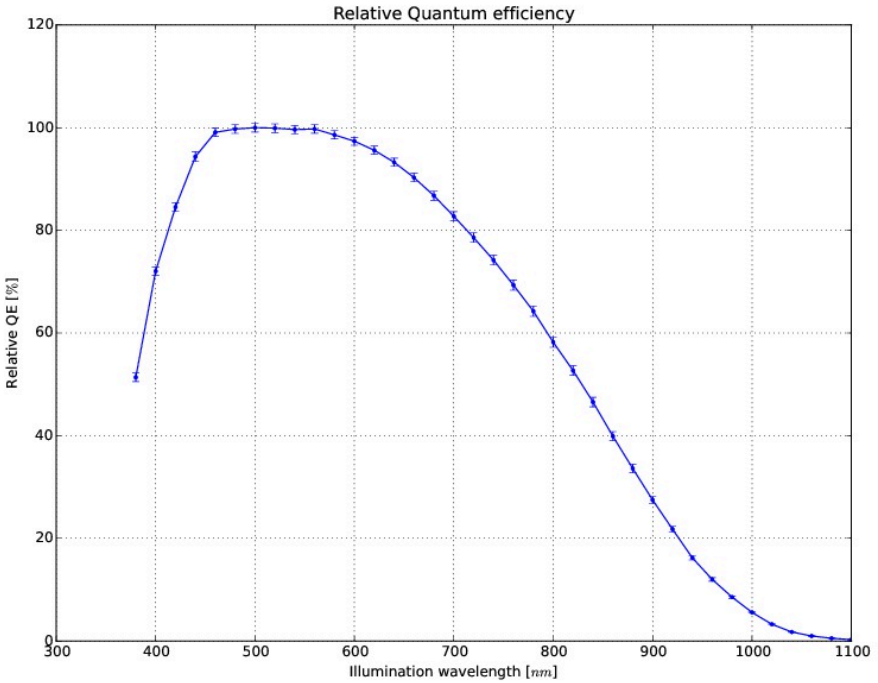


- Measurements during payload calibration
  - additional vignetting due to optics
  - denser wavelength sampling (FF combination)

Quantum efficiency

- CCD characterization :
  - Various exposures in monochromatic light at different λ
  - Wavelength bands of 30 nm
  - $QE = \frac{N_{electrons}}{N_{photons}}$ ← from CCD; ← from reference photodiode



from FM2 test report *(CHEOPS-UGE-SYS-120_1.2)*

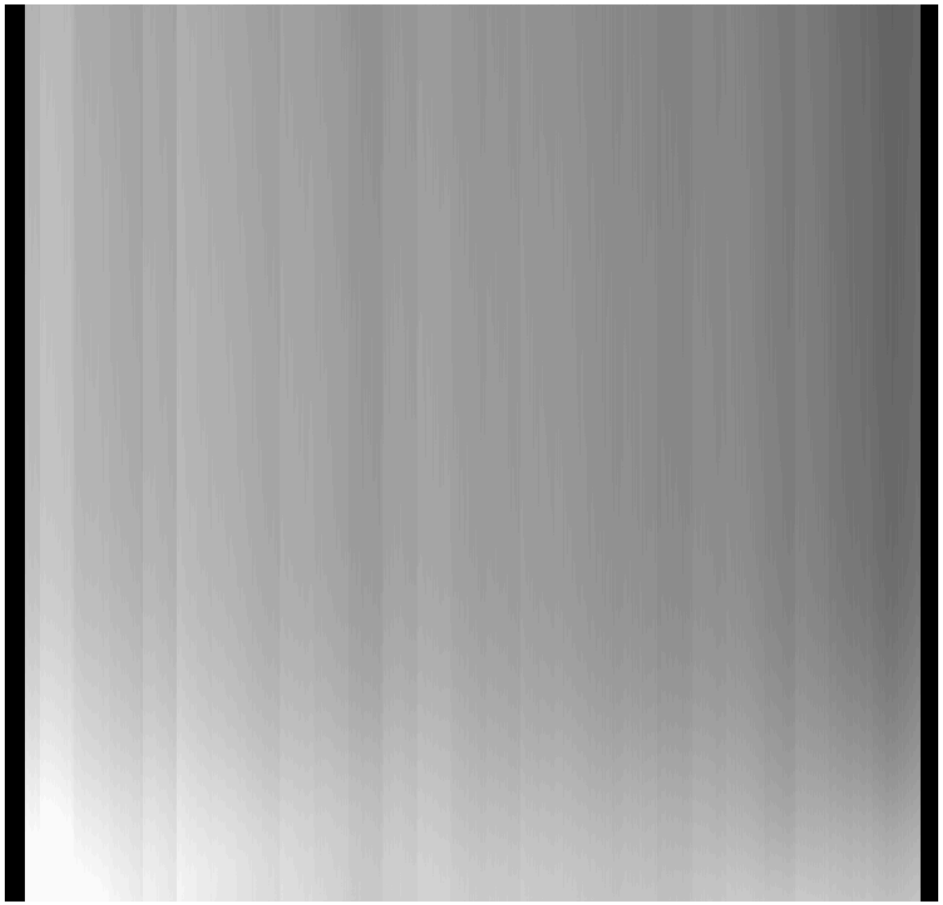
- Measurements during payload calibration
  - to include transmission of the whole optical system

Other tests of the CCD characterization

- Saturation
  - No memory effect

(No new measurement planned during calibration)

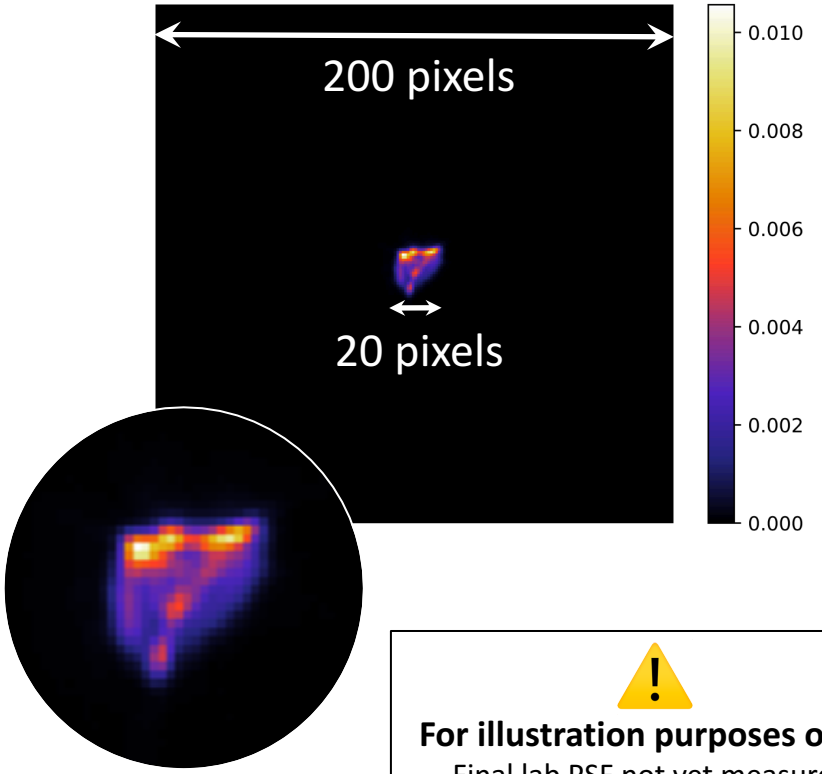
FM1 saturation data



Other tests during payload calibration campaign

PSF shape

- Functional test
  - check alignment and any optical issue
  - identify PSF for tracking
  - over FoV and λ
- No delivery of in-flight PSF
  - non-uniform illumination of the pupil
  - gravity effect



For illustration purposes only !
Final lab PSF not yet measured.
In-flight PSF expected to be different.

Other tests during payload calibration campaign

Photometric performances

- This is not a calibration
- Performance test 1 : stability
  - nothing moves + tracking loop
  - stability measurement
- Performance test 2 : flat field
  - with jitter
- Performance test 3 : full
  - with temperature variations (survival heaters)

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