Corot Calibration

OUTLINE

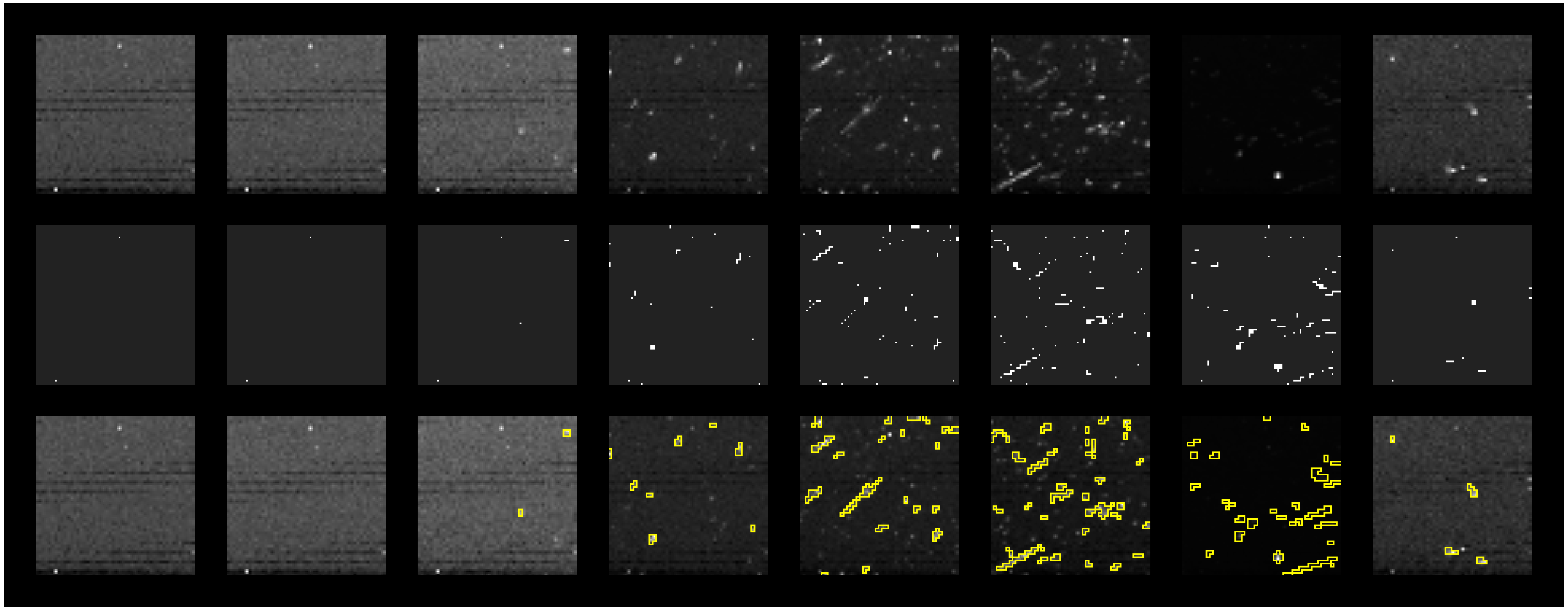
- Orbital Environment
  - Radiation Flux
  - Thermal Effects
    (on analogical components)
- Readout Electronics
  - Offset Level
  - Readout Noise
  - Electronics' Gain
- CCDs
  - PRNU
  - Dark current
  - Bright pixels

Radiation Flux

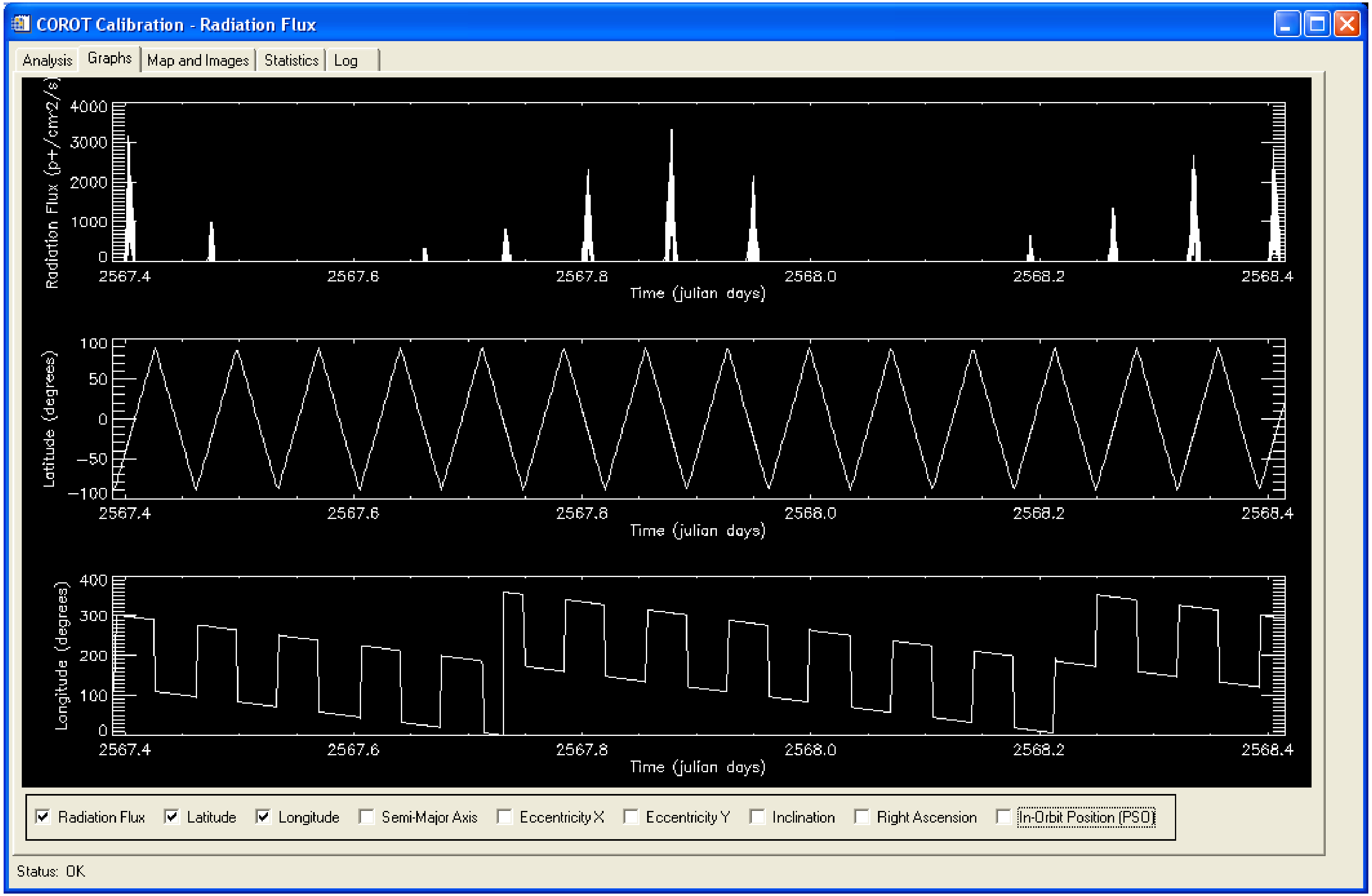
- Objectives:
  - Measure the radiation flux seen by the CCD detectors behind shielding (10mm Al)
  - Define SAA frontiers for the triggering of specific onboard software services (outlier rejection)
  - Characterize energy and size of particle impacts (statistical distributions)

Radiation Flux

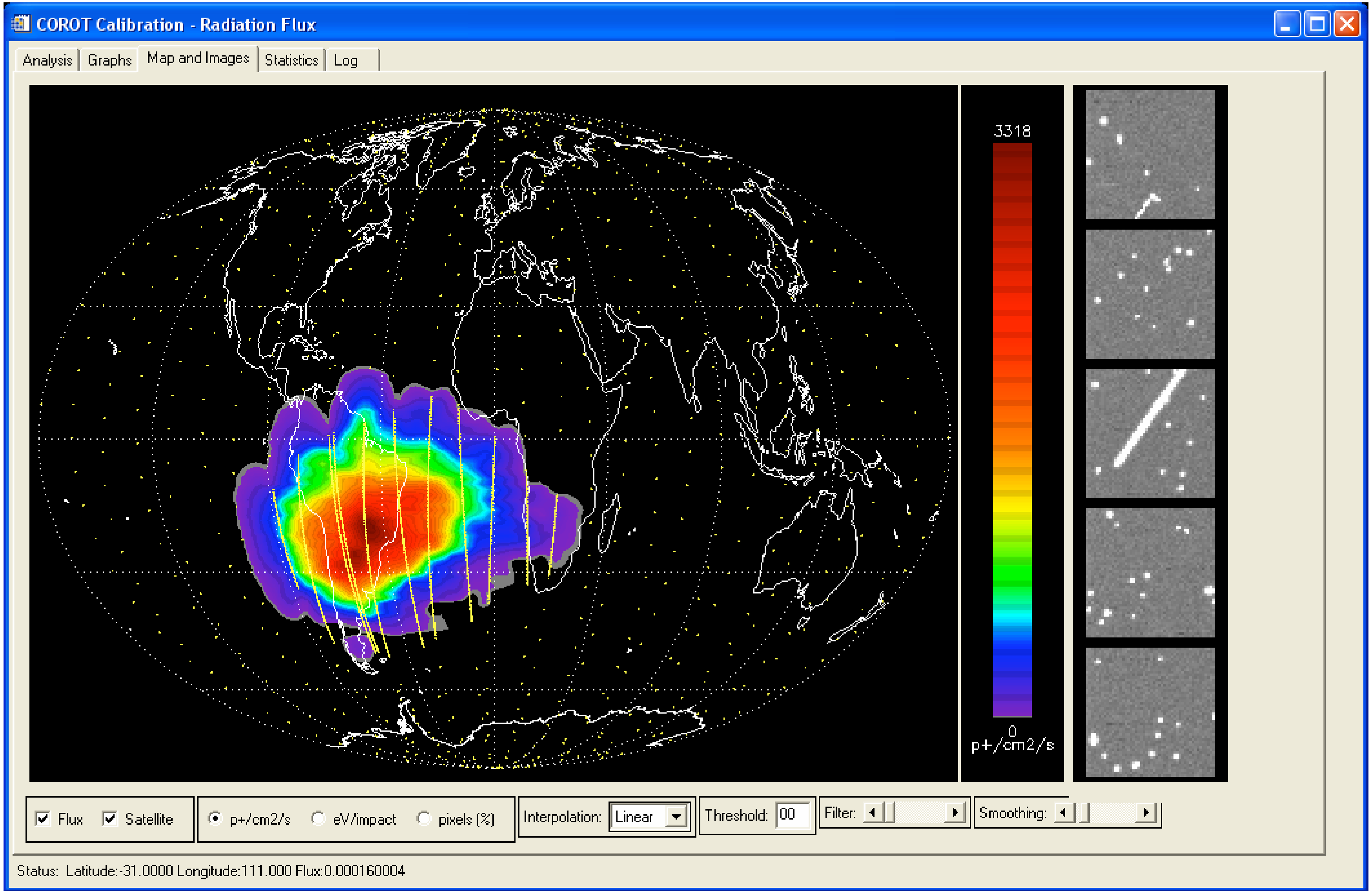
- 24hs of data acquisition [50x50]
  - Different acquisition conditions according to satellite position



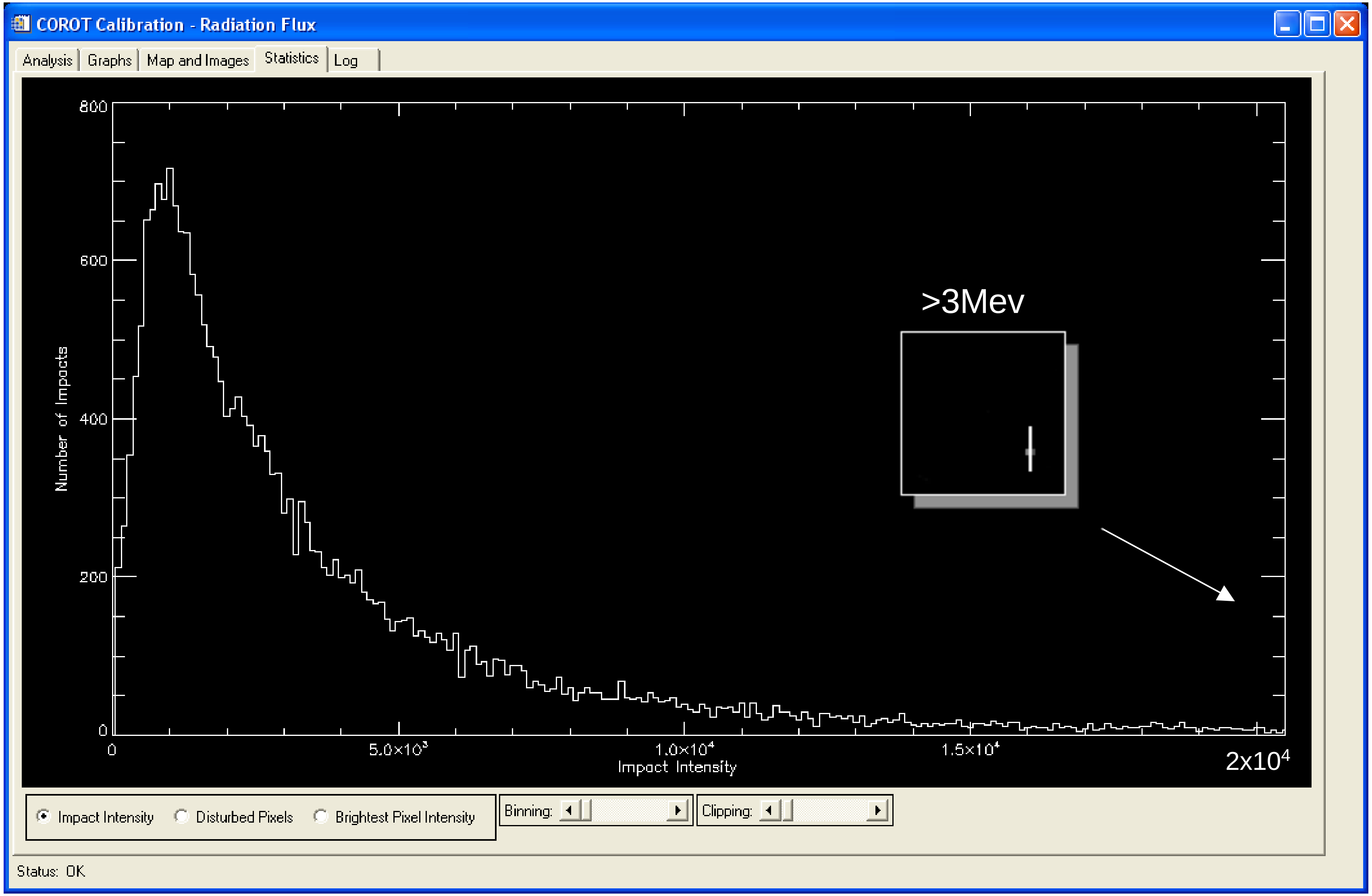
Radiation Flux and Orbital data



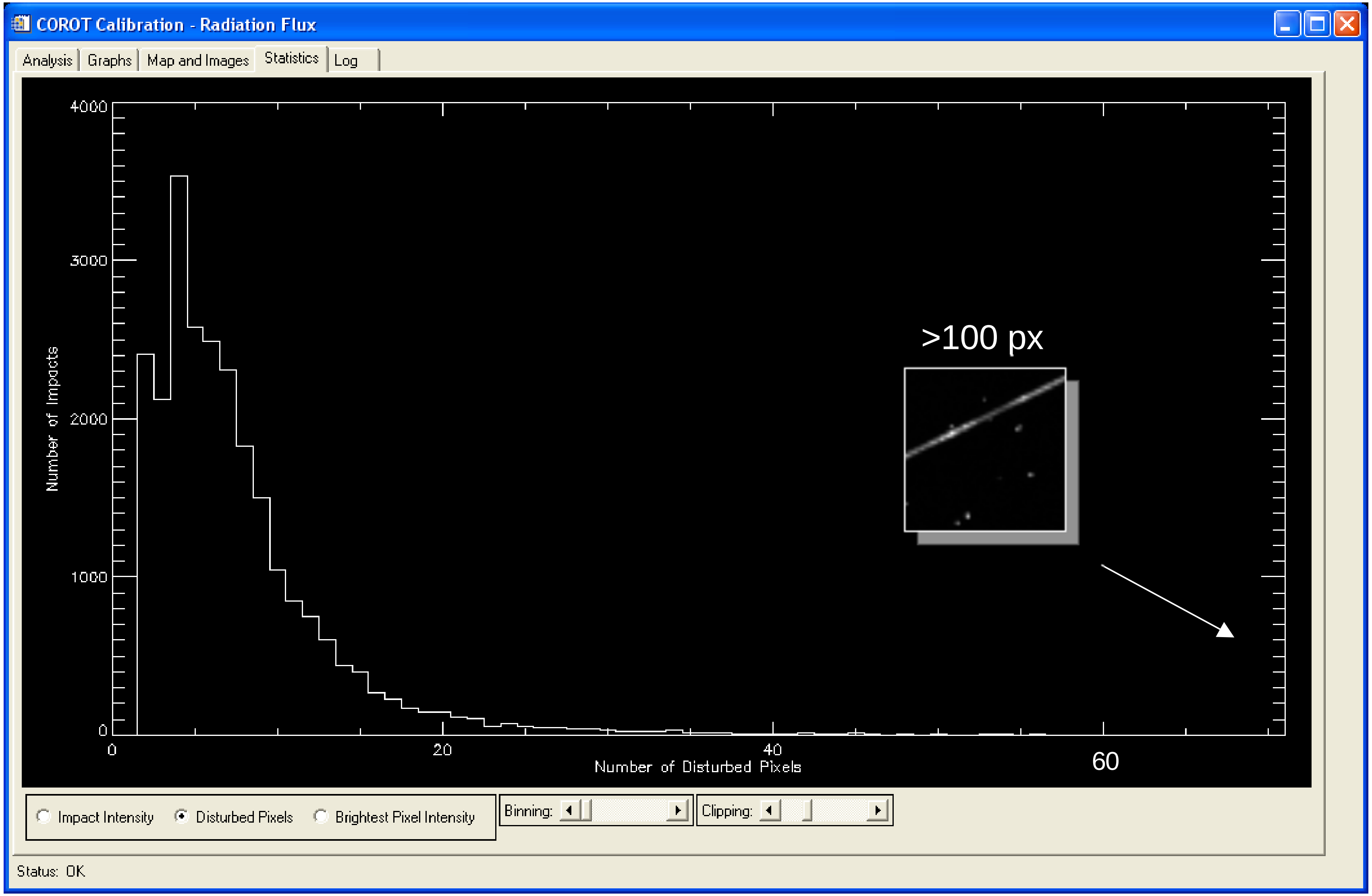
SAA frontiers (at 300p+/cm2/s)



Energy per impact (e-)

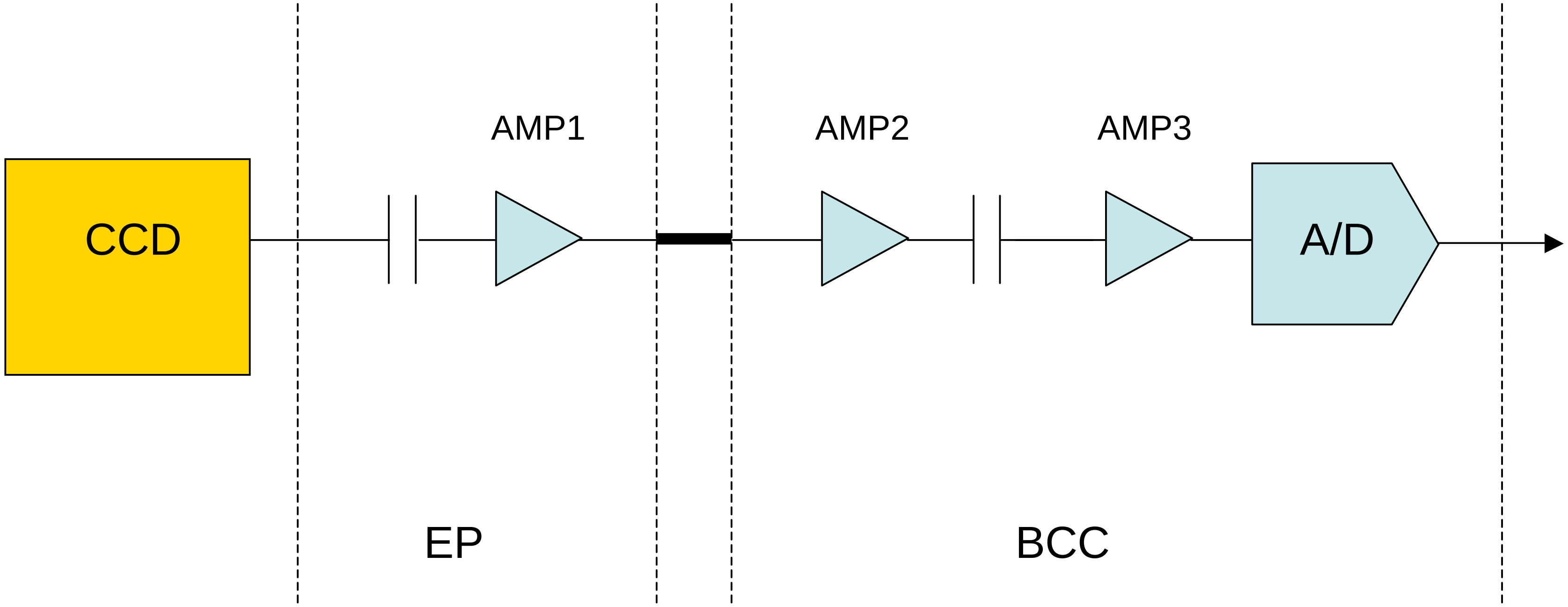


Disturbed pixels per impact



Readout electronics

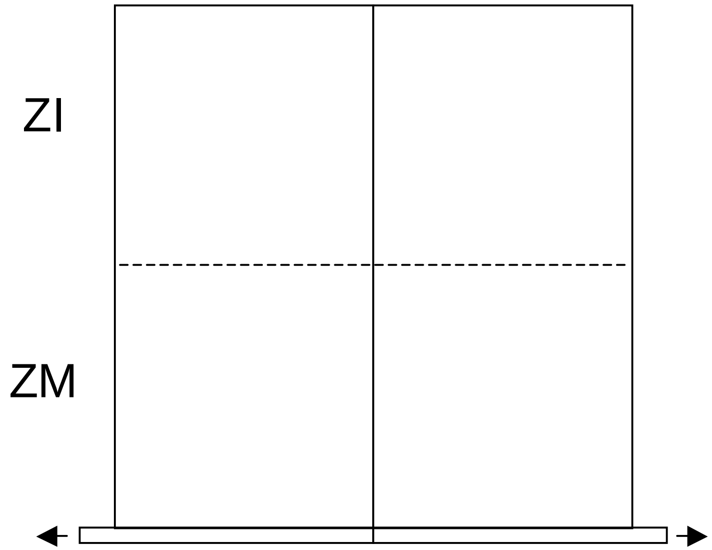
- Objectives:
  - Electronic Offset (sensitivities)
  - Readout noise
  - Chain gain (e-/ADU)



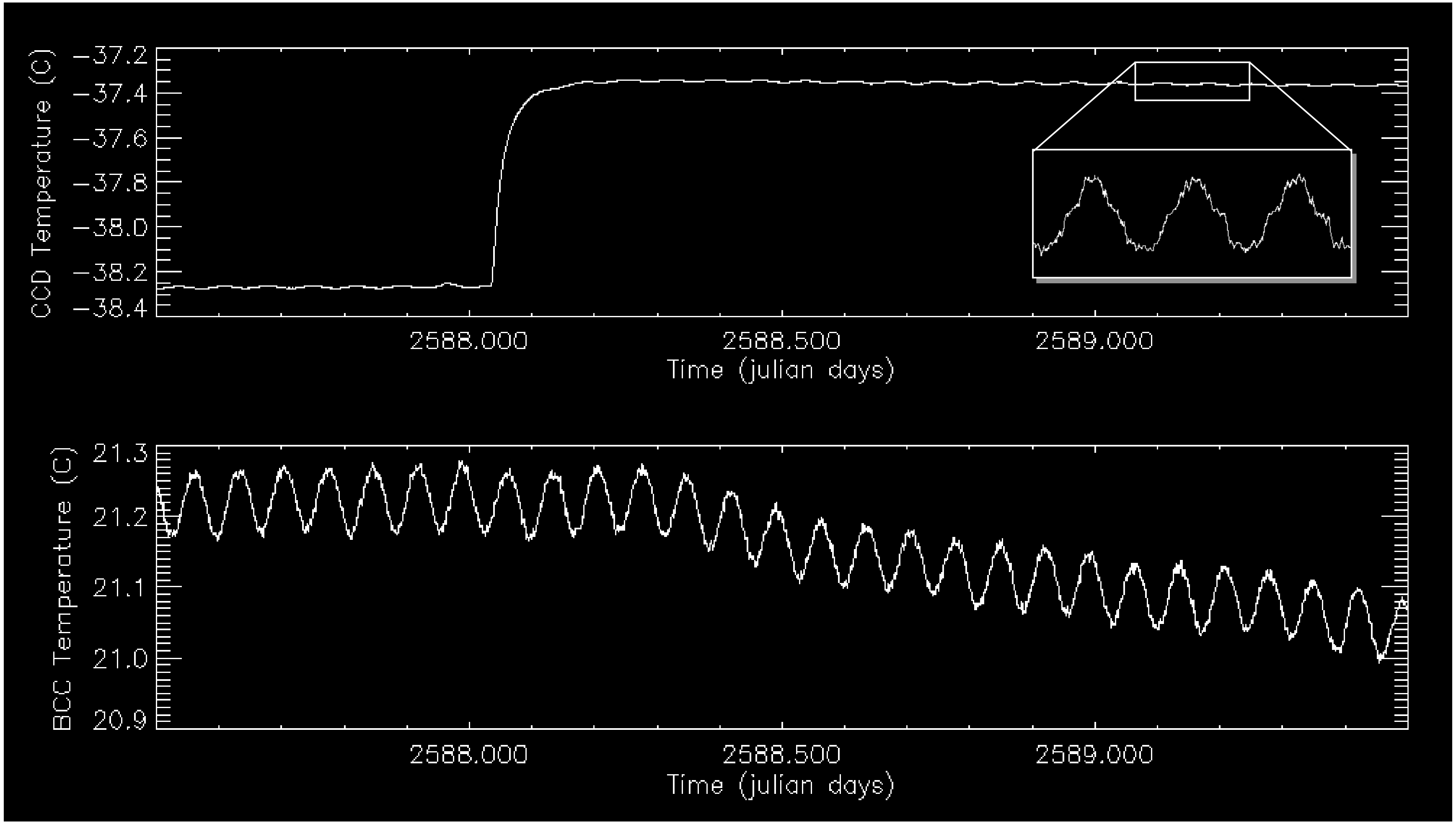
Electronic Offset

- Offset level imposed to assure proper A/D conversion
- Measured at emptied CCD output registers

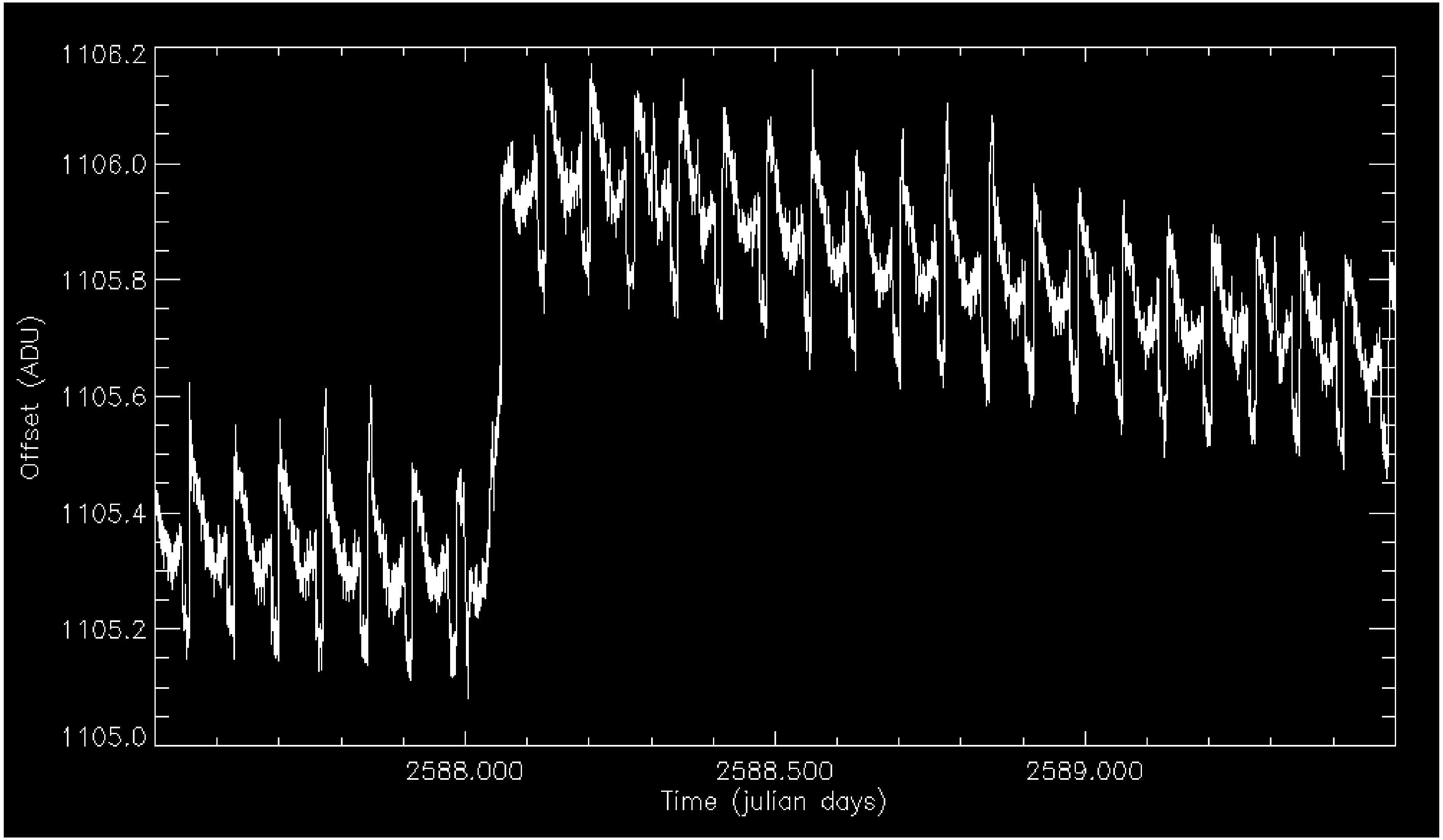
- Superposed effects:
  - Thermal sensitivities
  - Crosstalk
  - Readout noise
  - Power supply (?)
  - etc..



(Some) Relevant Temperatures



Offset Astero



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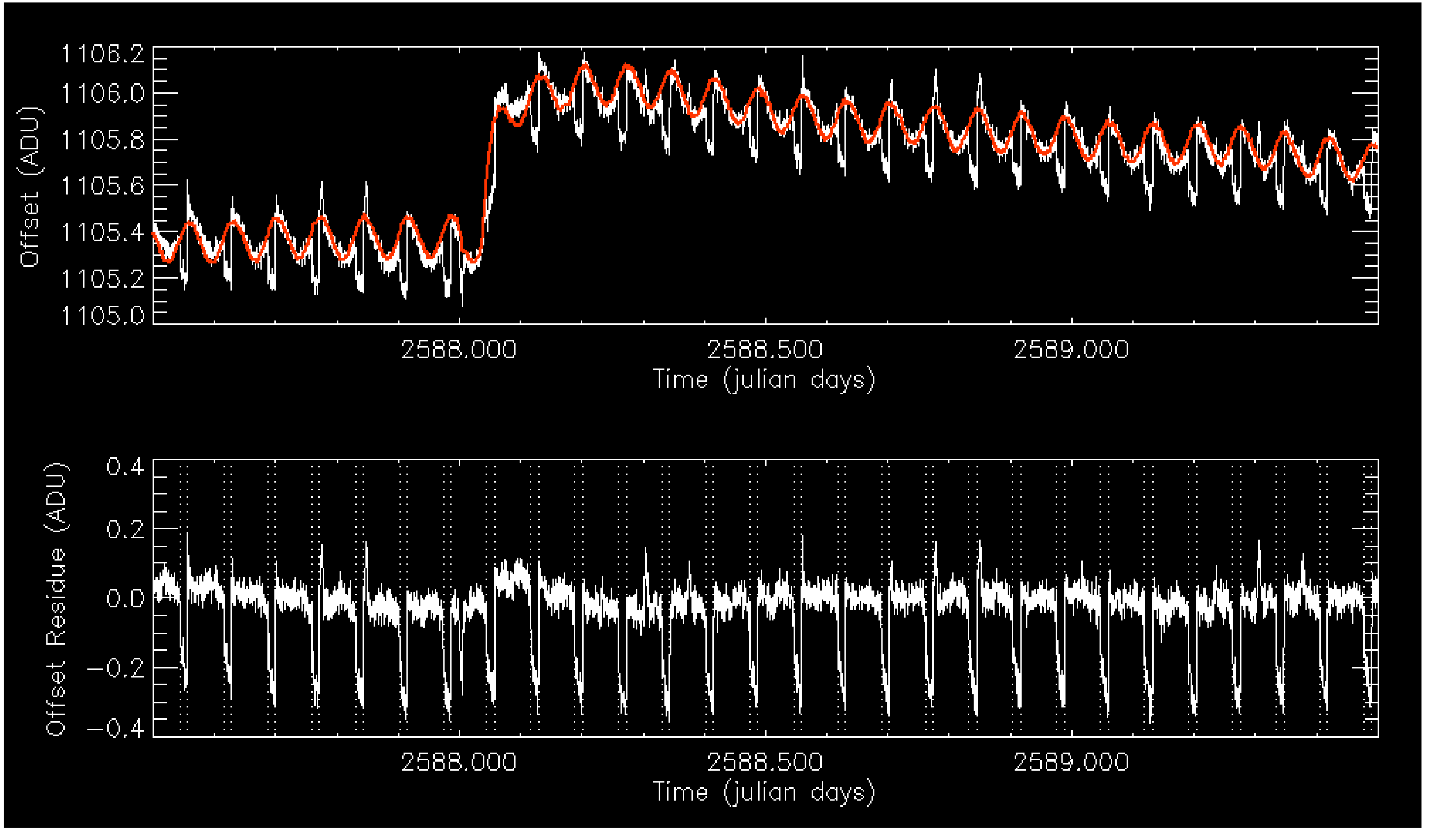
Offset Residue after subtraction of thermal effects



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Electronic Offset

- Thermal sensitivities:
  - CCD, BCC, BEP, ..
  - 0.5 to 2 ADU/C, depending on the chain
- Negative steps
  - Sunlight->Shadow->Sunlight transitions
  - Only for chain 1 by now (to be followed)
- 2nd order correction of photometric data TBD

Readout noise

- Readout Noise (ADU)

	CCD A1		CCD A2	
	left	right	left	right
In-Flight	4.34	4.26	4.25	4.36
Ground (VT)	5.5	5.4	5.5	5.3

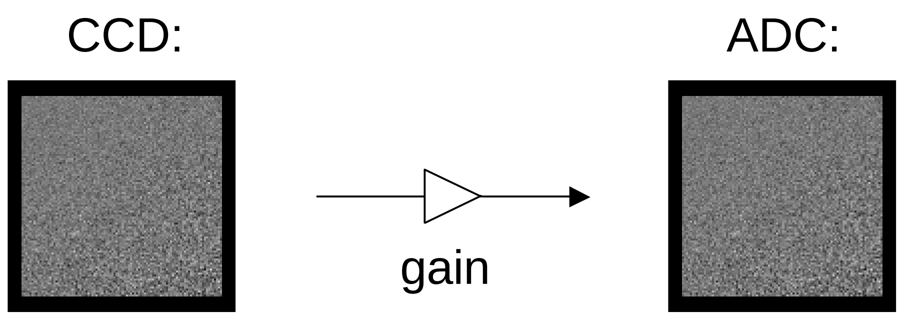
	CCD E1		CCD E2	
	left	right	left	right
In-Flight	3.83	3.69	3.79	3.72
Ground (VT)	4.6	4.6	4.5	4.5

(Note: slightly different evaluation methods)

Electronics’ Gain

- Gain of complete electronic chains
  - (CCD outputs -> readout electronics -> A/D converter)

- Evaluation principle (very simplified):



CCD: μ = _^{2} (Poisson)

ADC: gain . μ — gain^2 . _^{2}

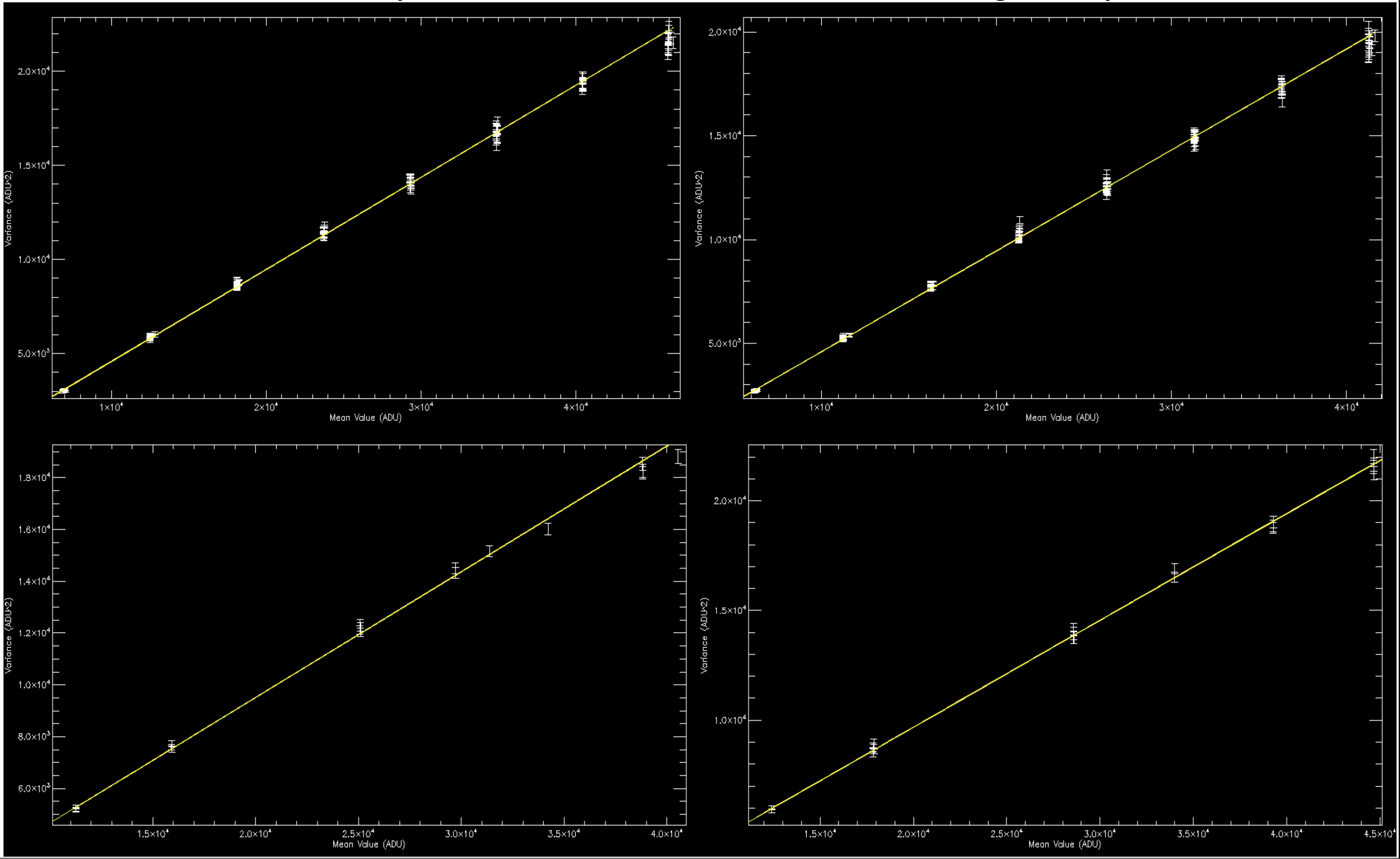
- Evaluated on a series of flashed images (after pre-processing)
  - Some data were rejected due to scattered light

Electronics' Gain

left output | right output

A1

E1



Electronics' Gain

- Estimated values (e-/ADU)

	CCD A1		CCD A2		precision
	left	right	left	right	
In-Flight	2.04	2.05	1.99	1.99	(+- 0.01)
Ground (VT)	2.1	2.1	2.0	2.0	(+- 0.1)

	CCD E1		CCD E2		precision
	left	right	left	right	
In-Flight	2.06	2.05	2.15	2.14	(+- 0.04)
Ground (VT)	2.1	2.1	2.2	2.1	(+- 0.1)

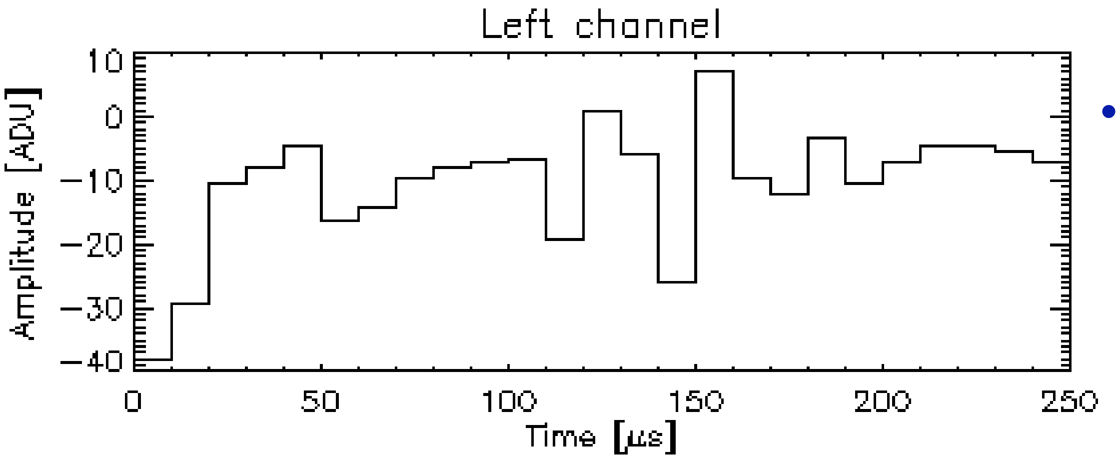
(precision derived from statistical uncertainties)

Crosstalk

- Electromagnetic interferences
  - 2 different cycles exist on the same electronic
    - Astero CCD are digitalised once per second
    - Exo CCD are digitalised once per 32 seconds

    => Digitalisations on ASTERO and EXO channels are not synchronous. When the electronic digitalise a pixels, it can be sensitive to what occur on the other CCDs.

  - Some sequences on CCD produce important perturbations on the electronic For exemple :
    - A line transfert on an EXO CCD lasts 250 µs
    - During this time, 25 pixels are digitelised on the ASTERO CCD (10µs per pixels)
    - Due to the EMI, an offset will be add to these 25 pixels :

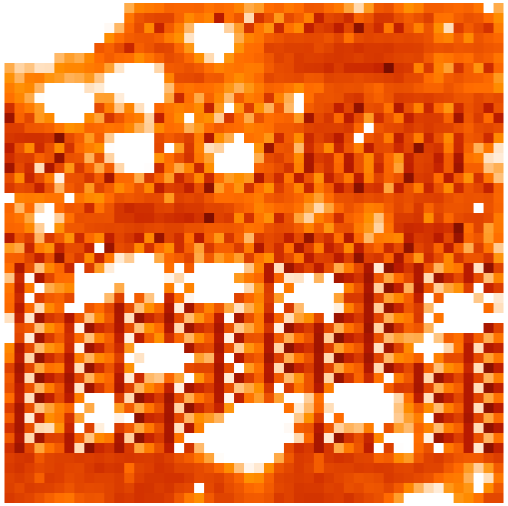


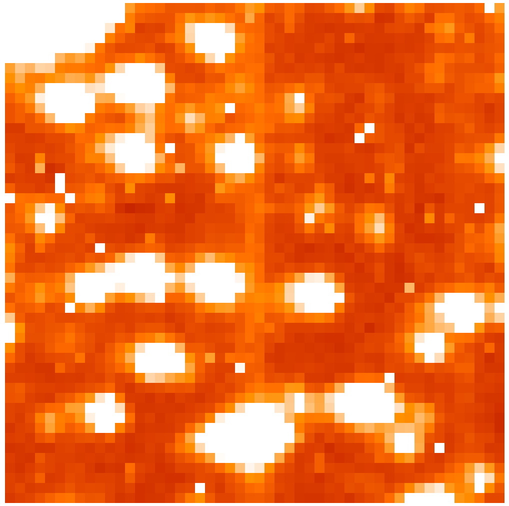
- Objectives
  - Caracterise the crosstalk for each sequences

Crosstalk

- Correction of an image on Exoplanet channel

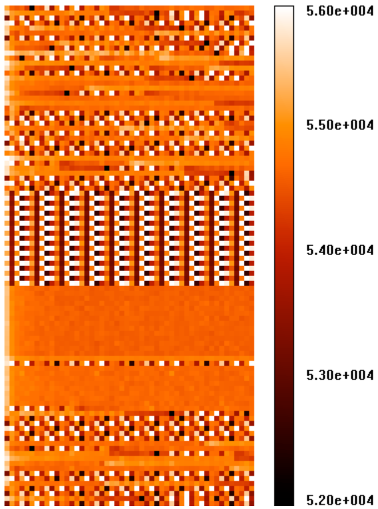
Before correction

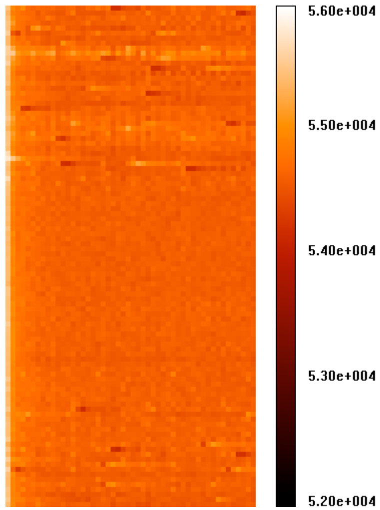




After correction

Correction is not perfect

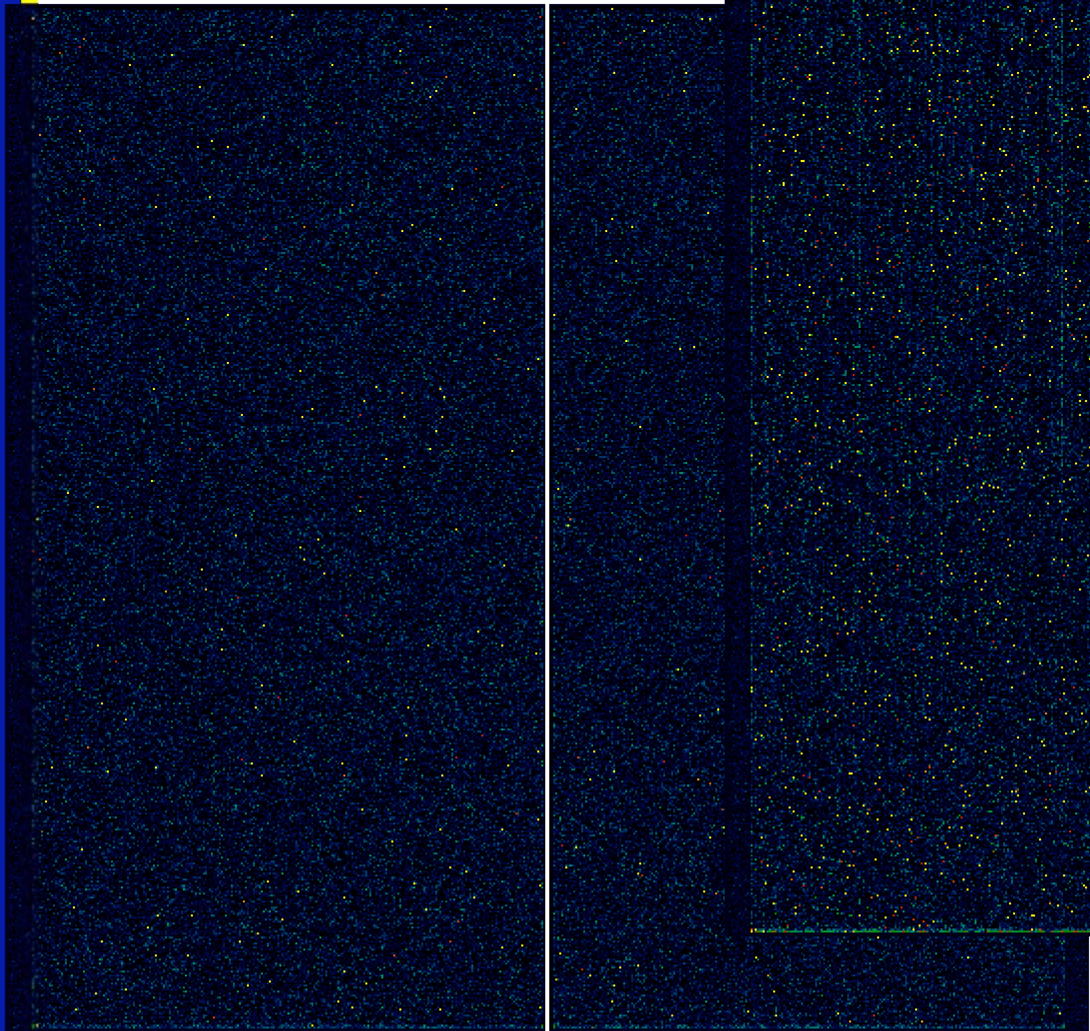




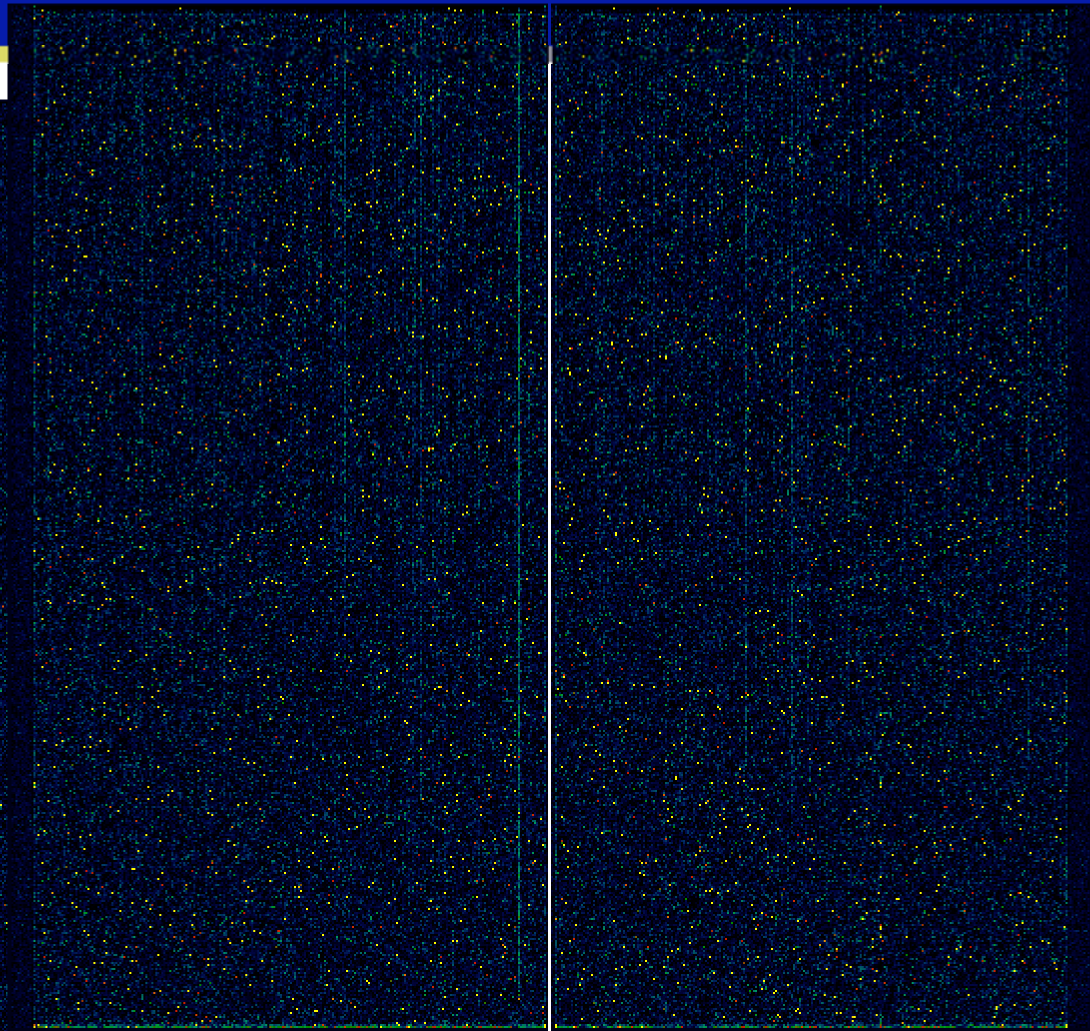
Caracterisation of CCDs

- Objectives
  - Dark field
  - Bright pixels map
  - Pixel response non-uniformity
  - Black pixels map

Dark field

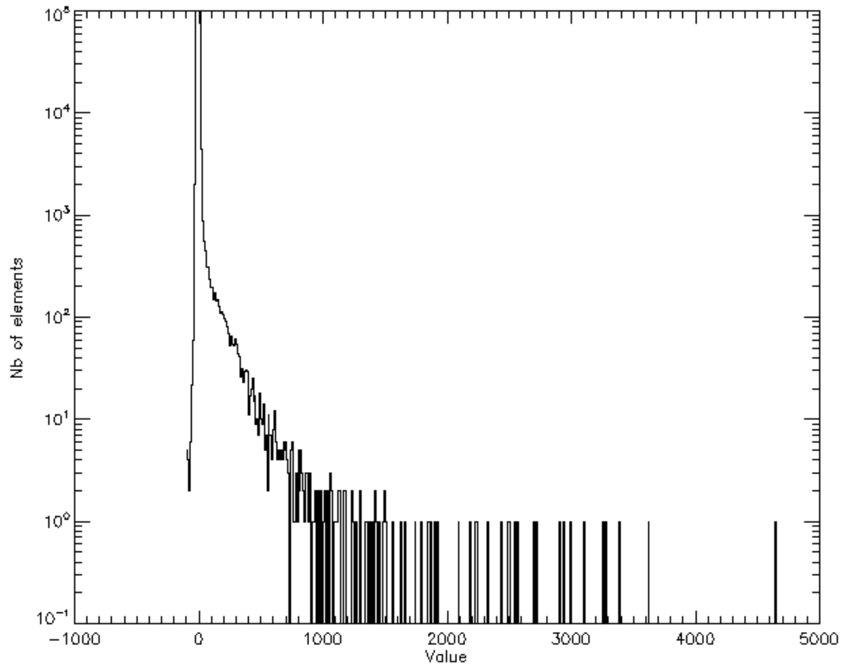


~2400 pixels > 300 e-/exp. (January 2nd = d+6)

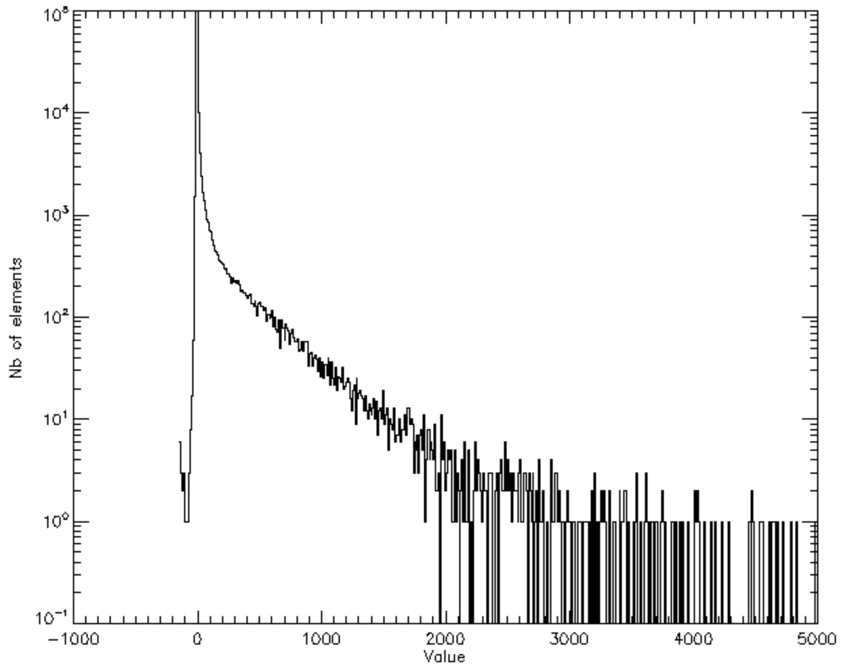


~9000 pixels > 300 e-/exp.
(January 15th = d+19)

Evolution of dark pixels



January 2^{nd} = d+6



January 15^{th} = d+19

- Rate of bright pixel generation
  - 15000 pixels per month > 300 e-/exp.
  - 3200 pixels per month > 1000 e-/exp.
  - 30 pixels per month > 10000 e-/exp.

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Consequences of bright pixels

- What is the limit of bright pixels for science ?
  - The exoplanet field is more sensitive
  - According to the specification :
    - For a star with mV=15.5 => noise must be lower than 700ppm over 1h
  - Considering a poissonian behavior of these bright pixels
  - And with mean background of 15 e-/pix/s and readout noise of 10 e-/pix

⇒ The limit is 15 000 e- due to bright pixels in the mask.
It is equivalent to a background increase of 6 e-/pix/s

- Bright pixels compared to the photon noise

300 e-/exp. ~ 8% of photon noise (30000 pixels today, 450000 in 2.5 year)
1000 e-/exp. ~ 15% of photon noise (6400 pixels today, 96000 in 2.5 year)
10000 e-/exp. ~ 50% of photon noise (60 pixels today, 900 in 2.5 year)

- 1/10th of the CCD surface covered by the 6000 masks of EXO channel

=> At the end of the mission : 5 pixels greater than 300 e-/pix/exp. in each mask

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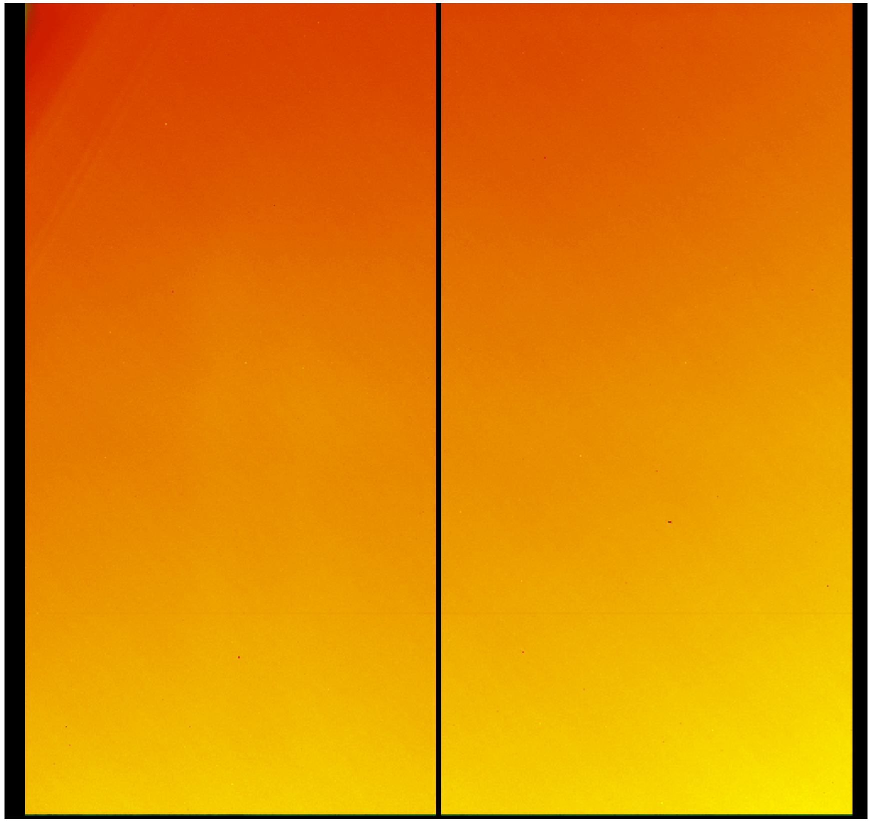
Pixel response non uniformity

- Flat field with 3 colors + one with sun light over the south pole flyby
- Results
  - local PRNU about 0.6 % conform to ground based measurement
  - ~10 black pixels / CCD + 2 columns on A2 (same as we measure on ground)



Calibration summary

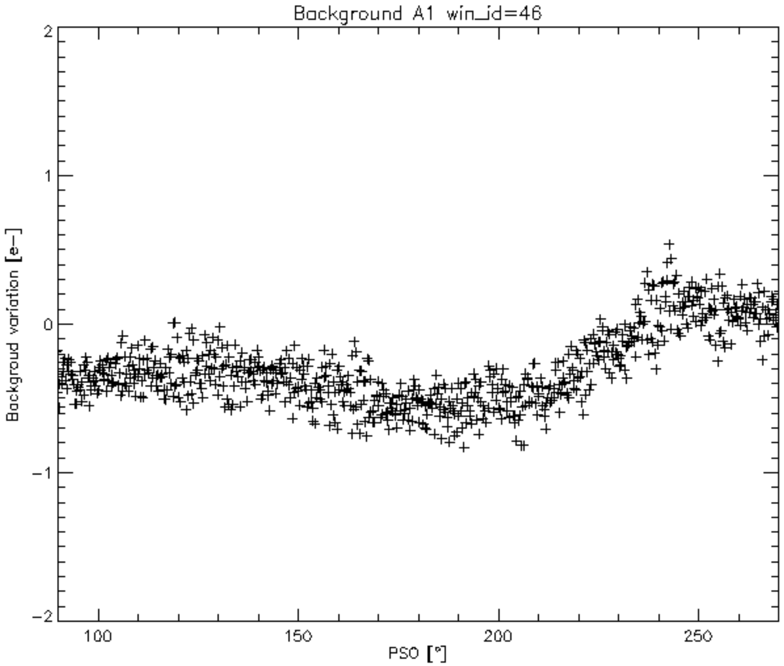
		Done	Open
SP1	Offset thermal sensitivity	V	
	Readout noise	V	
	Offset dependance		O
	Dark current	V	
SP2	Map of radiation flux	V	
SP3	Gain	V	
SP4	Map of bright pixels	V	
	Dark field	V	
	Flat field led	V	
	Map of black pixels	V	
SP5	Crosstalk calibration		O

Background with the cover open

- Evolution of background on the orbit

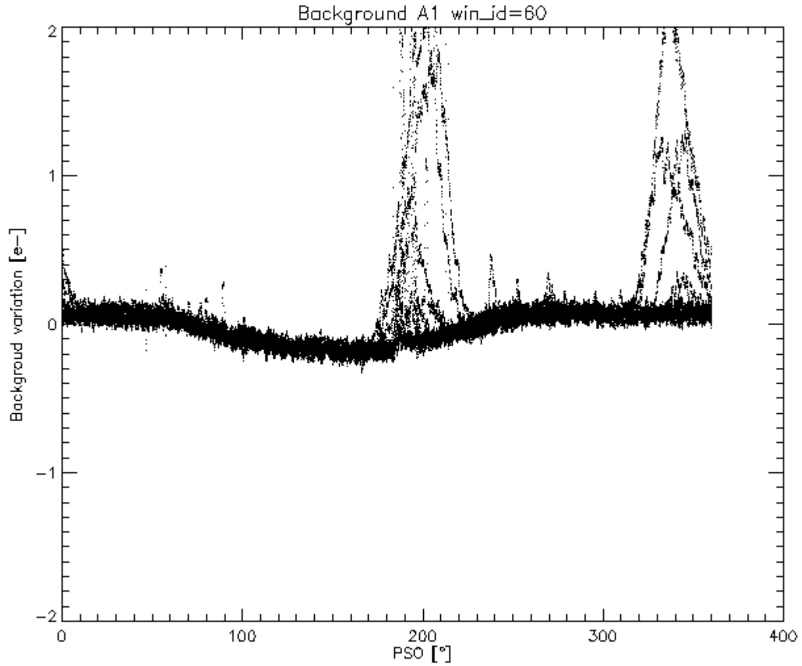
PSO : Position on Orbit
90° => north pole
270° => south pole

3 orbits on the edge of Corot eye



=> 0.5 e- from north pole to south pole essentially due to earth stray light

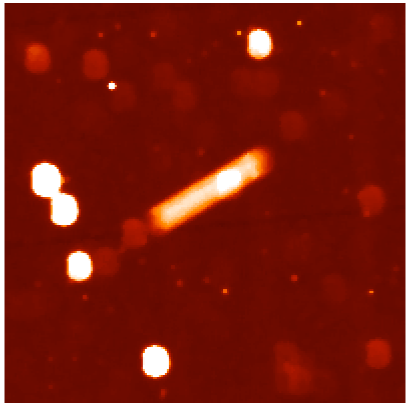
During the initial run

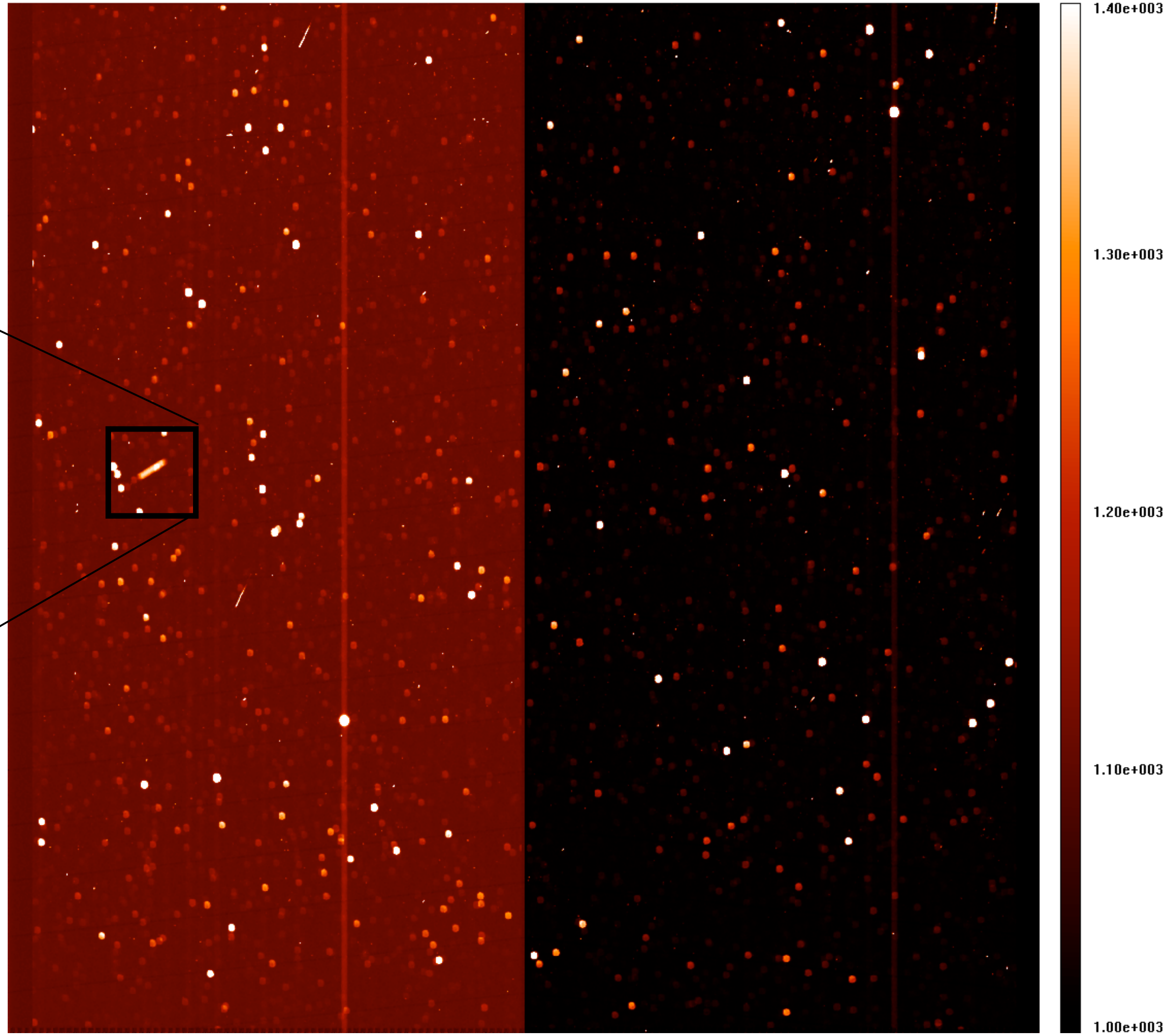


=> 0.3 e- from sunny side to shadow side

Moving objects

- Object in a full image

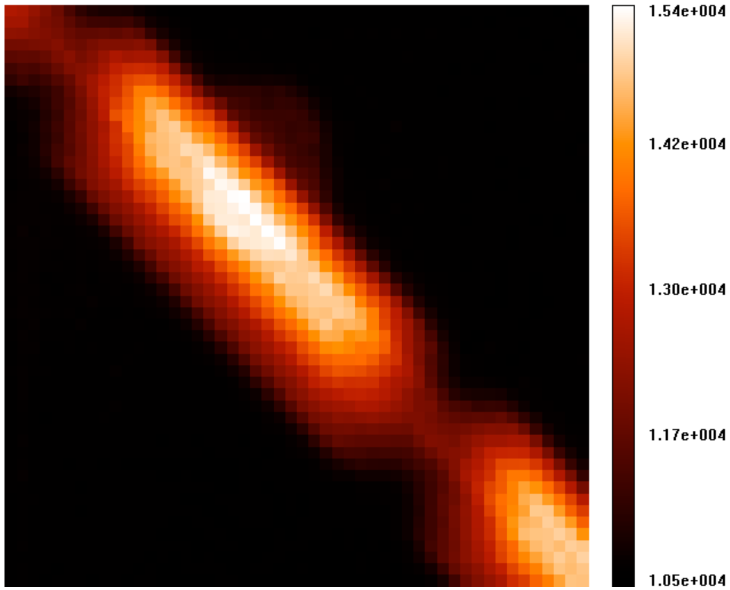




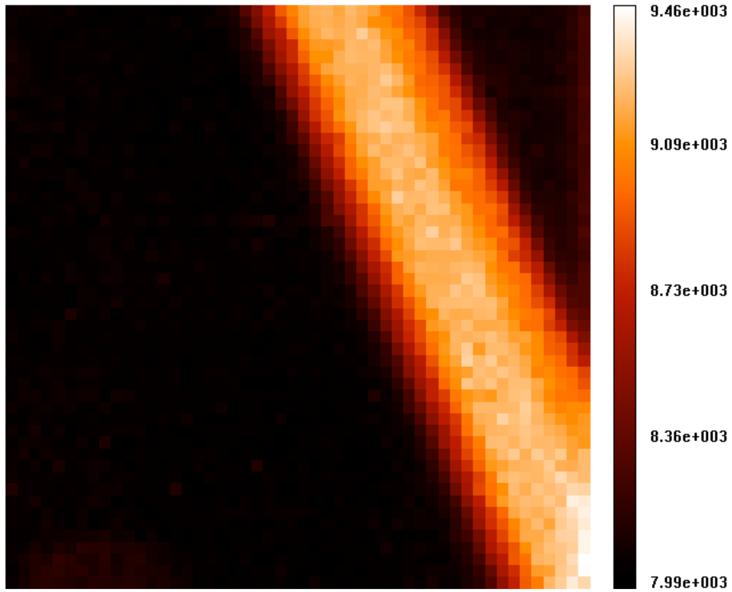
Moving objects

- Objects passing through astero windows

Full window astero
Date : 2007-01-17T22:57:20.000 win_id=45 A2



2007-01-17T21:32:07.000 win_id = 47 A1



Point Spread Functions

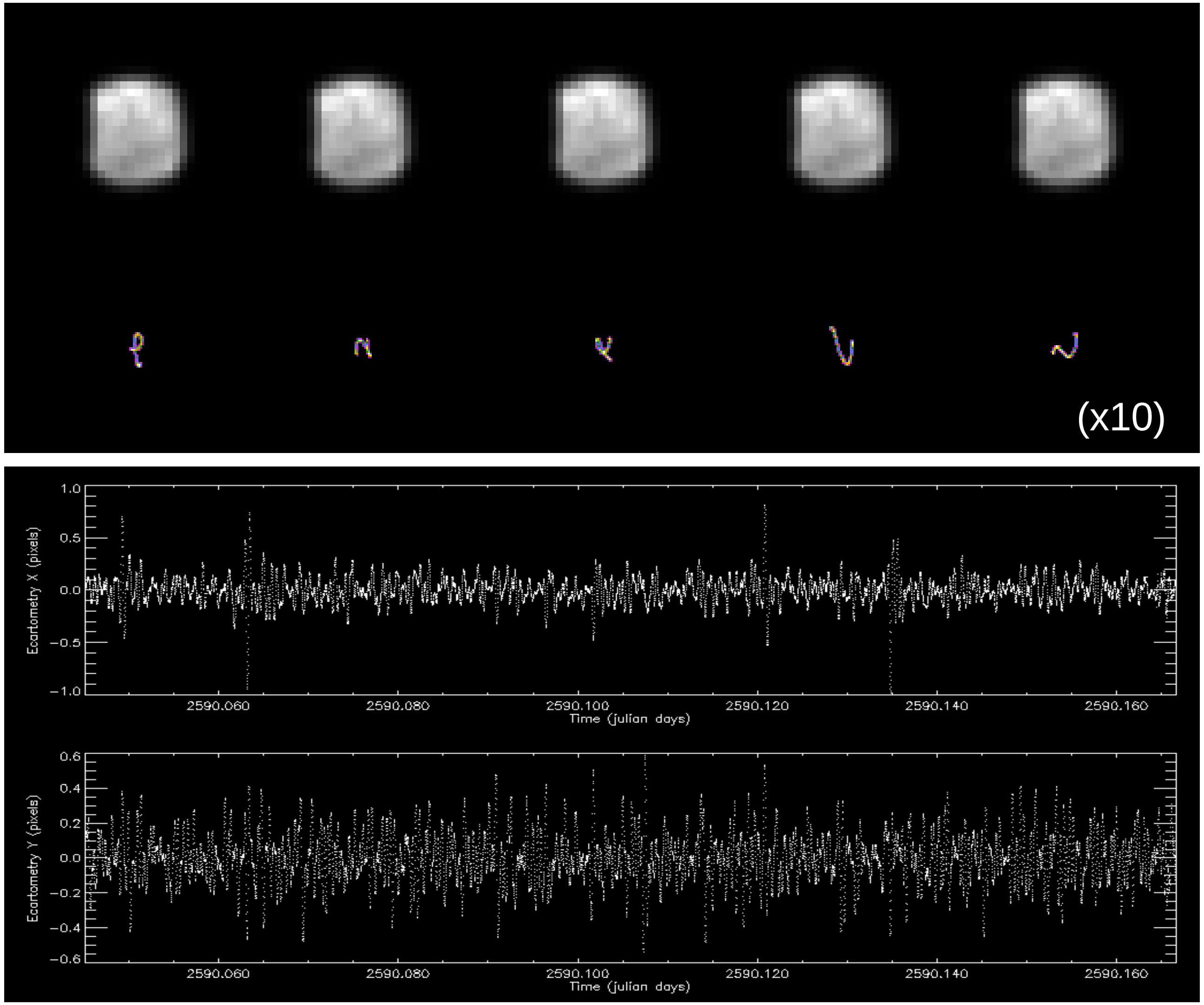
- Astero PSF reconstruction based on:
  – A set of star images (35x35)
  – The satellite attitude (x,y projection)

- Justification:
  – Optimization of photometric apertures
  – Satellite jitter correction (edge effects)
  – Fitting photometry

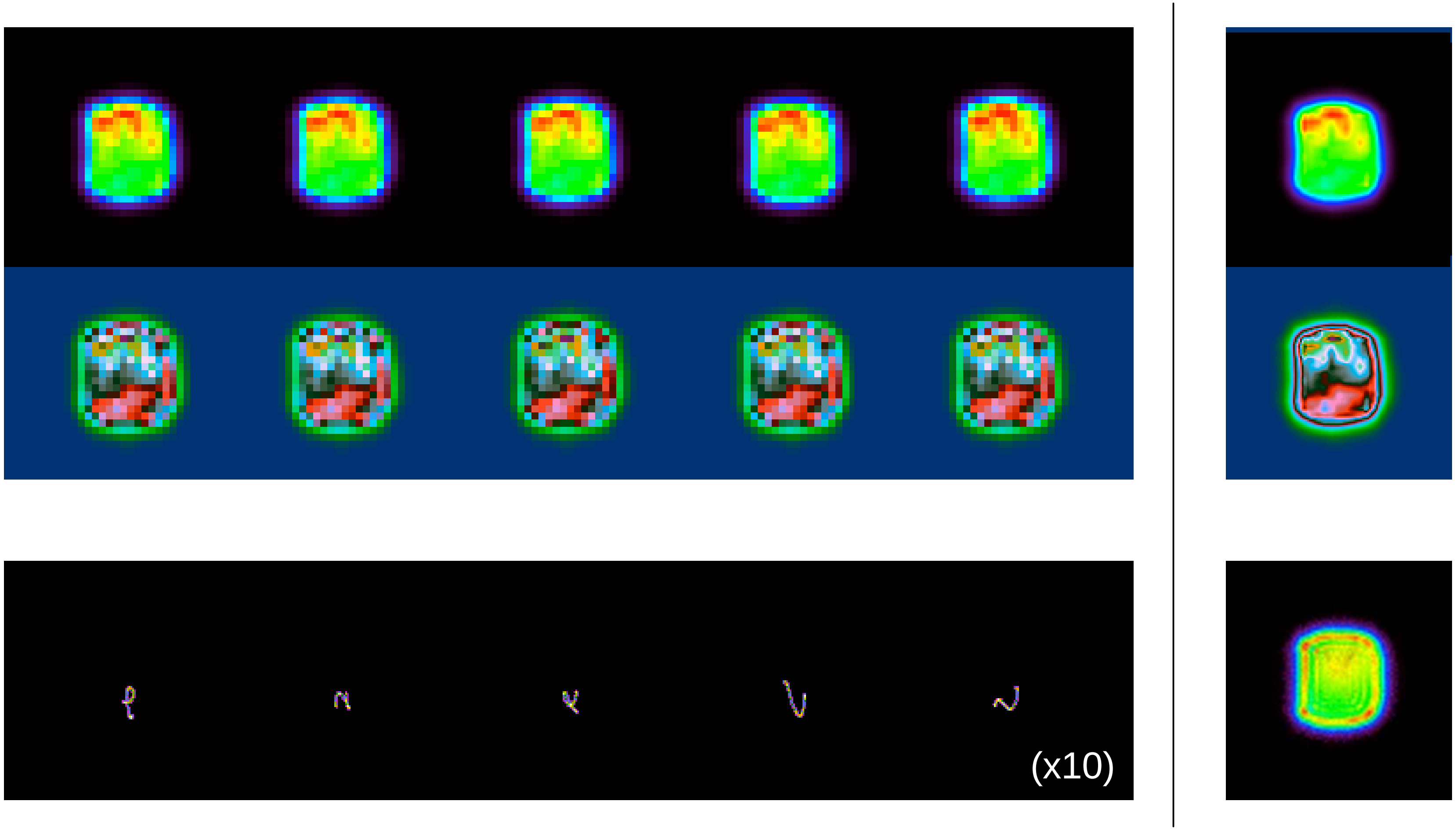
- PSF -> motion blur -> CCD undersampling

- Inverse problem solved by an iterative algorithm
  – including reconstruction of sub-pixel structures

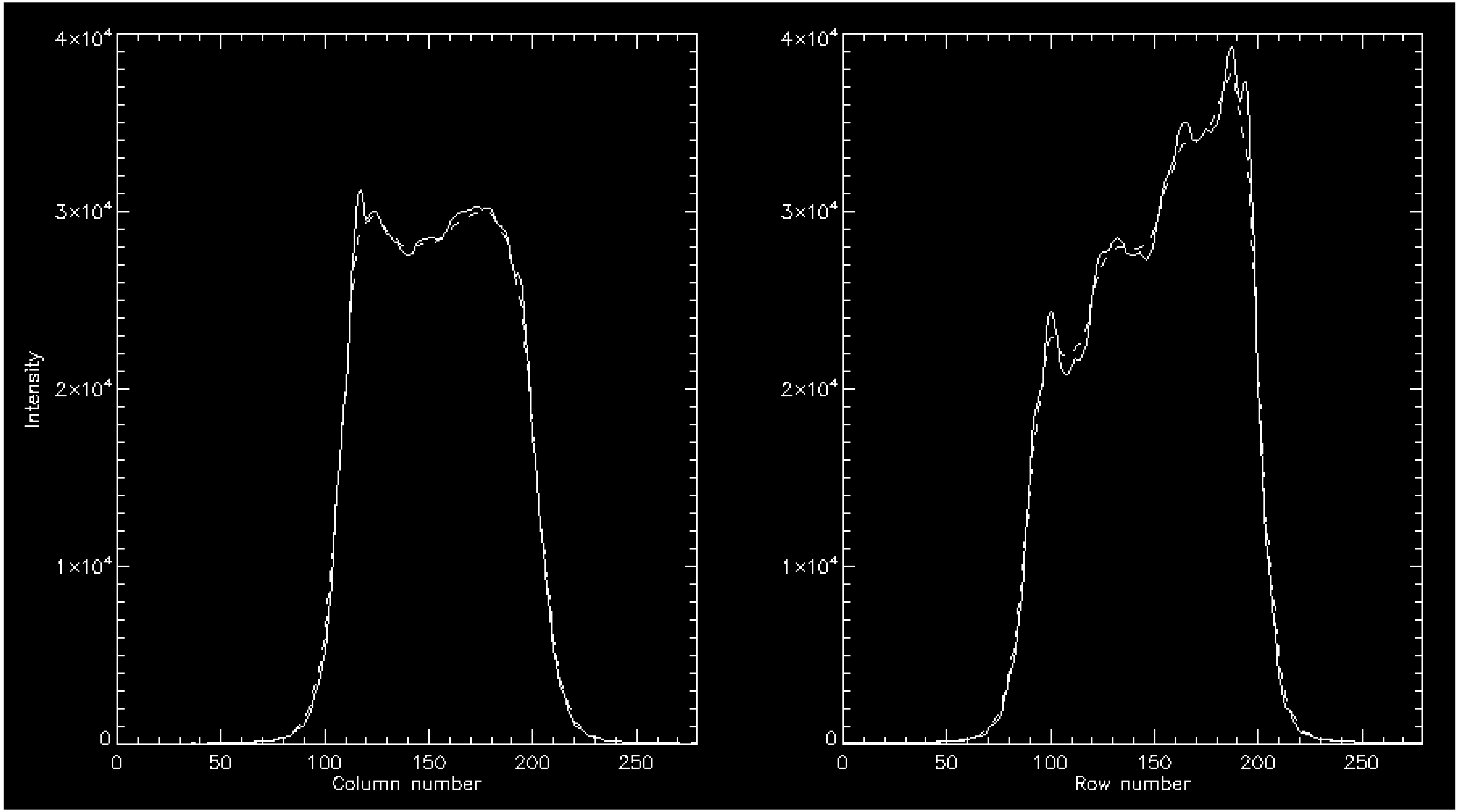
Point Spread Functions



PSF Reconstruction

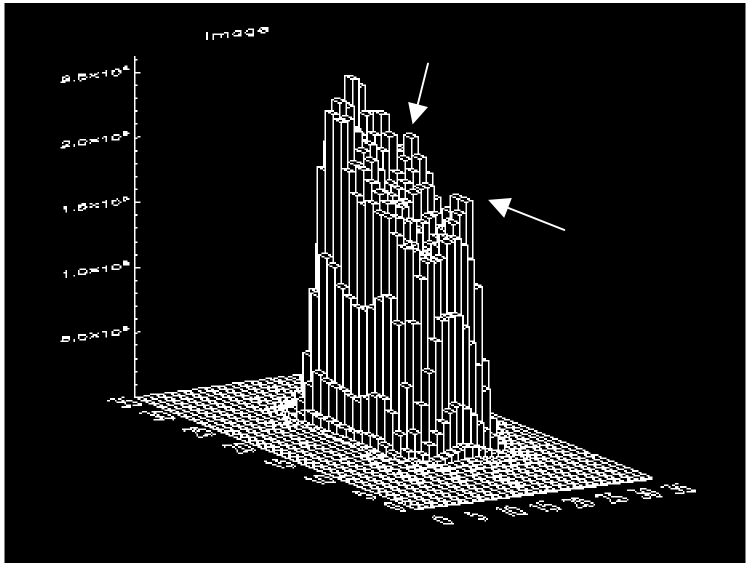


Reconstructed PSF (slices)

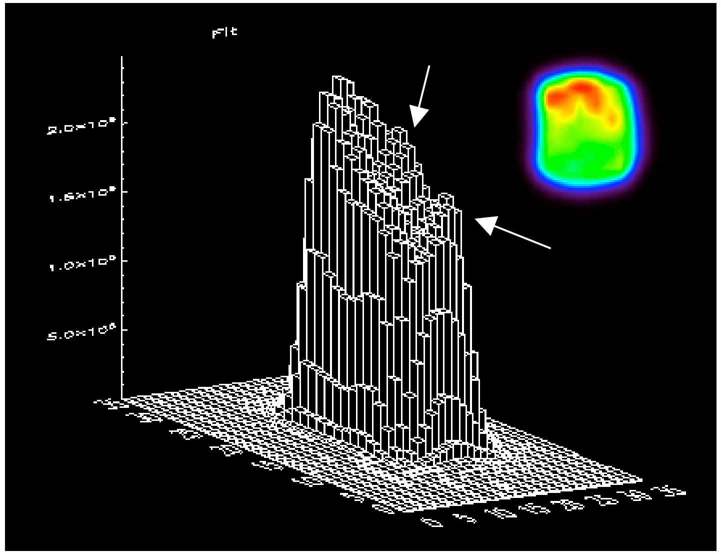


PSF fitting

Acquired data



Recentre-and-average



PSF reconstruction