StarDICE@OHP

An artificial star for SNe Ia calibration

F. Hazenberg (LPNHE)

For the DICE collaboration:

P. Antilogus, P. Astier, P. Bailli, E. Barrelet, M. Betoule, S. Bongard, J. Cohen-Tanugi, J. Corridian, J.-C. Cuillandre, F. Feinstein, A. Guyonnet, C. Juramy, A. Le Van Suu, H. Lebolo, E. Nuss, R. Pain, B. Plez, S. Prunet, L. Le Guillou, N. Regnault, P. Repain, P.-F. Rocci, K. Schahmaneche, P. Tisserand, F. Villa

StarDICE section n°6.1 of the roadmap of the calibration working group

Today: 5‰ uncertainty on flux calibration —> 3% uncertainty on ***w***
For < 1% on ***w*** —> ~1‰ on fluxes

Laboratory flux uncertainties ~0.1‰

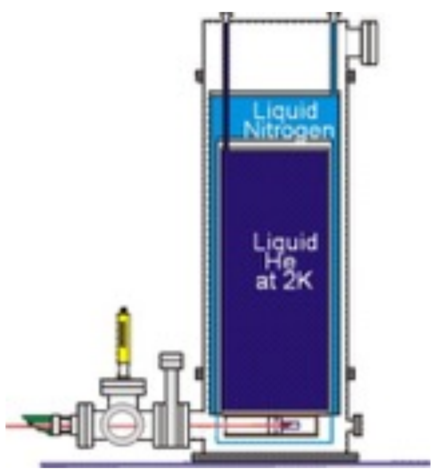
Goal

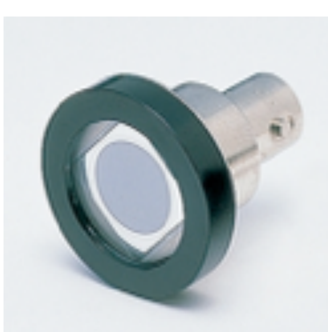
Use laboratory flux standards for the calibration of SNe Ia

Proposed metrology chain

Shortest chain, using NIST standards

National **I**nstitute of **S**tandards and **T**echnology : Responsible for optical **Watt** value





Hamamatsu S2281

DETECTORS	SOURCES
POWR (NIST)	SIRCUS/SCF (NIST)
Calibrated Si photodiode	Convenient and stable calibrated source
Conventional Telescope	Astronomical sources

Stars + SNe Ia

Optical formula

Make the calibrated source look like a star **geometrically**

We want our telescope to observe:

- a small source at finite distance O(100m) smaller than a pixel
- Stars of magnitude m=13

< pixel size (9µm)

typical LED size (500µm)

A'B' = f x AB/OA

~100m

t ~ $10^3/D^2$ hours

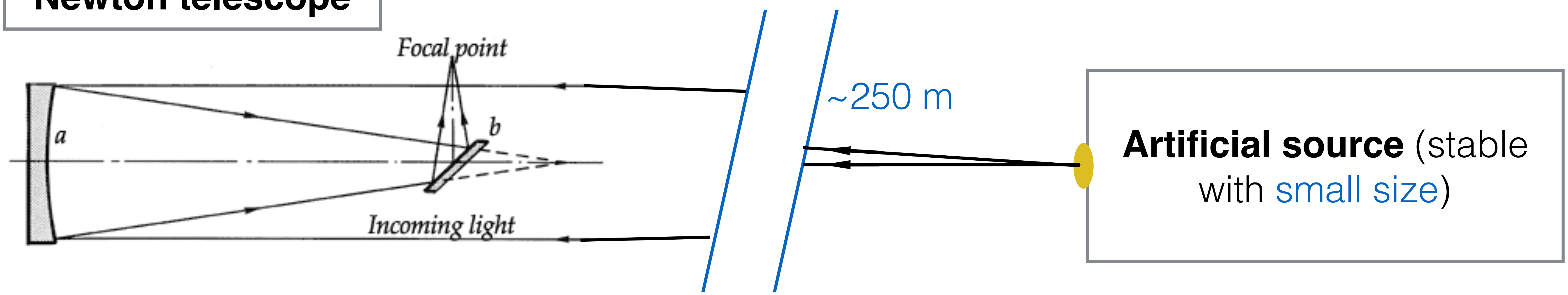
time needed to gather 10^6 e-

mirror diameter in cm

f ~ 1m

D ~ 25cm

Newton telescope



Best possible artificial star from the ground

Differences Astrophysical/Artificial sources

- Source at **finite** distance:

  —> different optical ways

  —> different ghosts if additional optics

We use a **newton** telescope
—> simplest optics

- Different **atmosphere** width:

Star

Data model:

$$\phi_{adu} = \int \lambda a(\lambda) T(\lambda) A(\lambda) S(\lambda) d\lambda$$

- S Star SED
- T telescope transmission
- A atmospheric transmission
- a aperture correction

Artificial source

Data model:

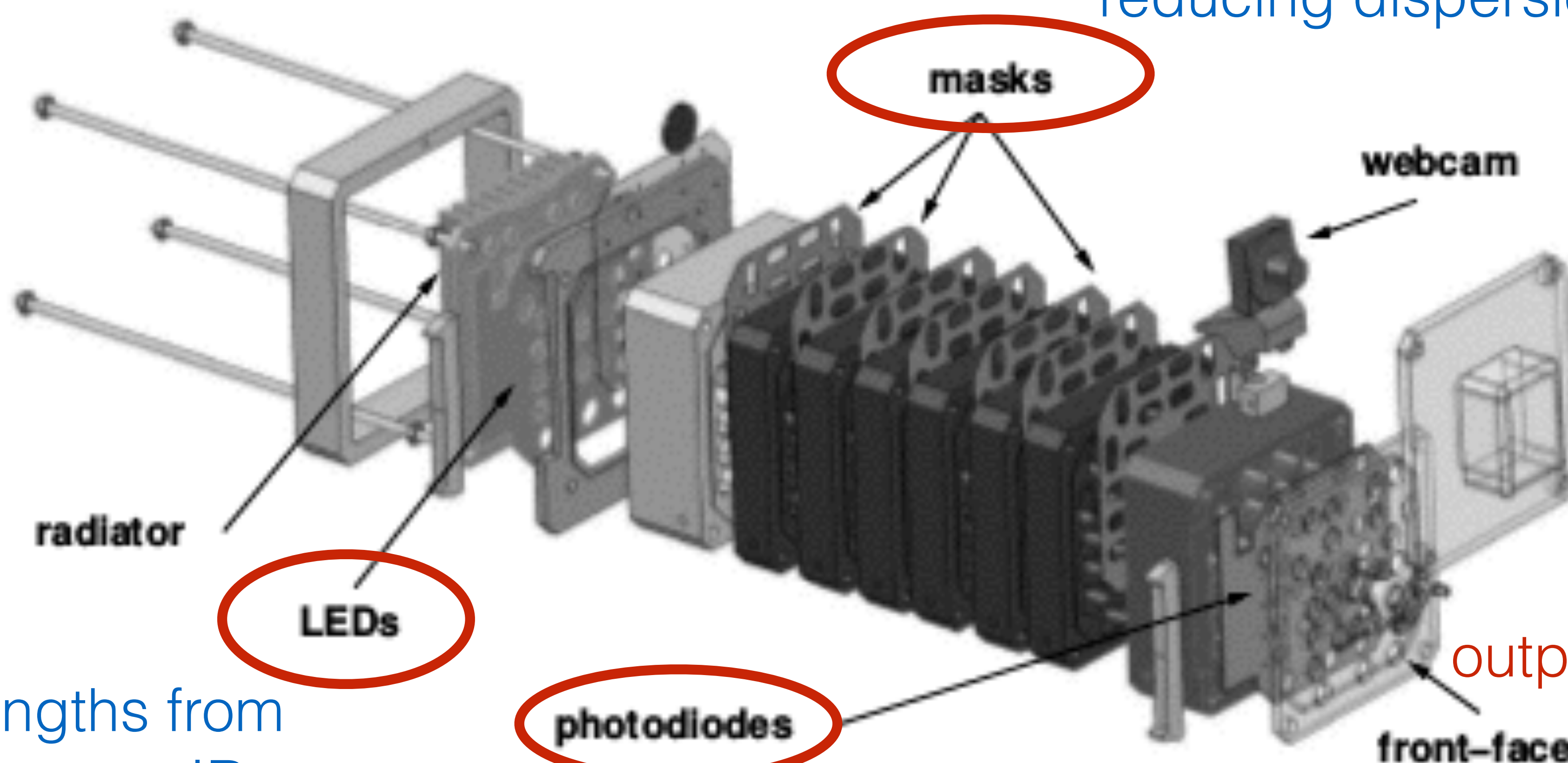
$$\phi_{adu} = \int \lambda b(\lambda) T(\lambda) C(\lambda) d\lambda$$

- C Calibration source SED
- T telescope transmission
- $A \sim 1$
- $b \neq a$ finite d & less diffusion

A stable artificial light source: DICE

Test source, used at CFHT

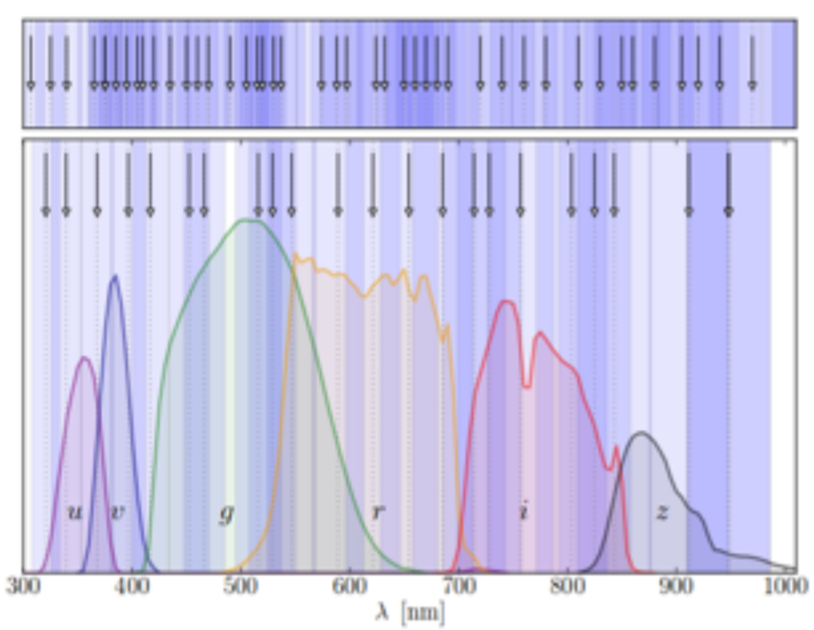
reducing dispersion angle

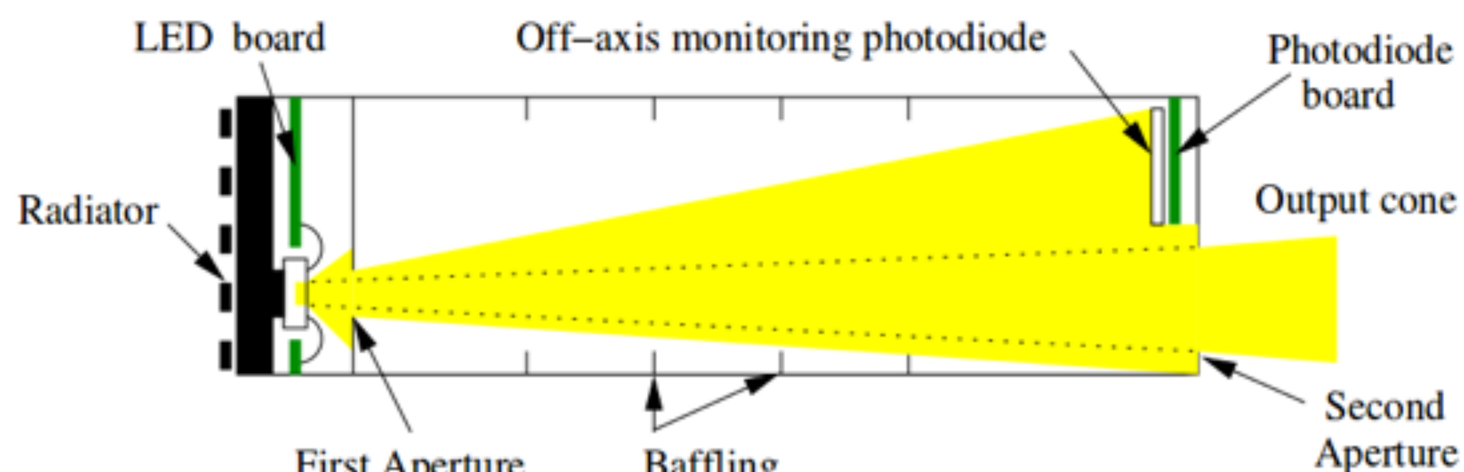


output dispersion ~2°

24, wavelengths from near UV to near IR

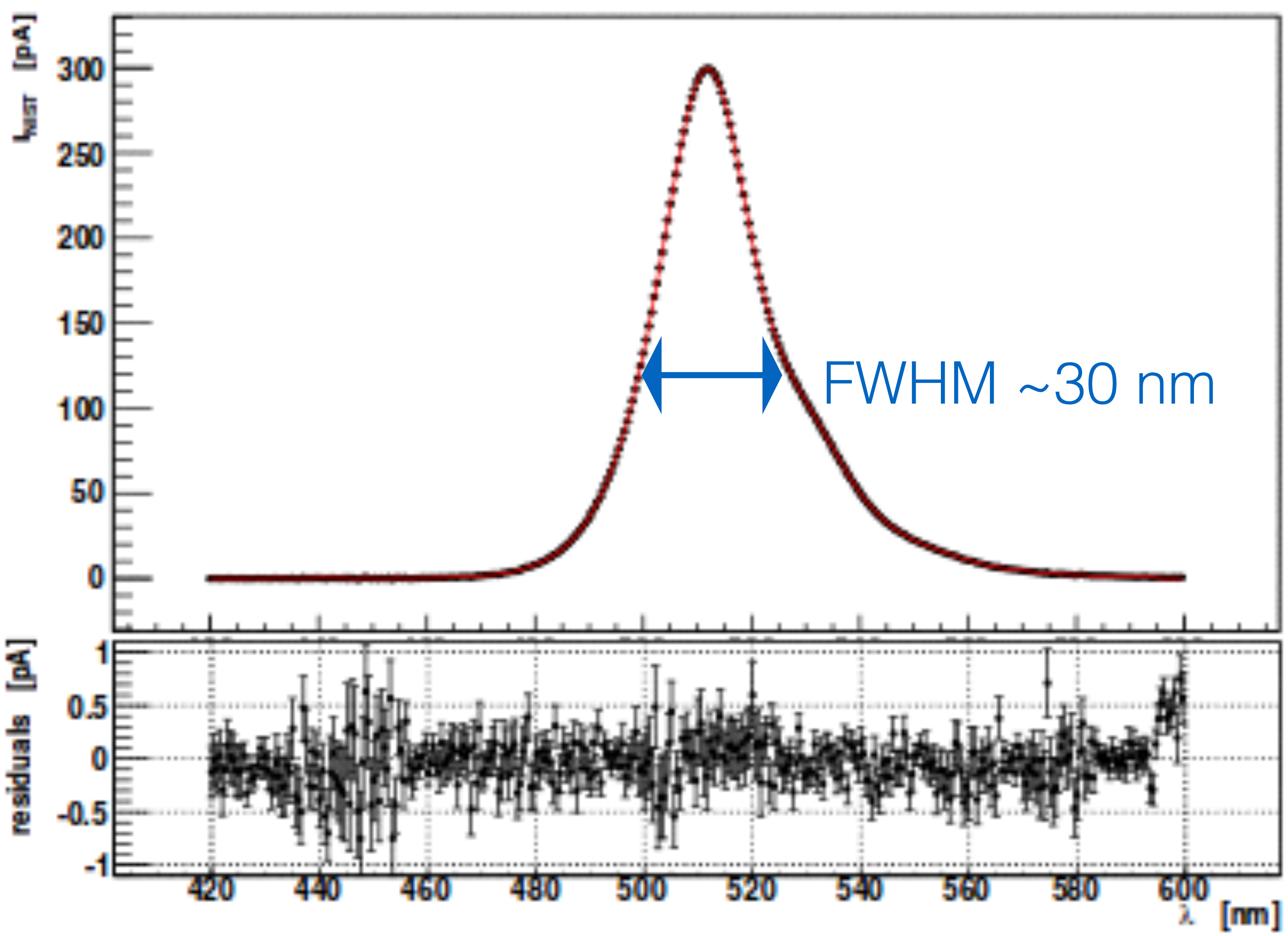
controlling emitted flux



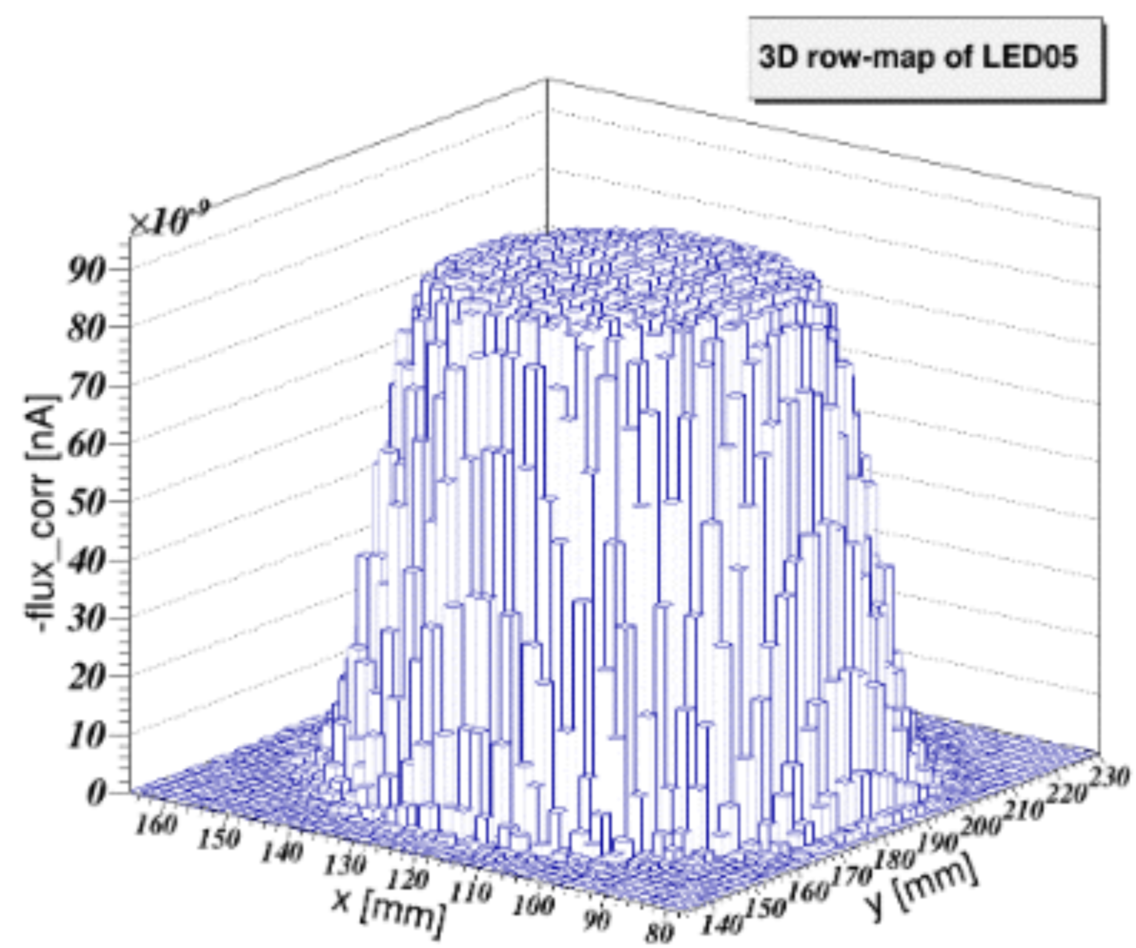


DICE calibration

LEDs flux with intensity calibrated by measuring their flux
in a **NIST** calibrated photodiode.
(Regnault et al, 2015)



LED spectrum



Beam map

Telescope

The **telescope** is a Newton one from LUPM (Laboratoire Univers & Particules de Montpellier)

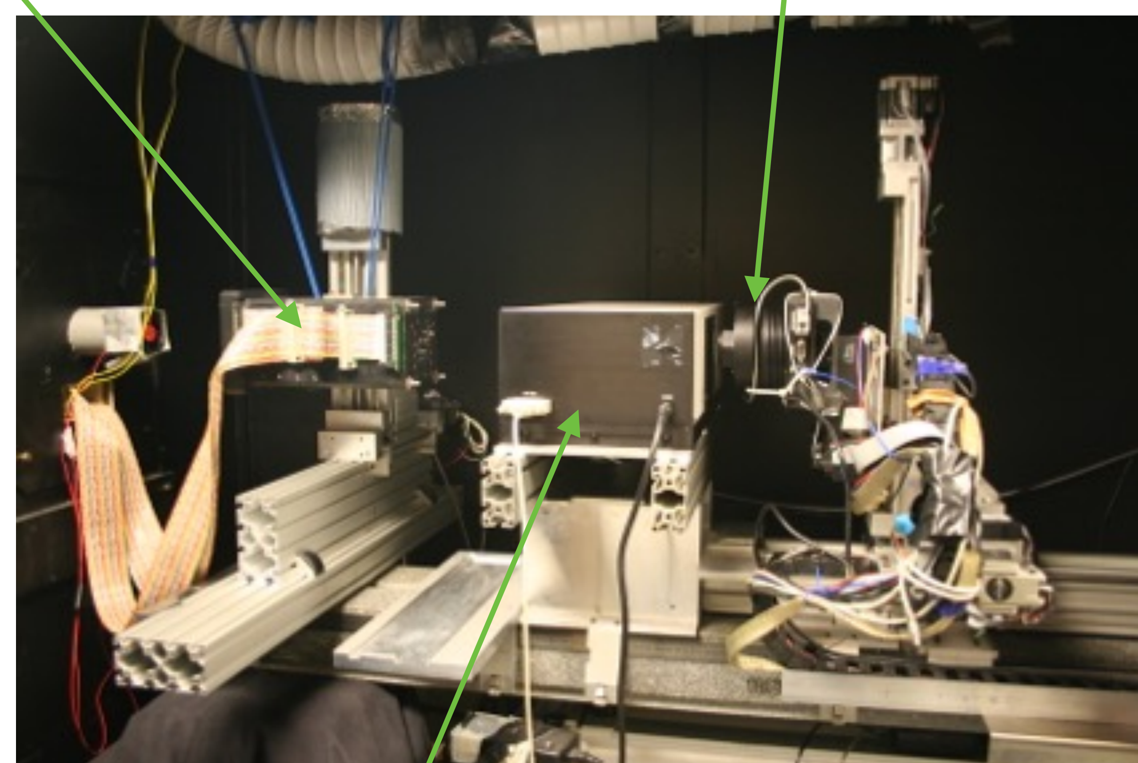
- diameter = 25 cm
- focale = 1m   f/D = 4

—>for an object at 250m : focus at 4mm

Camera

- Model : SBIG ST-7XME
- Resolution : 765x510 pixels
- filter wheel
- Peltier cooling
- From LUPM

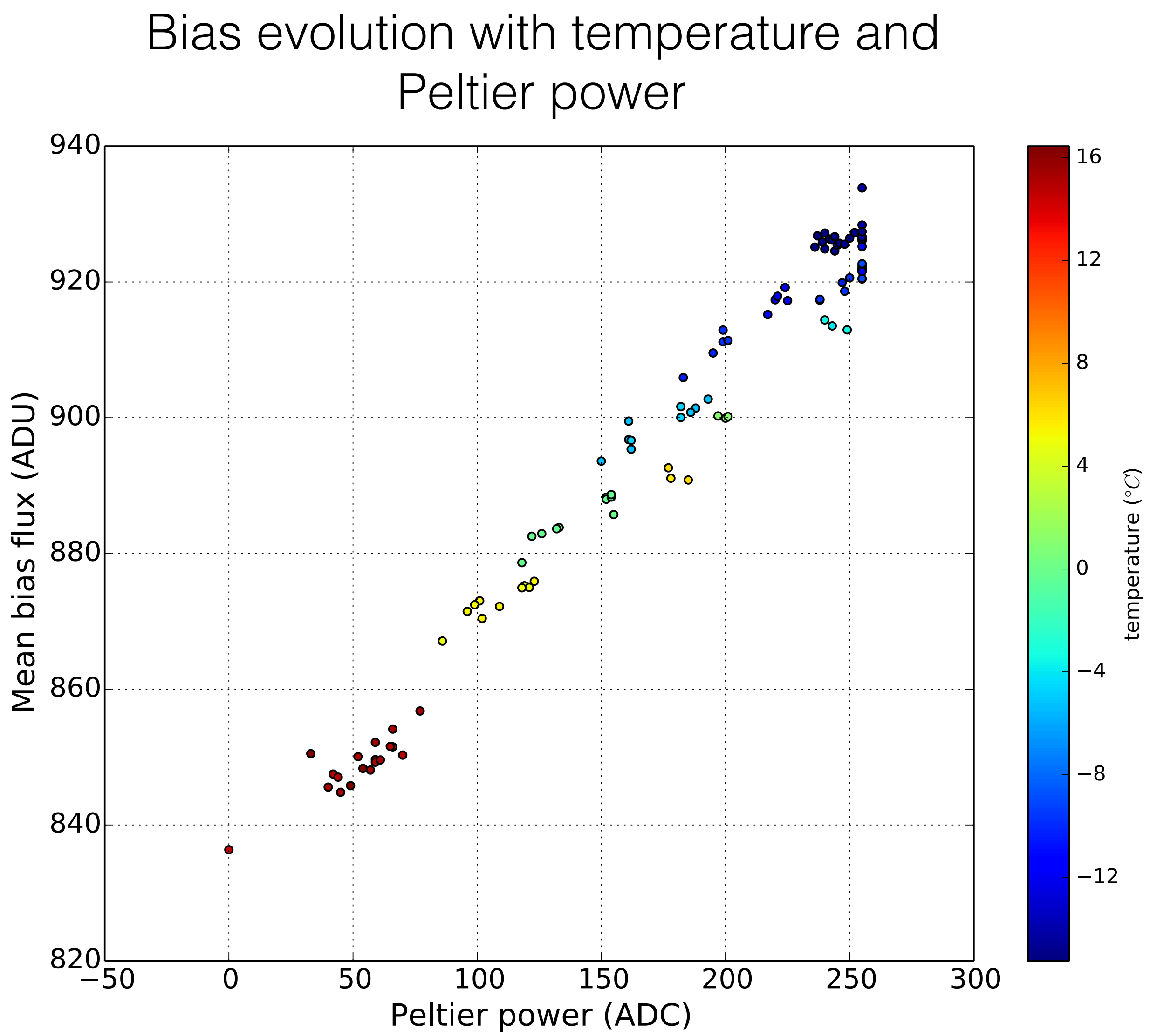
SBIG ST-7XME and its filter wheel

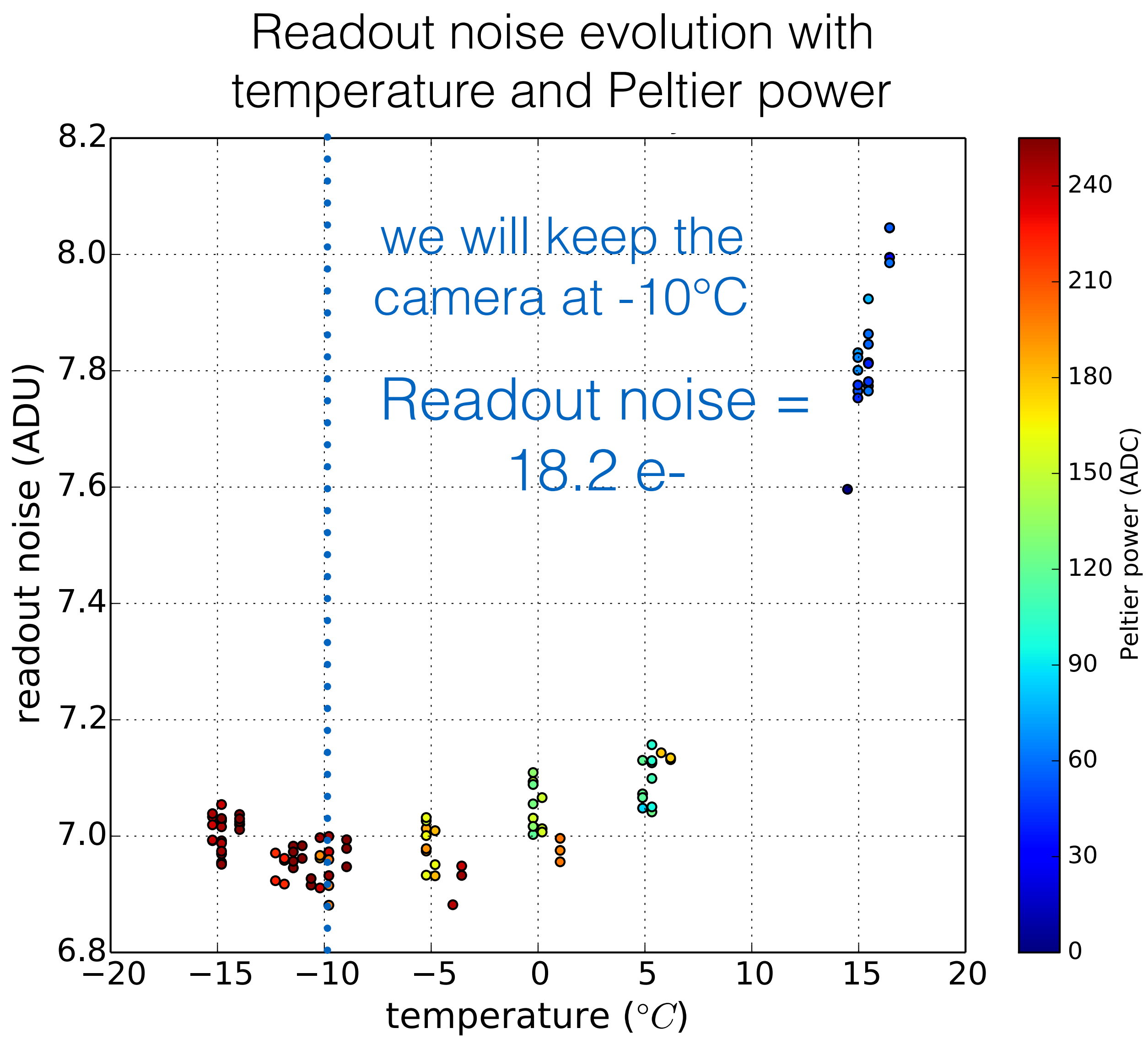


Test bench characterization:

- Biases (value and readout noise)
- Dark current
- Gain value and stability
- Quantum efficiency
- Filter transmission

Biases



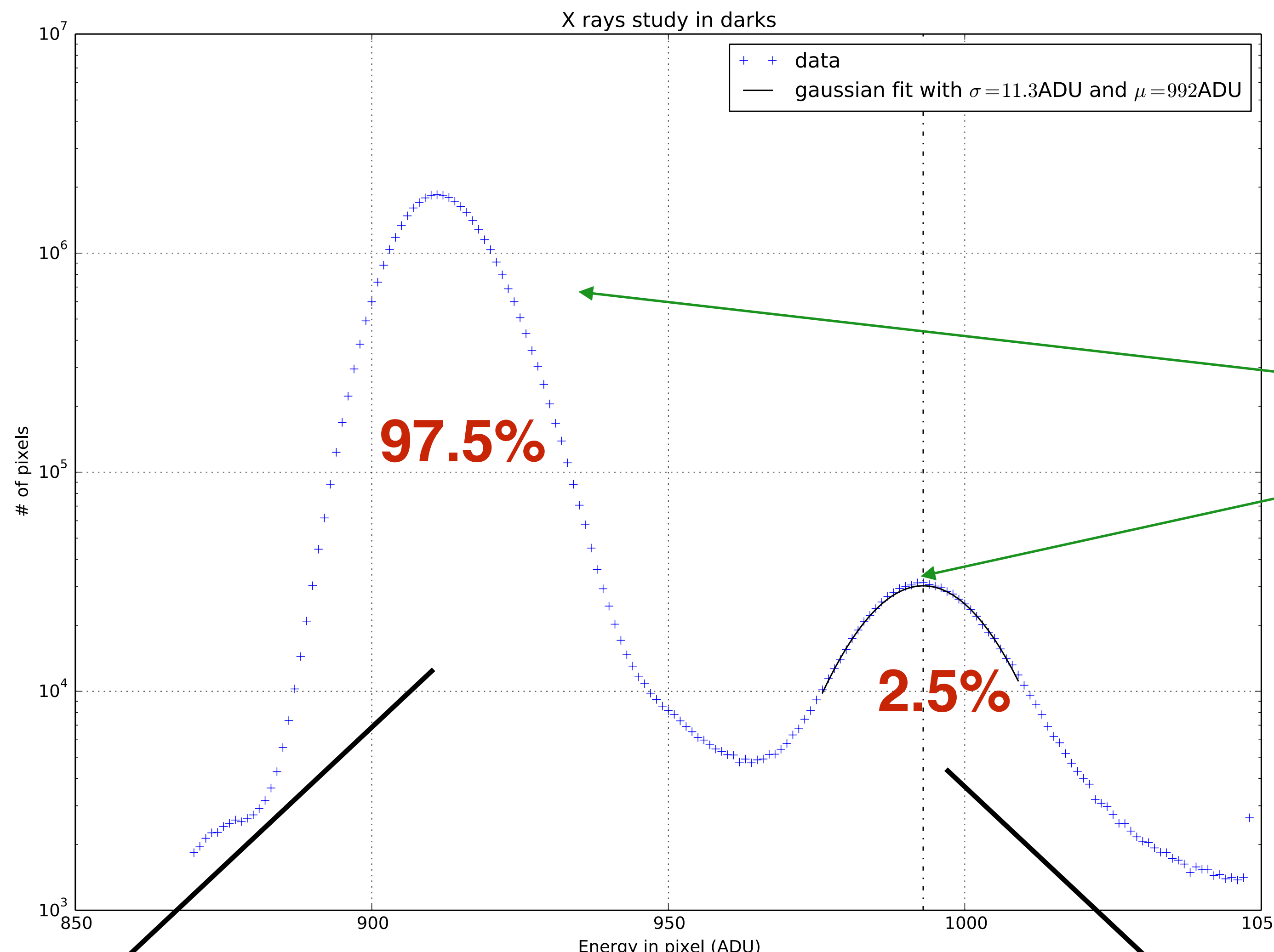


Bias level varies with Peltier Power

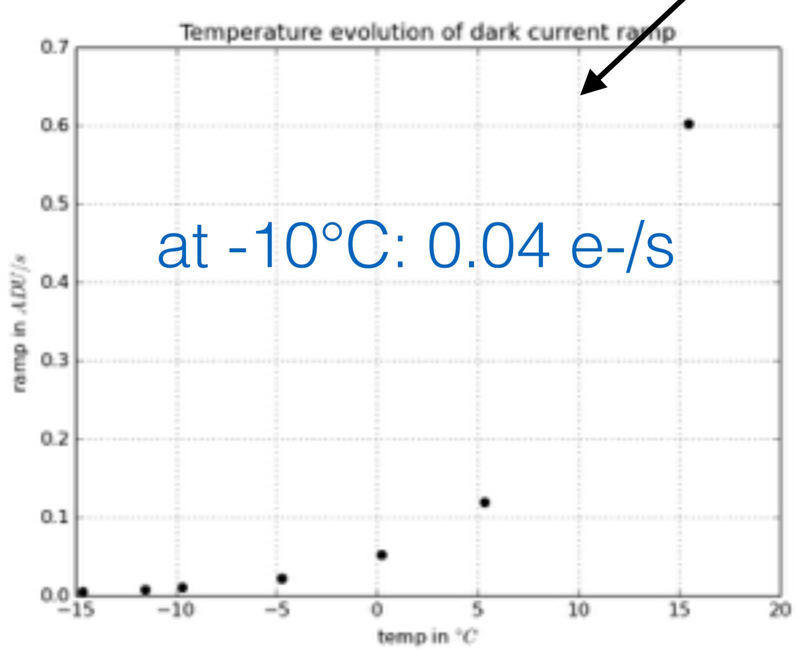
Temperature and Peltier power have to be constant

Readout noise varies with CCD temperature

Dark images

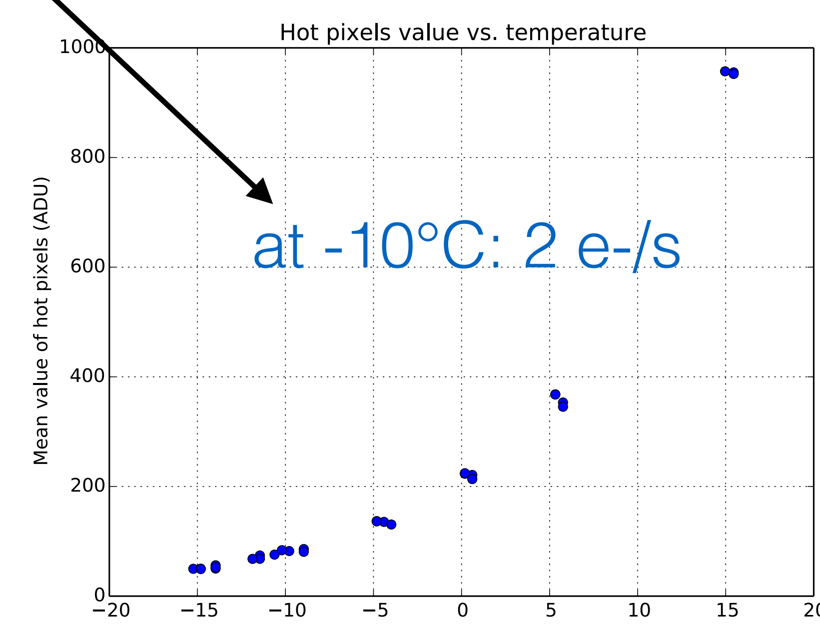


Two different populations of pixels : standards and hot ones



Dark current for 1s in standard pixels

We have to take dark images before each illuminated one and subtract them



Dark current for 100s in hot pixels

Flat fields

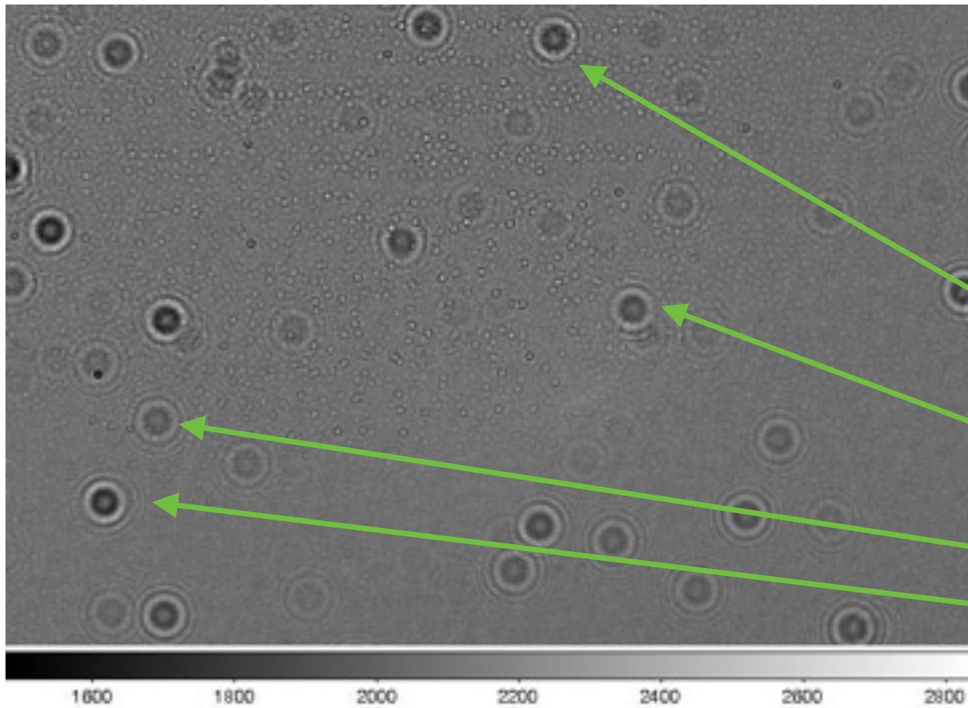


Image of LED #18 (red)

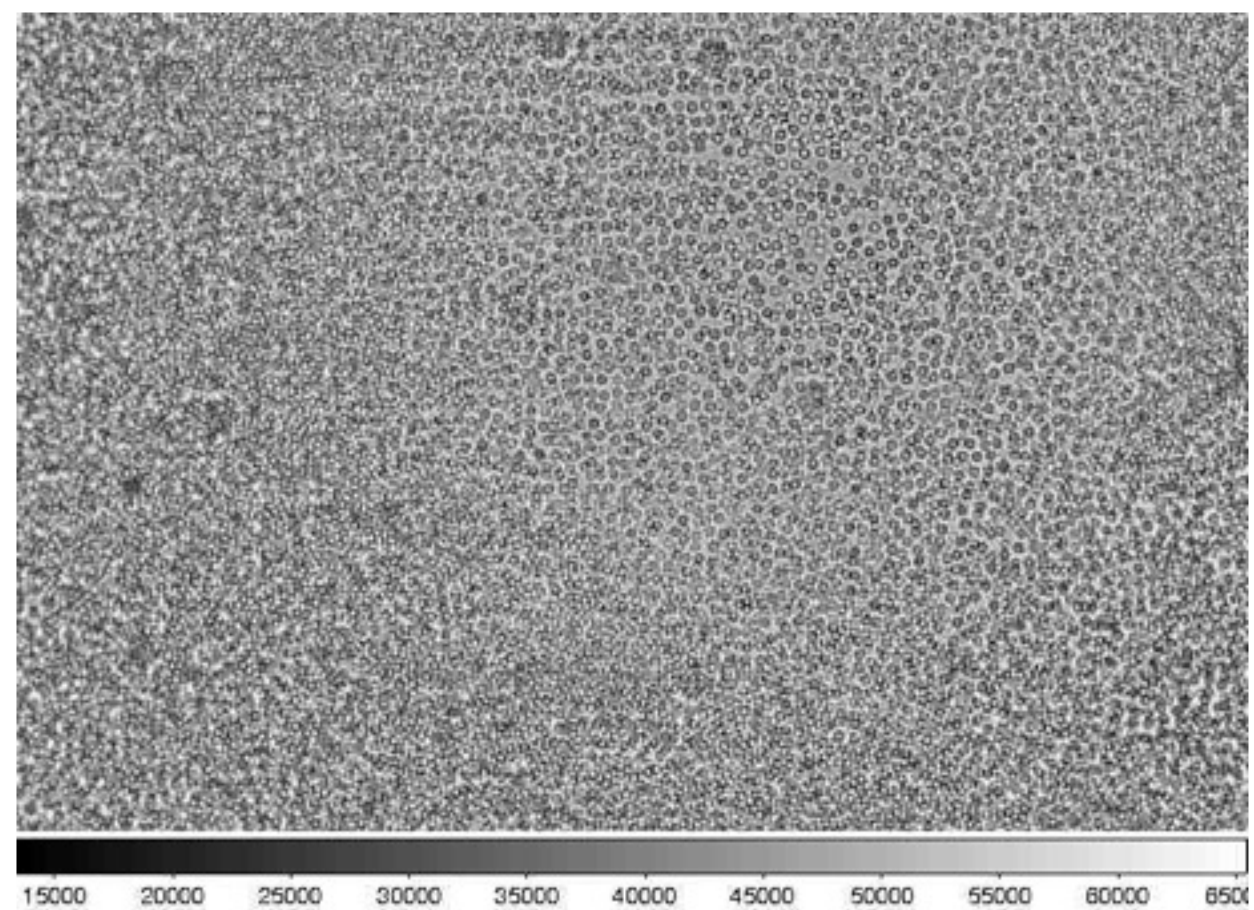
Presence of dusts over the CCD

+

Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

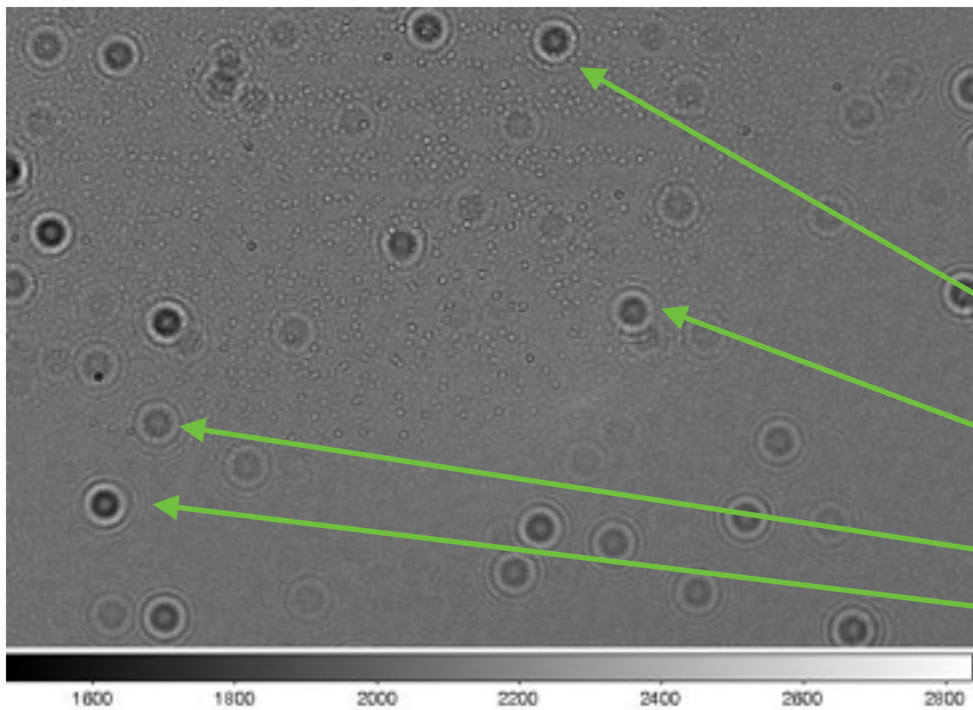


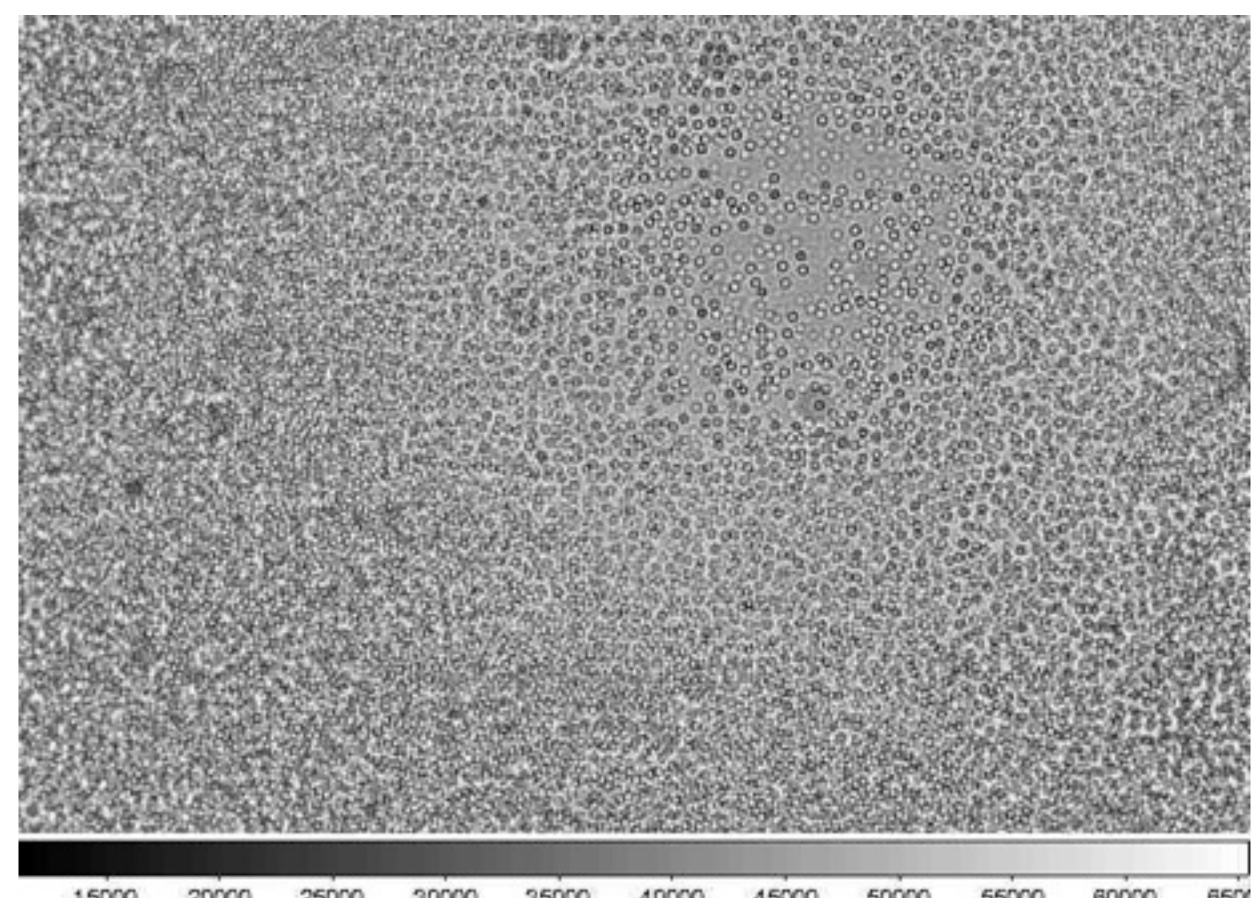
Image of LED #18 (red)

Presence of dusts over the CCD

+

Almost monochromatic source

Diffraction patterns



There is steam over the CCD when we turn it on, it lasts ~1 hour

Flat fields

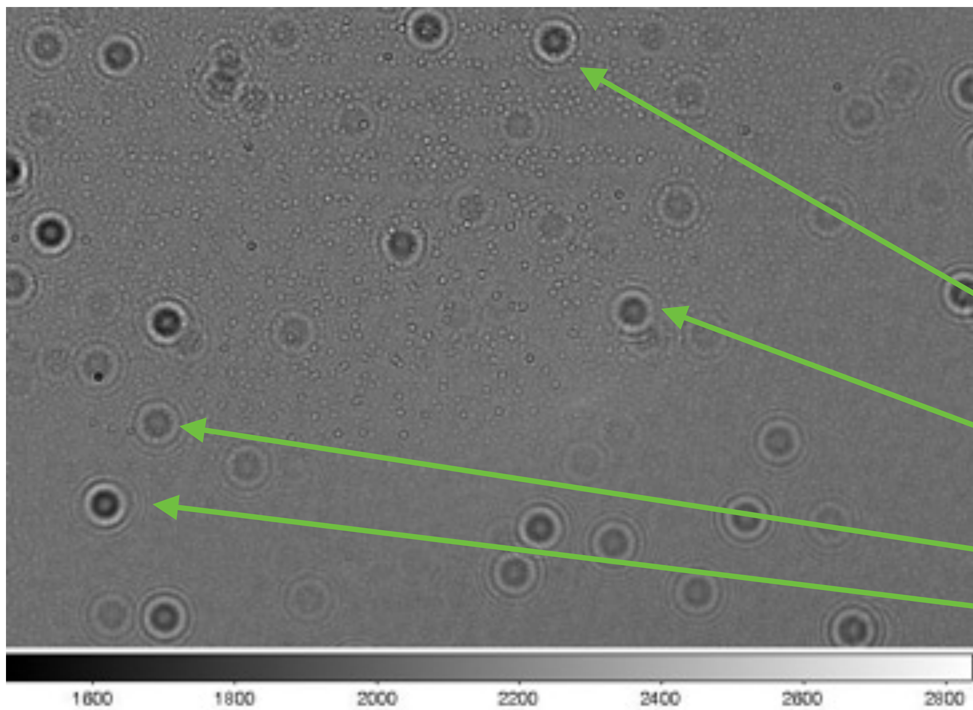
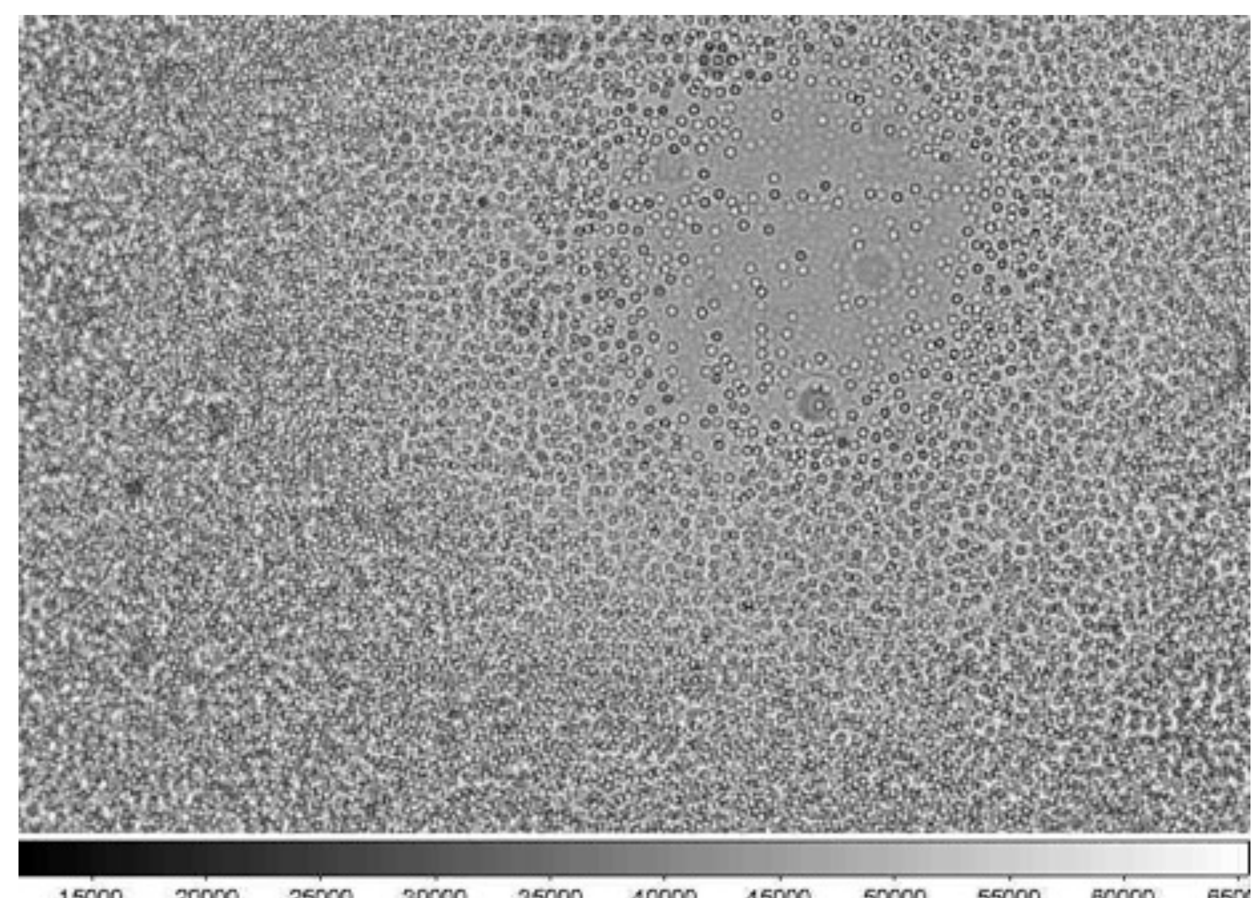


Image of LED #18 (red)

Presence of dusts over the CCD
+
Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

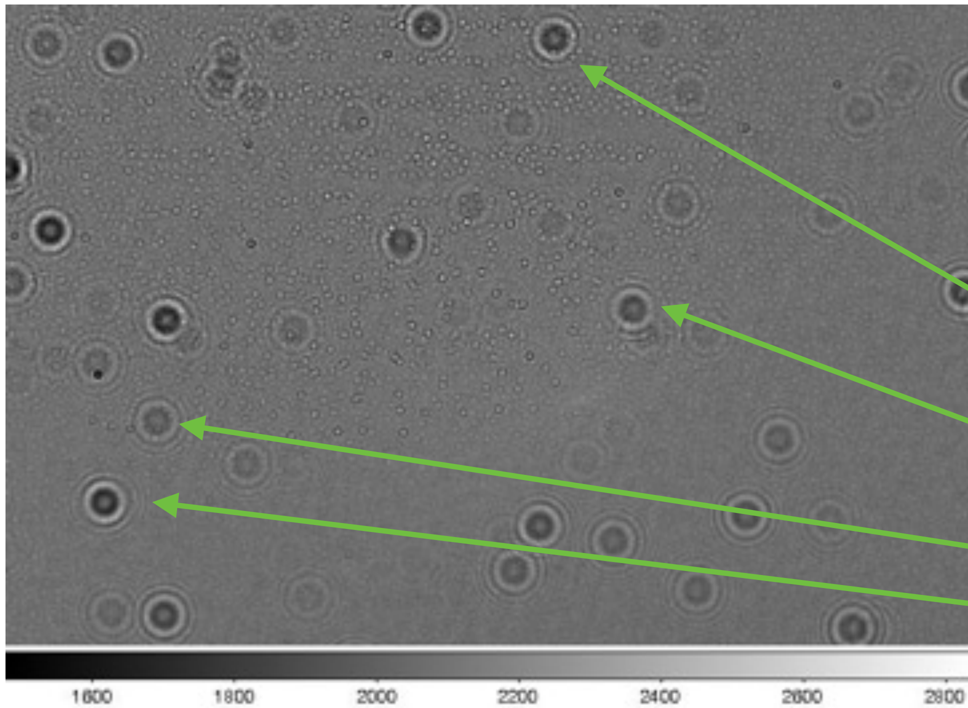


Image of LED #18 (red)

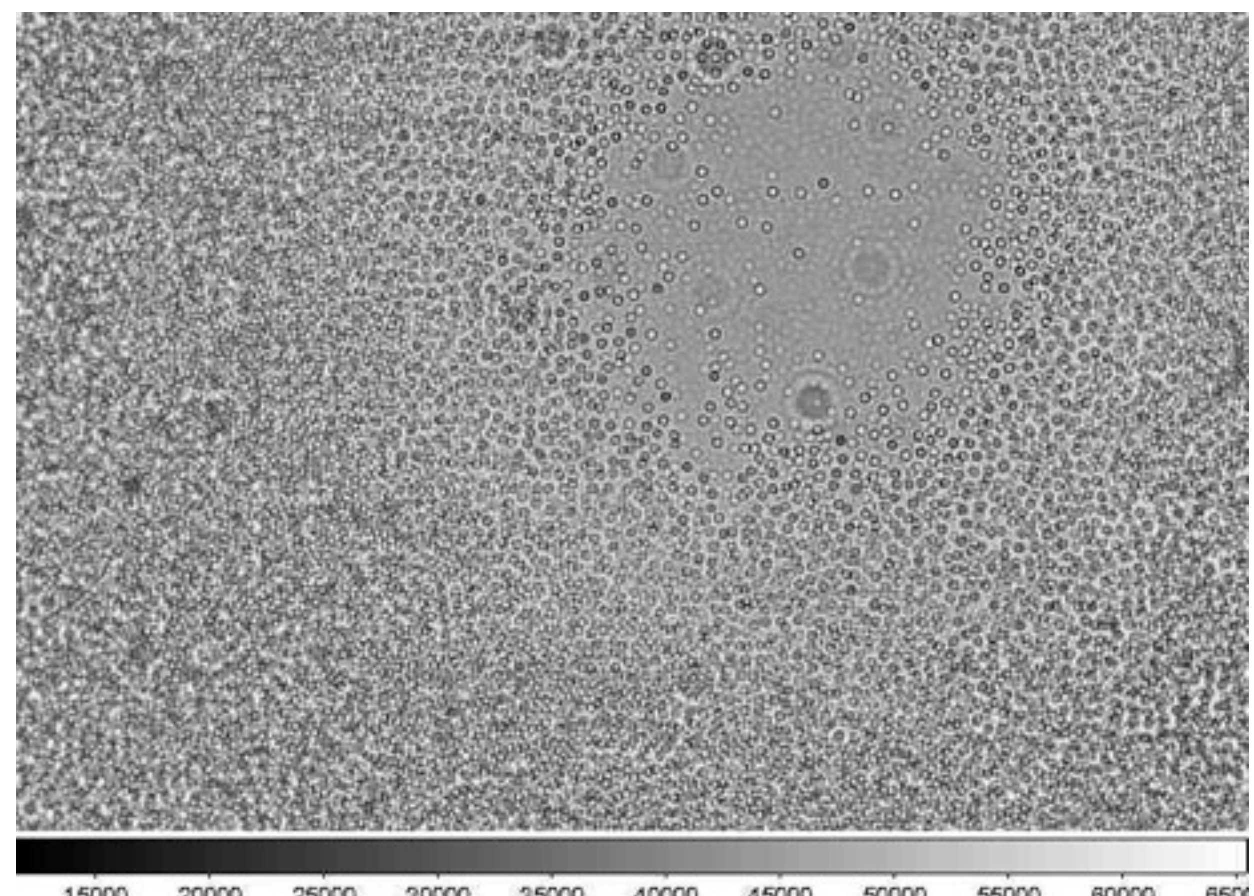
Presence of dusts over the CCD

+

Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

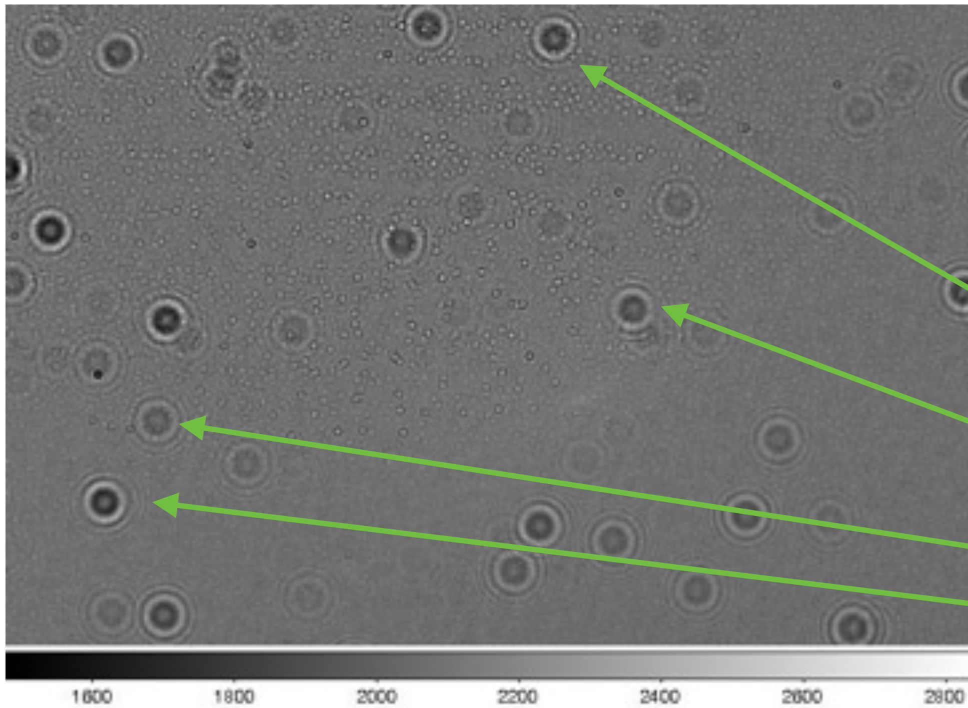
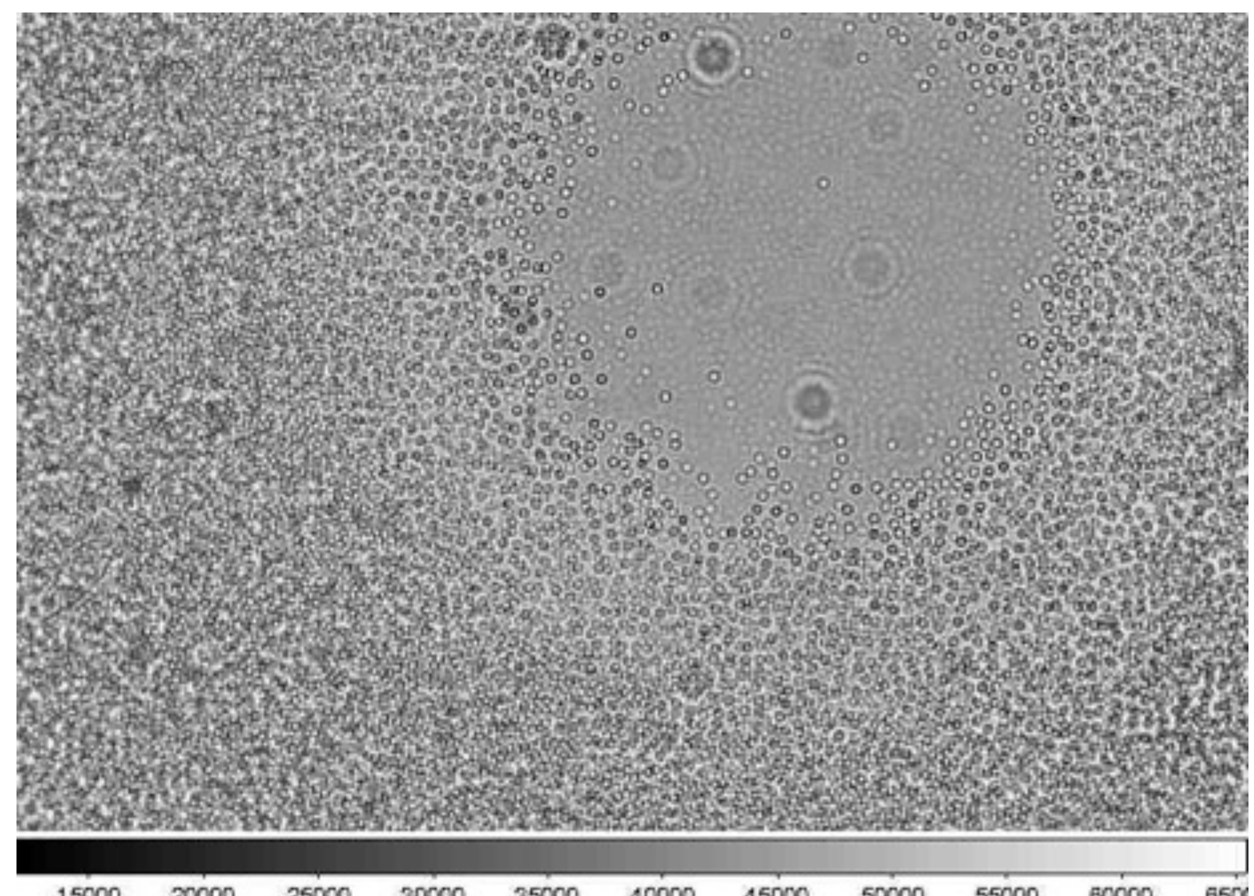


Image of LED #18 (red)

Presence of dusts over the CCD
+
Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

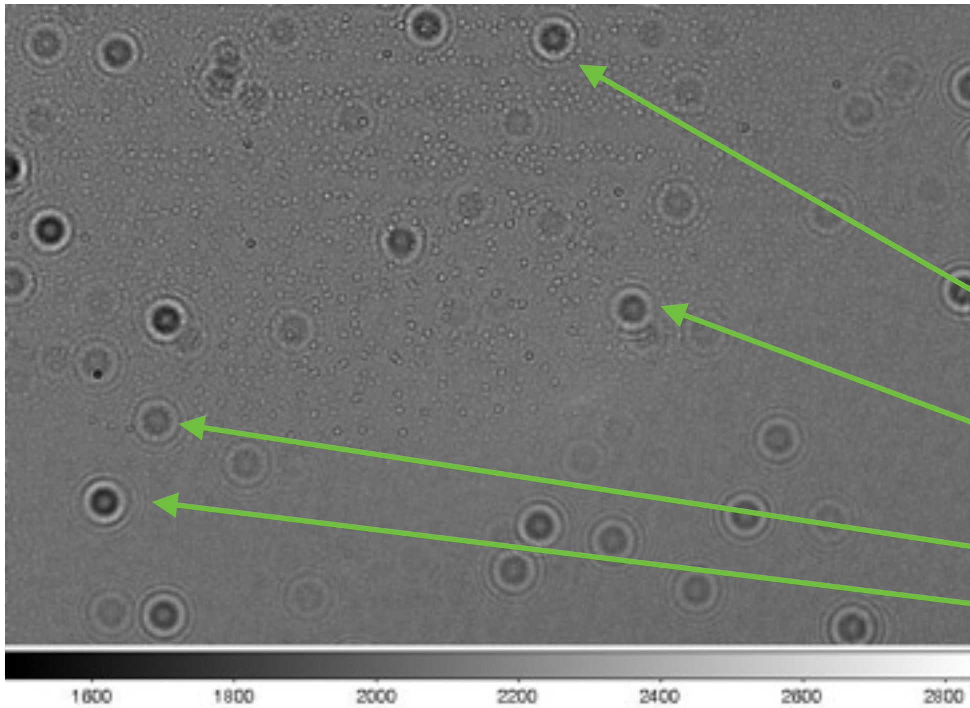


Image of LED #18 (red)

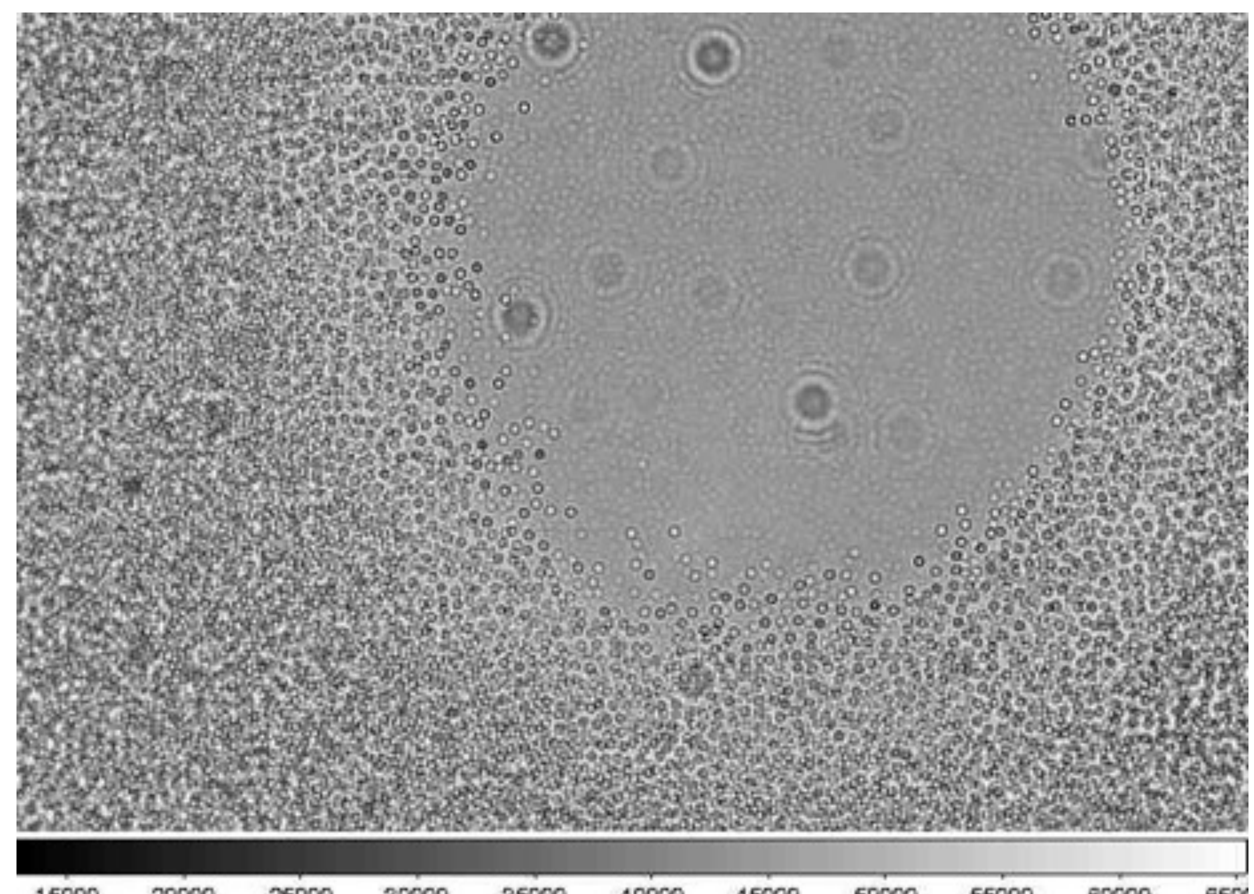
Presence of dusts over the CCD

+

Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

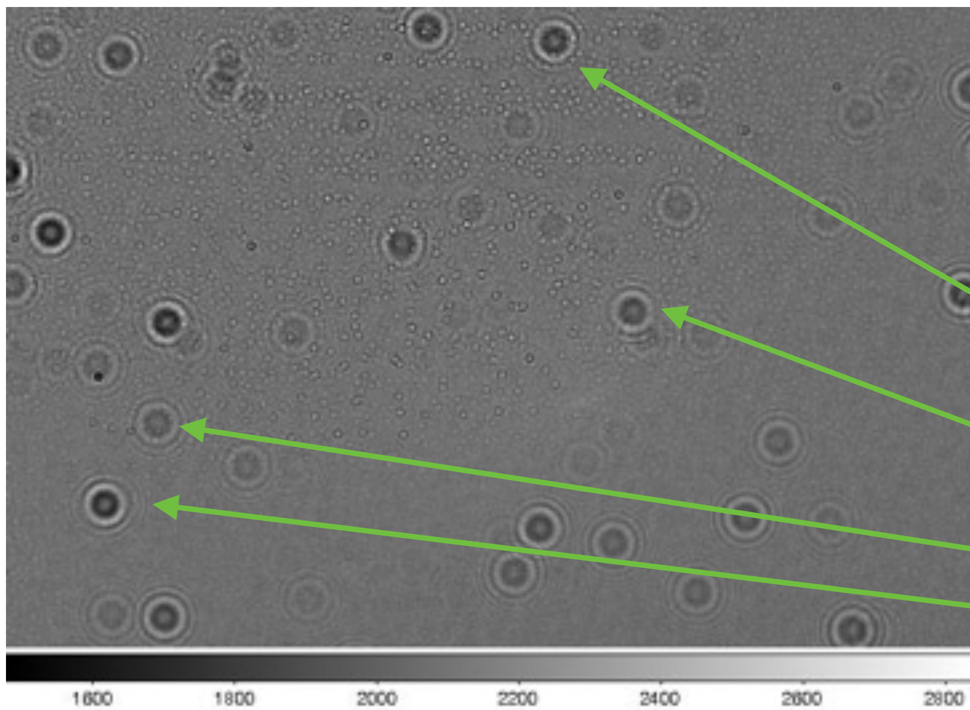


Image of LED #18 (red)

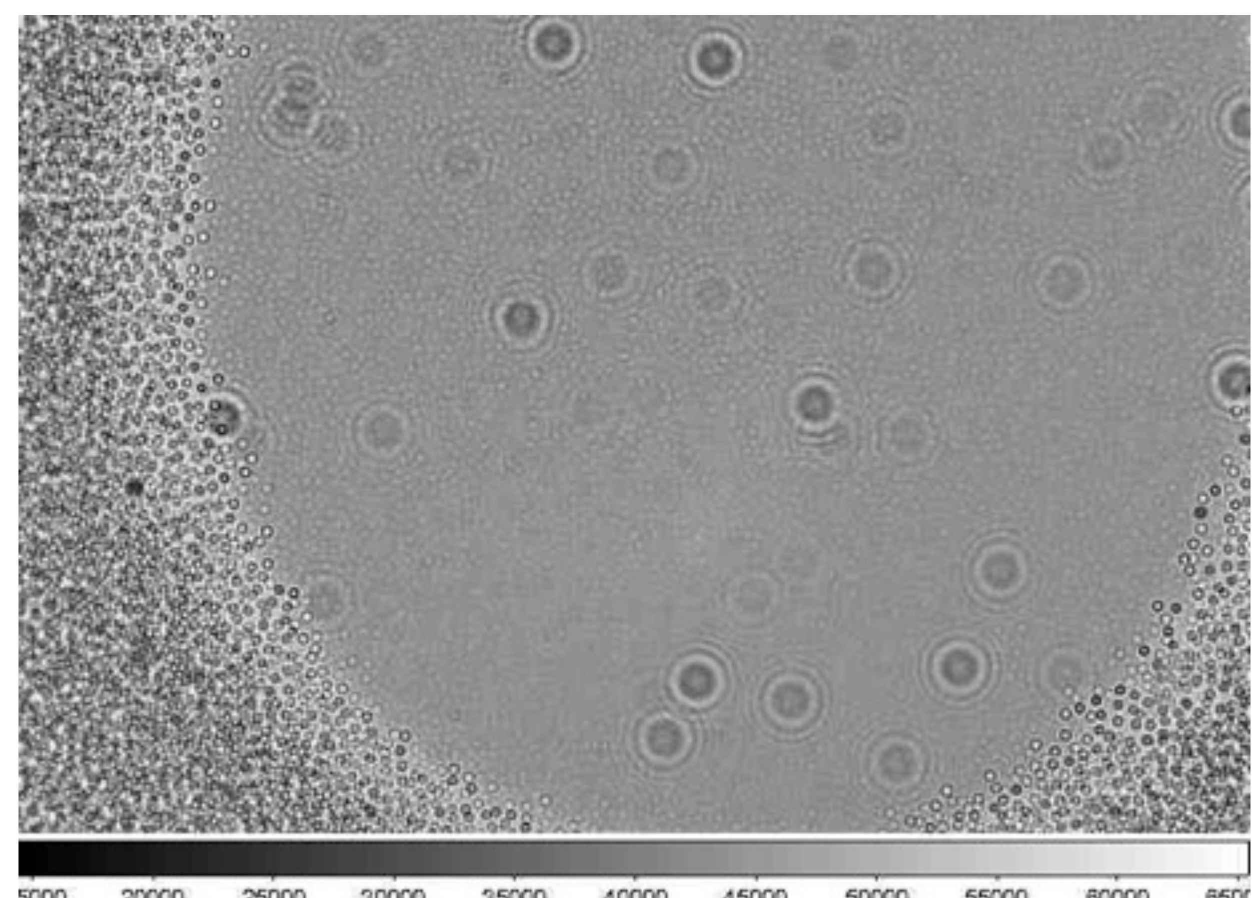
Presence of dusts over the CCD

+

Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

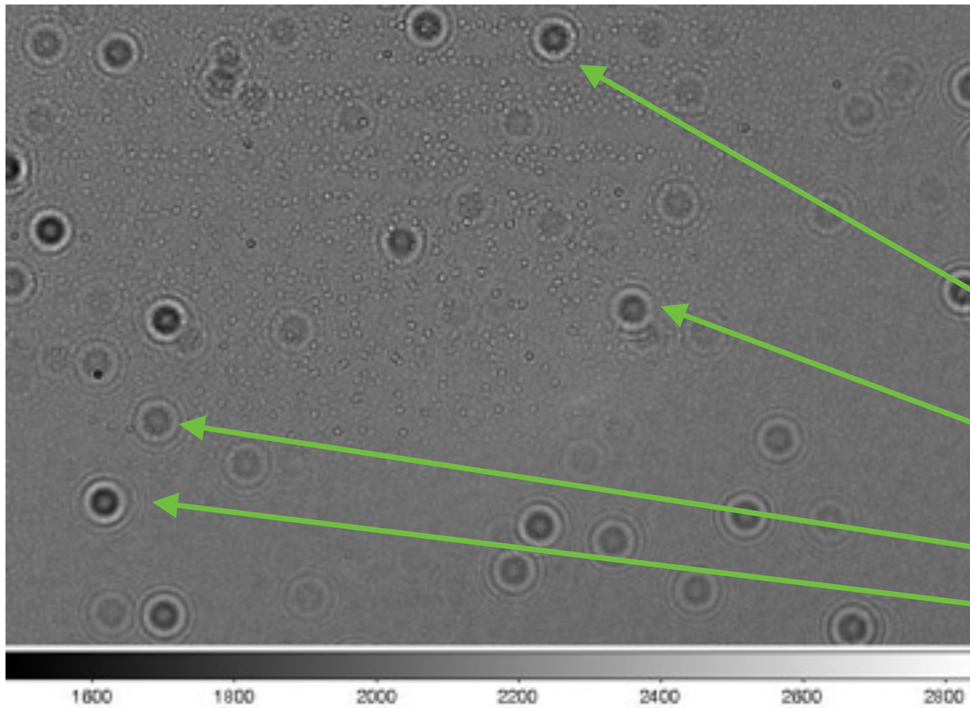


Image of LED #18 (red)

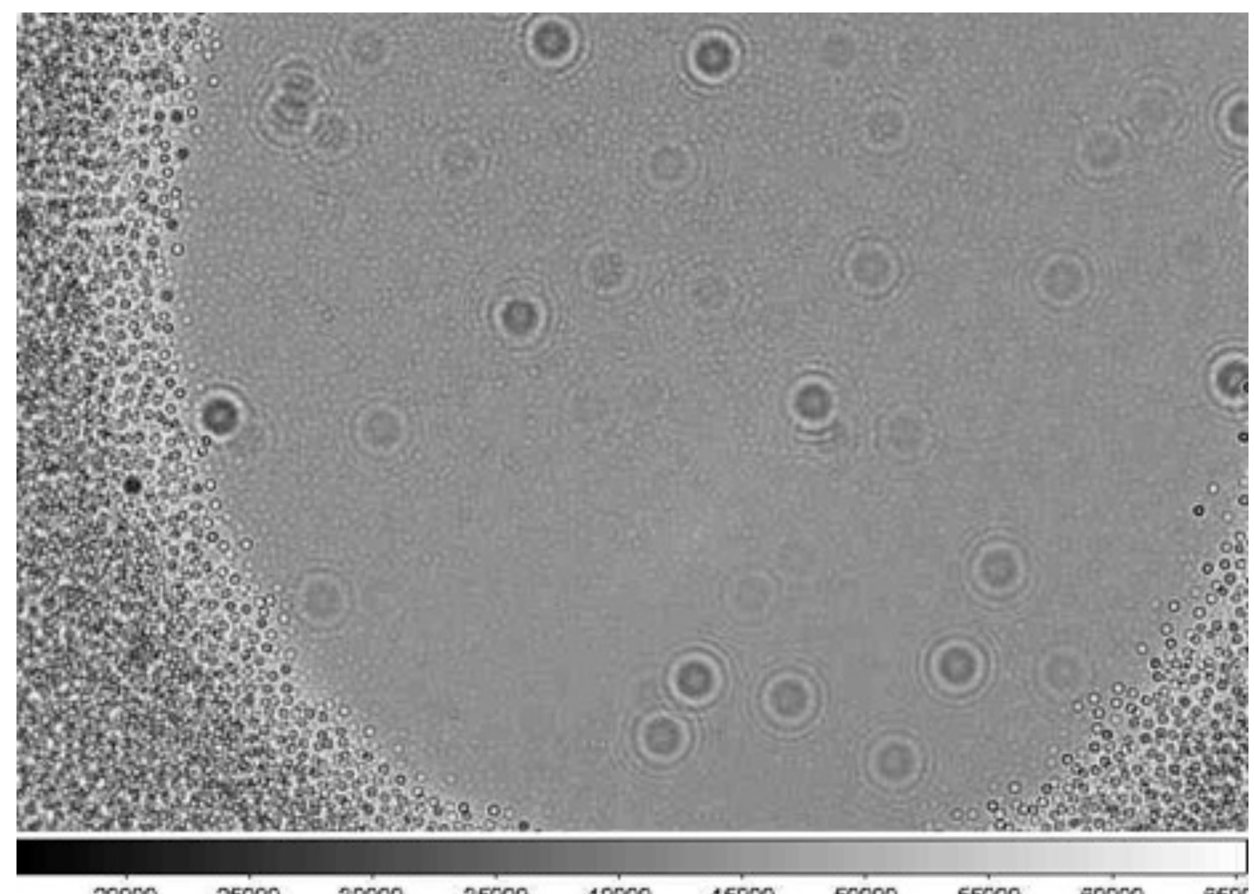
Presence of dusts over the CCD

+

Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

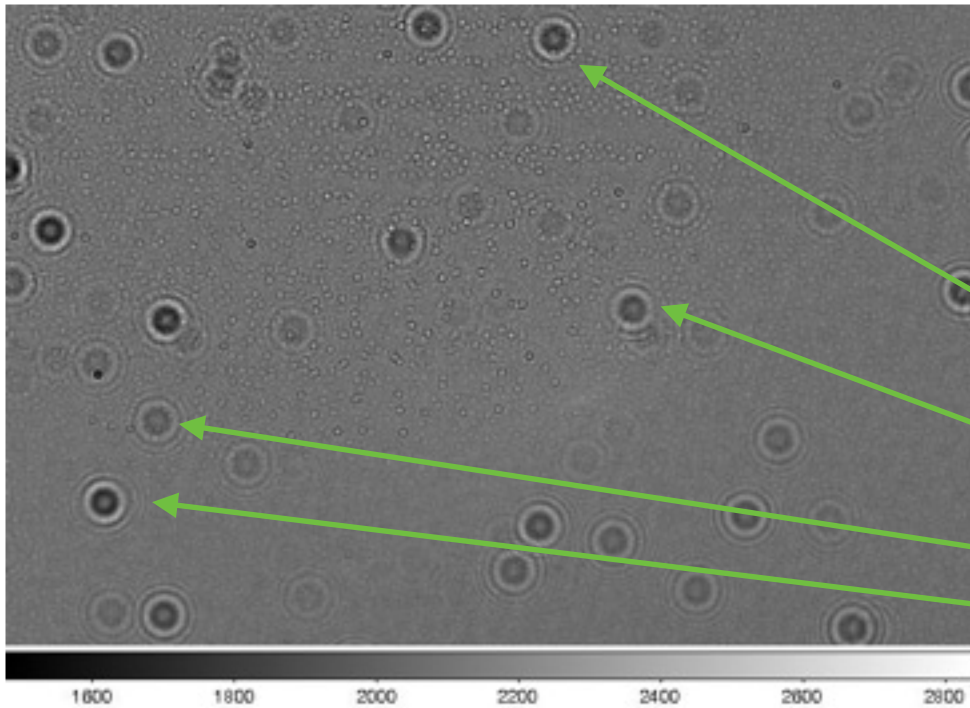


Image of LED #18 (red)

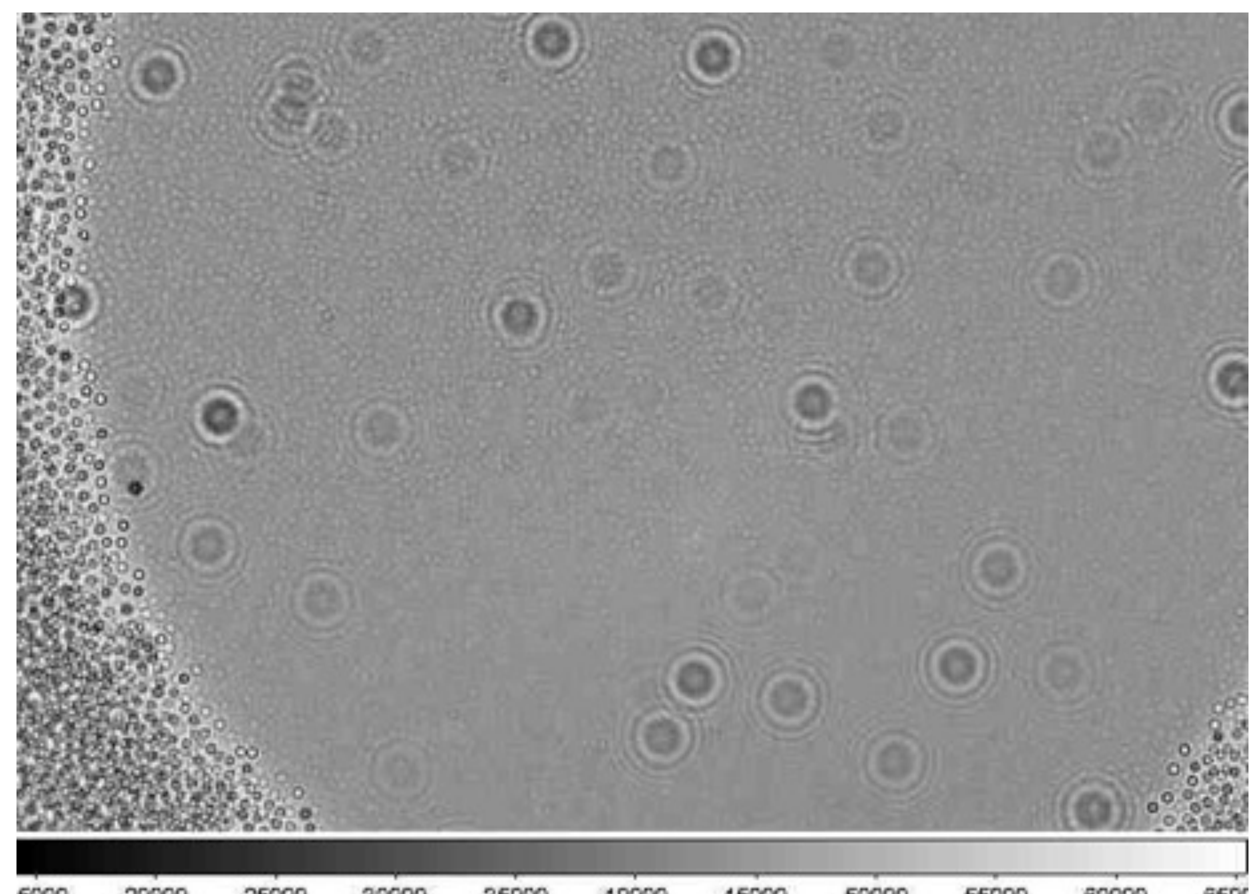
Presence of dusts over the CCD

+

Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

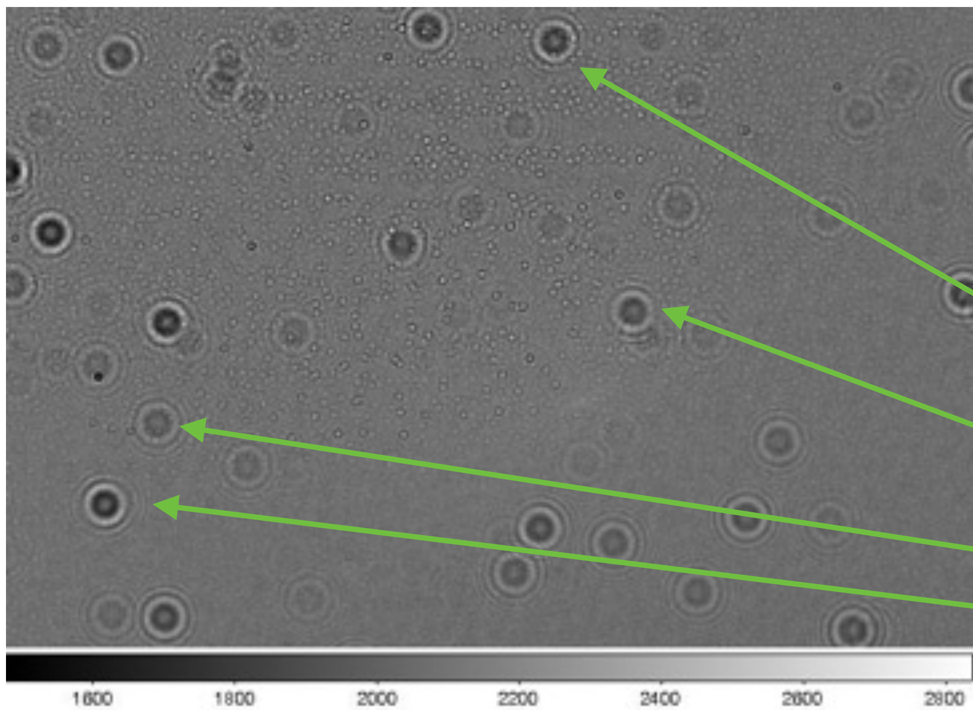


Image of LED #18 (red)

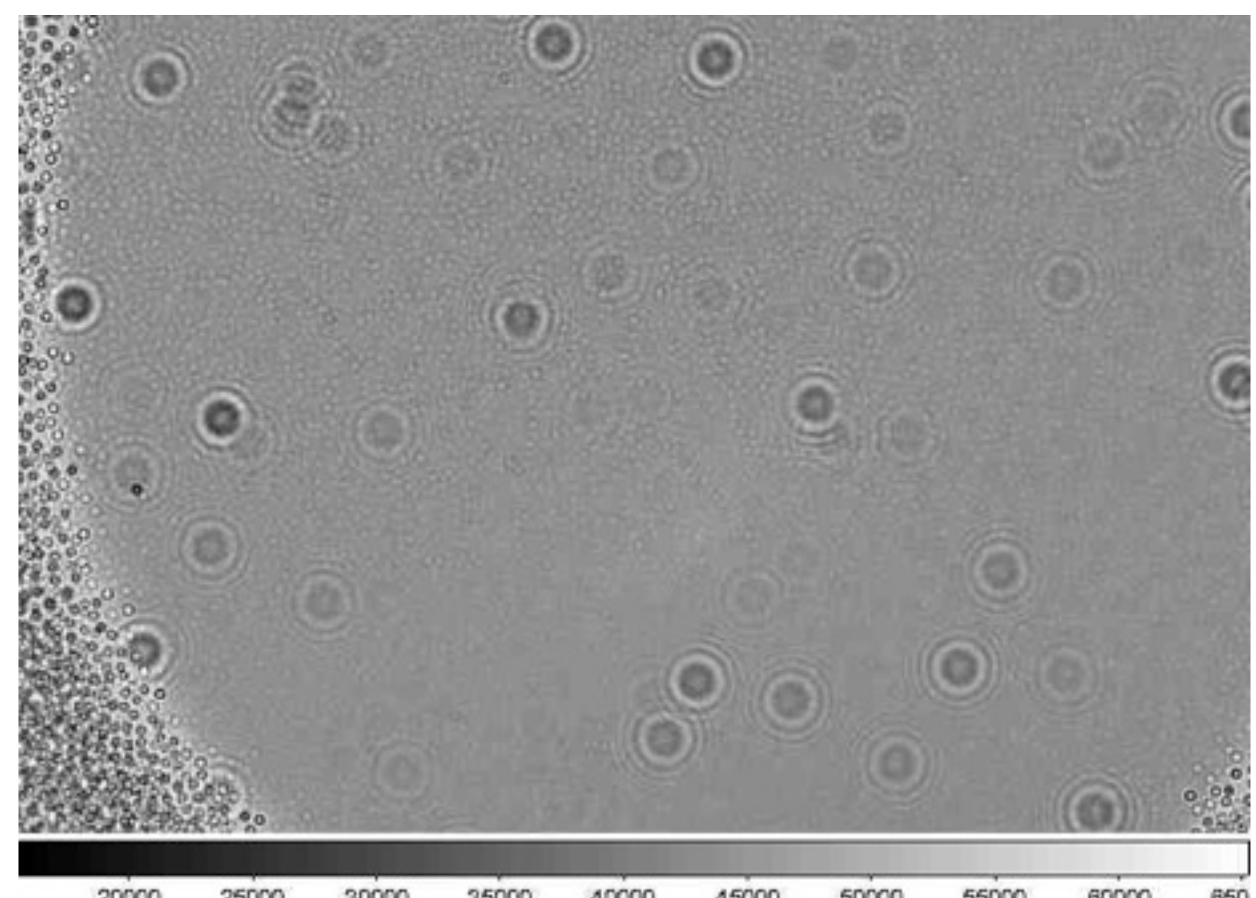
Presence of dusts over the CCD

+

Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

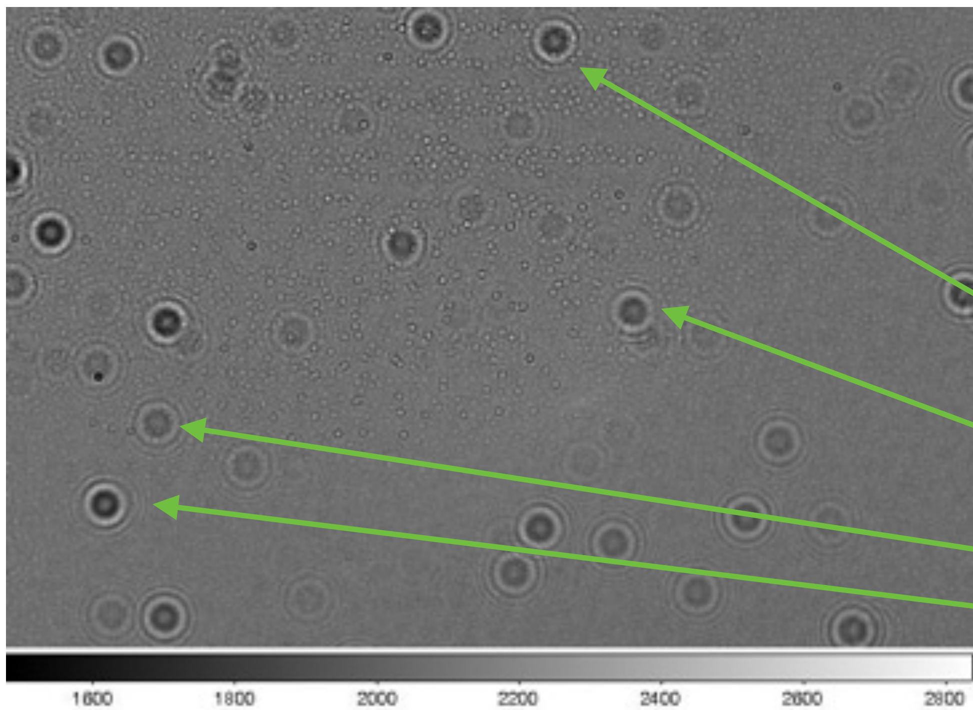
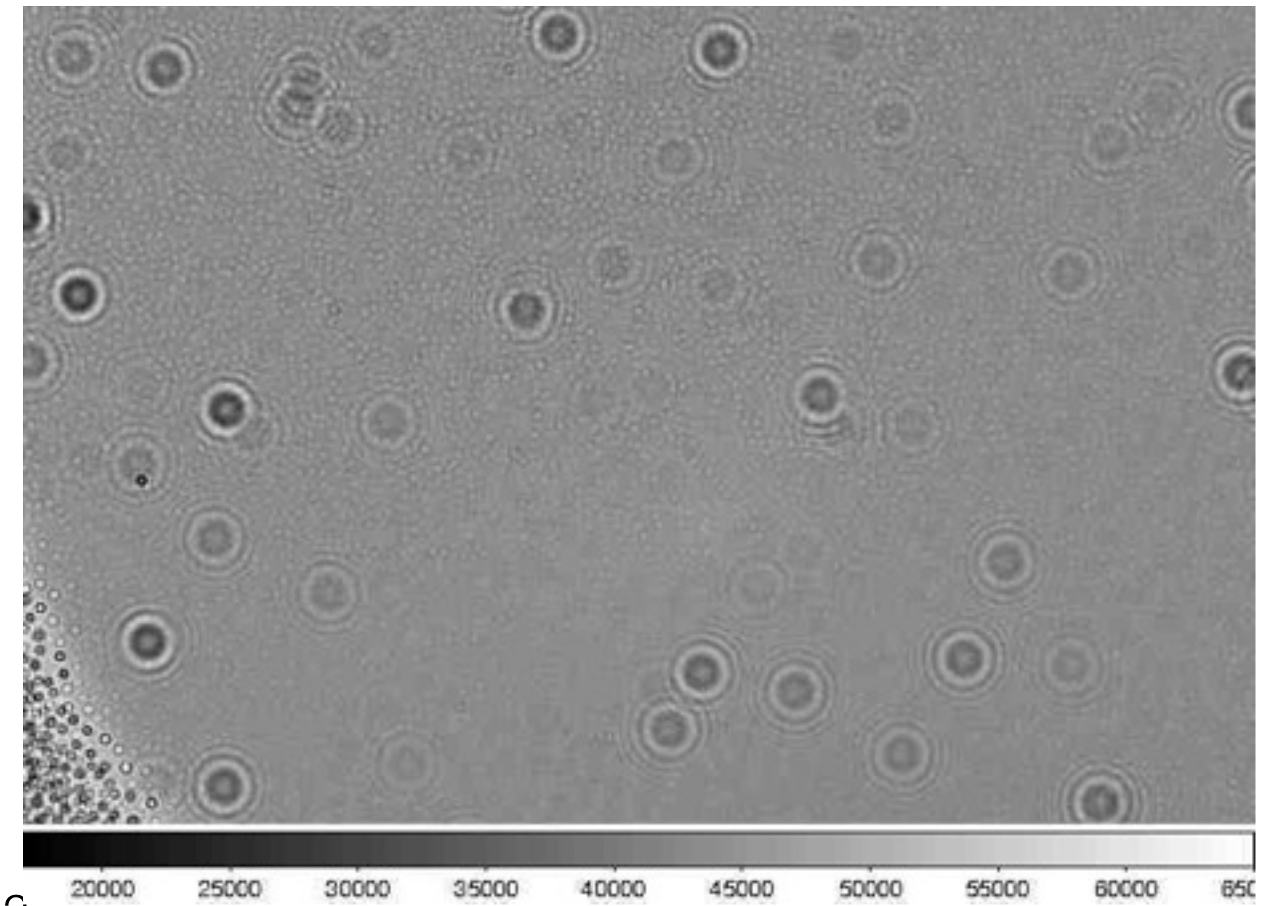


Image of LED #18 (red)

Presence of dusts over the CCD
+
Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

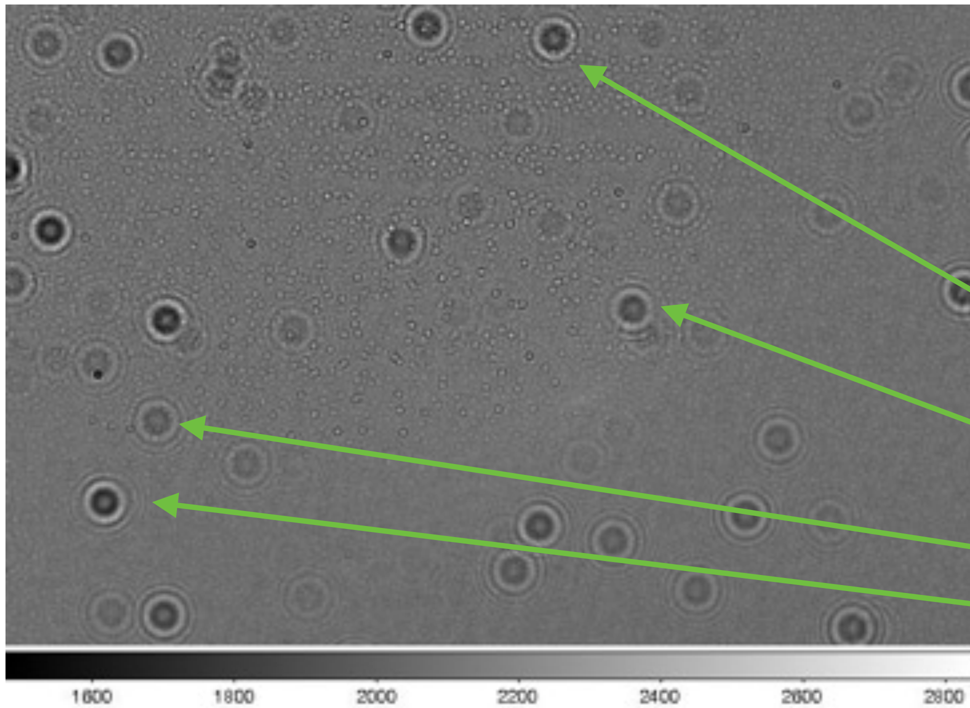
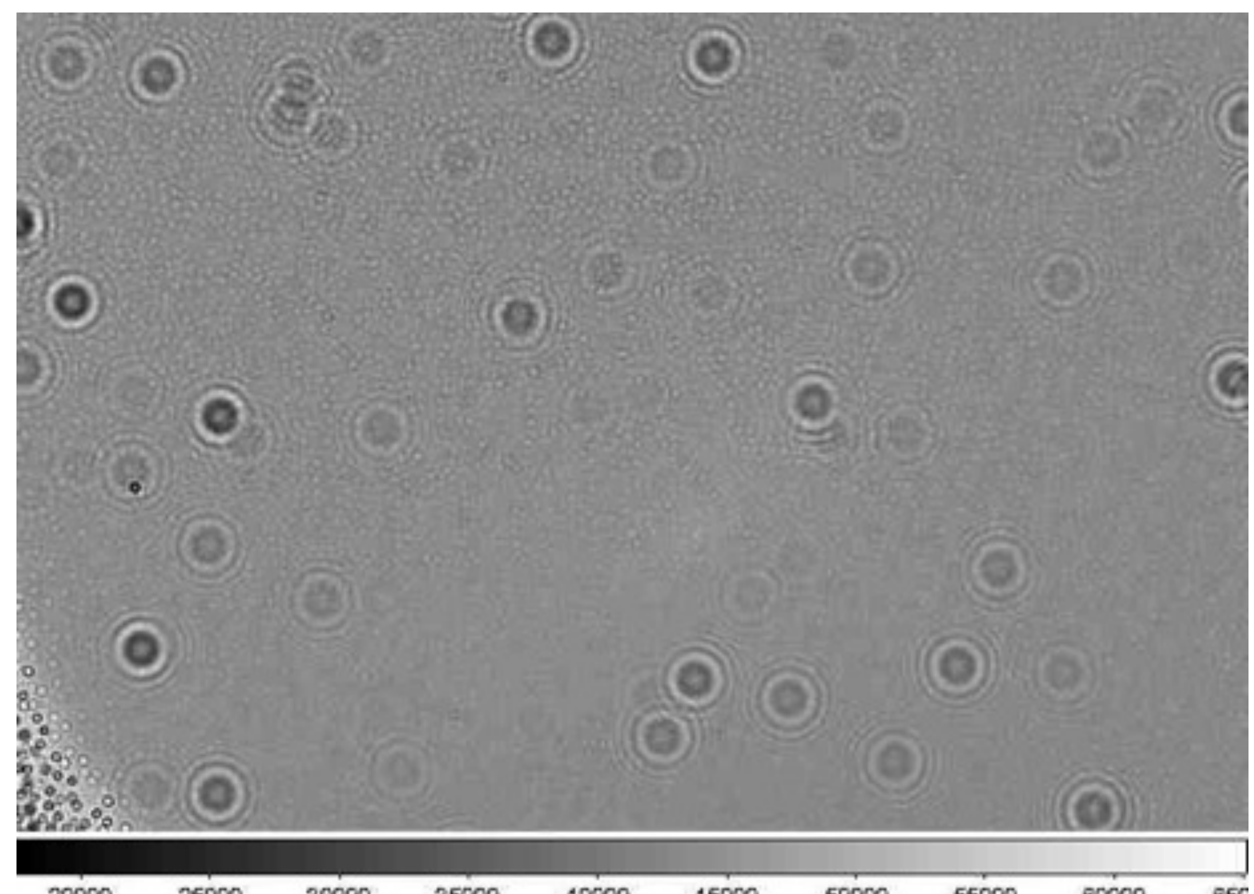


Image of LED #18 (red)

Presence of dusts over the CCD
+
Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Flat fields

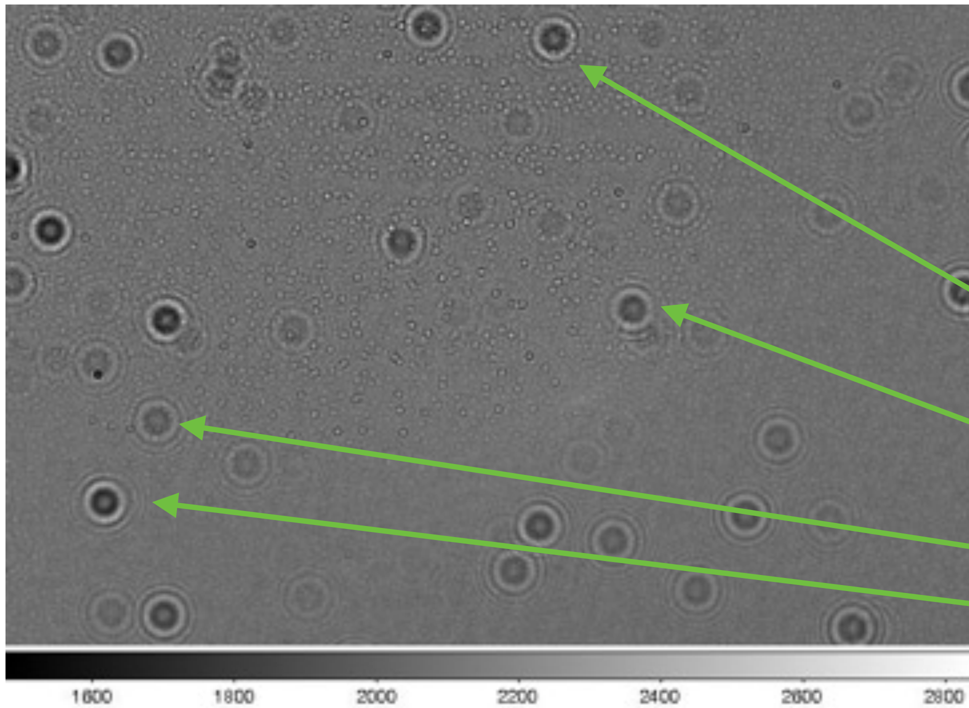


Image of LED #18 (red)

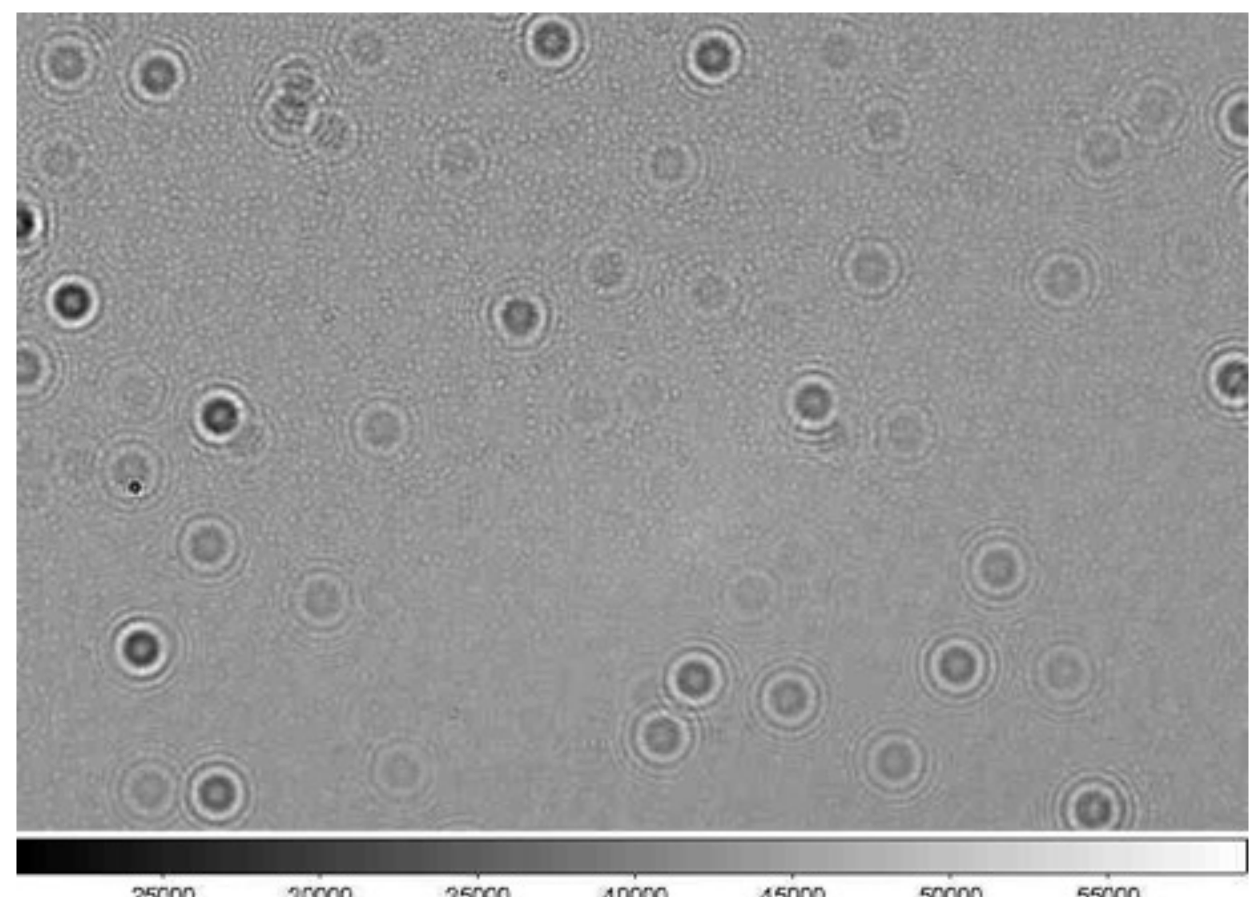
Presence of dusts over the CCD

+

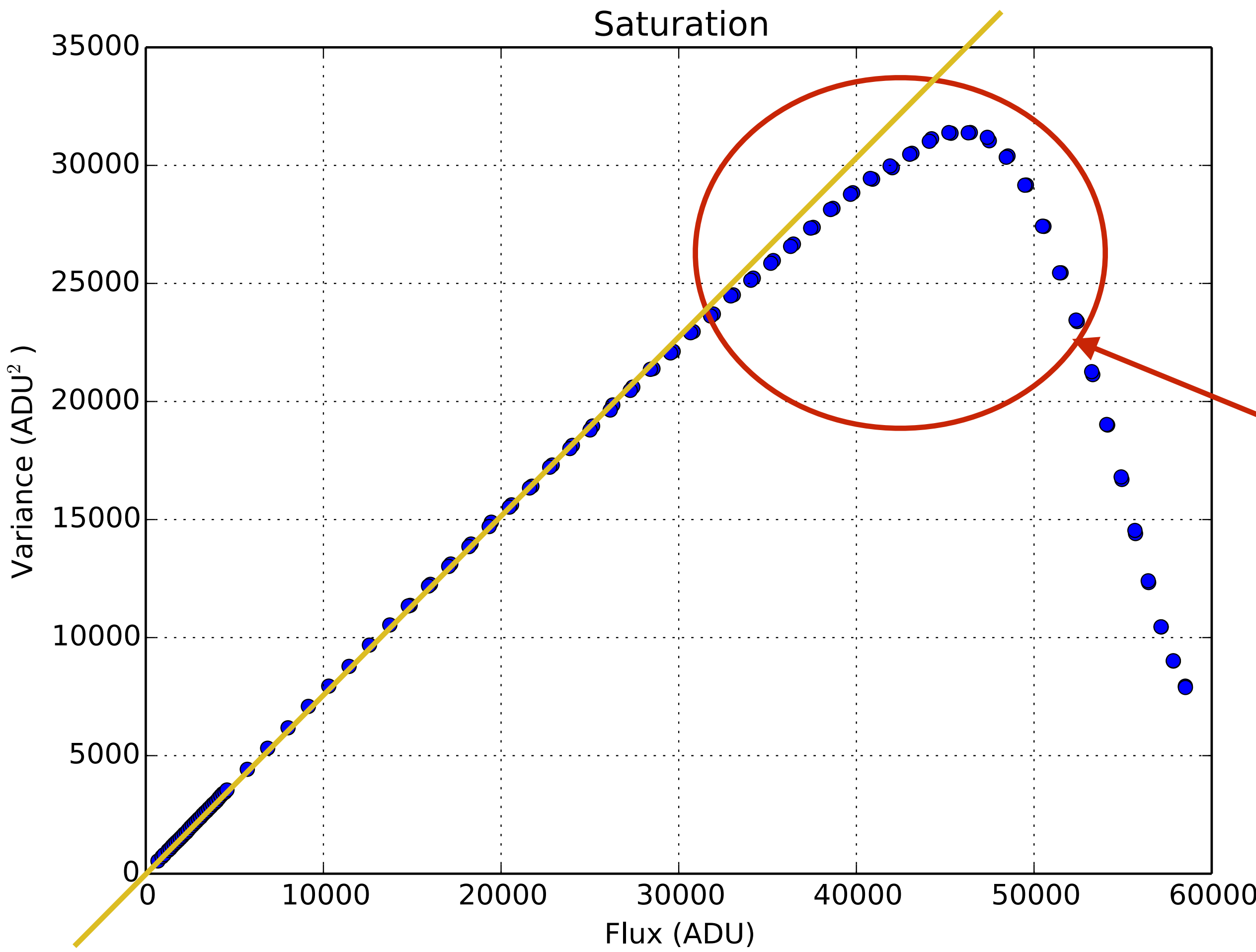
Almost monochromatic source

Diffraction patterns

There is steam over the CCD when we turn it on, it lasts ~1 hour



Gain



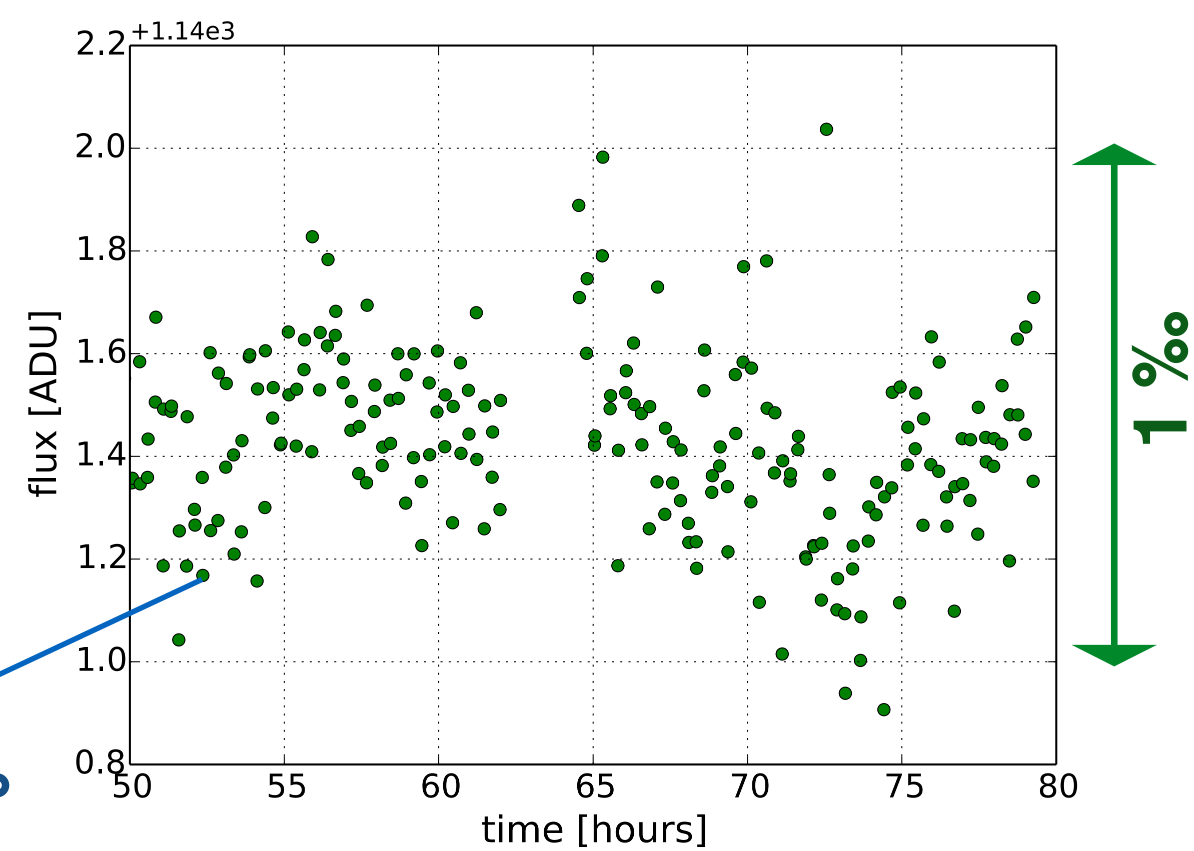
slope = 2/gain

Variance of a subtraction of two images in the same conditions (extracted from flat-fields of different exposure times)

saturation at ~35k ADU —> 90k e-

Gain ~ 2.6 e-/ADU

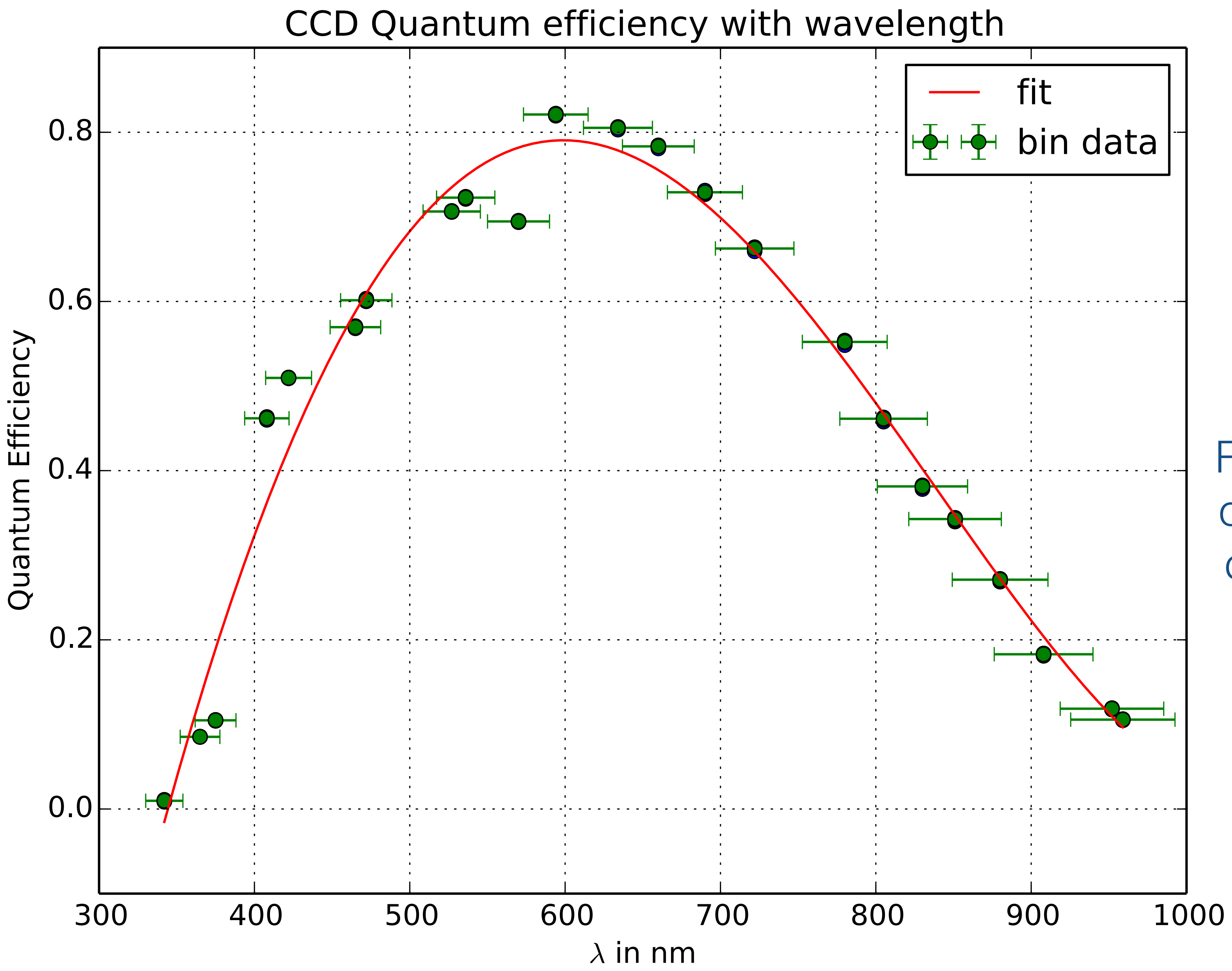
Stability over 30 hours



σ = 0.2 ‰

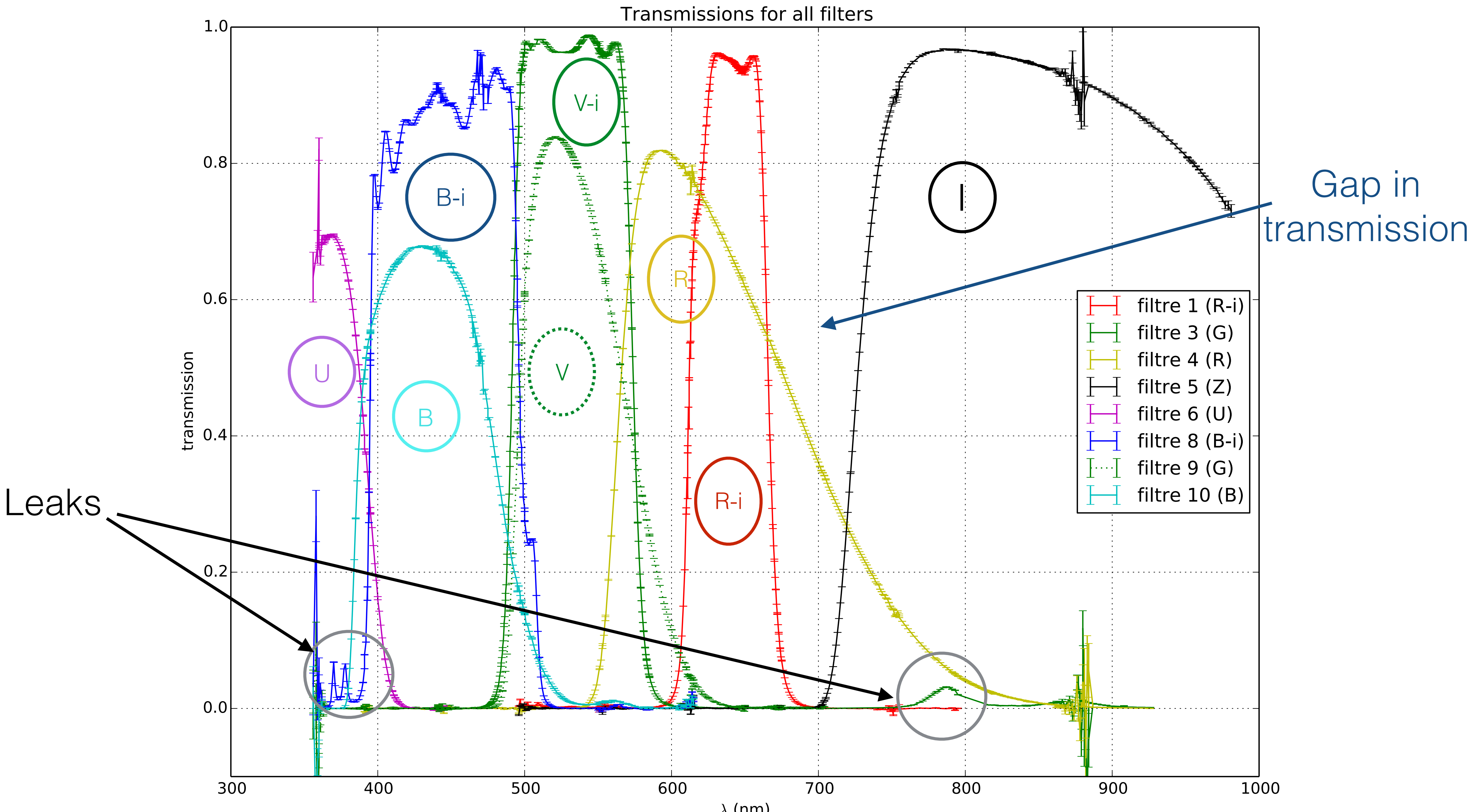
Gain very stable!

Quantum efficiency



Ratio between the number of electrons created in the camera the photon flux in the NIST photodiode

Filter Transmissions

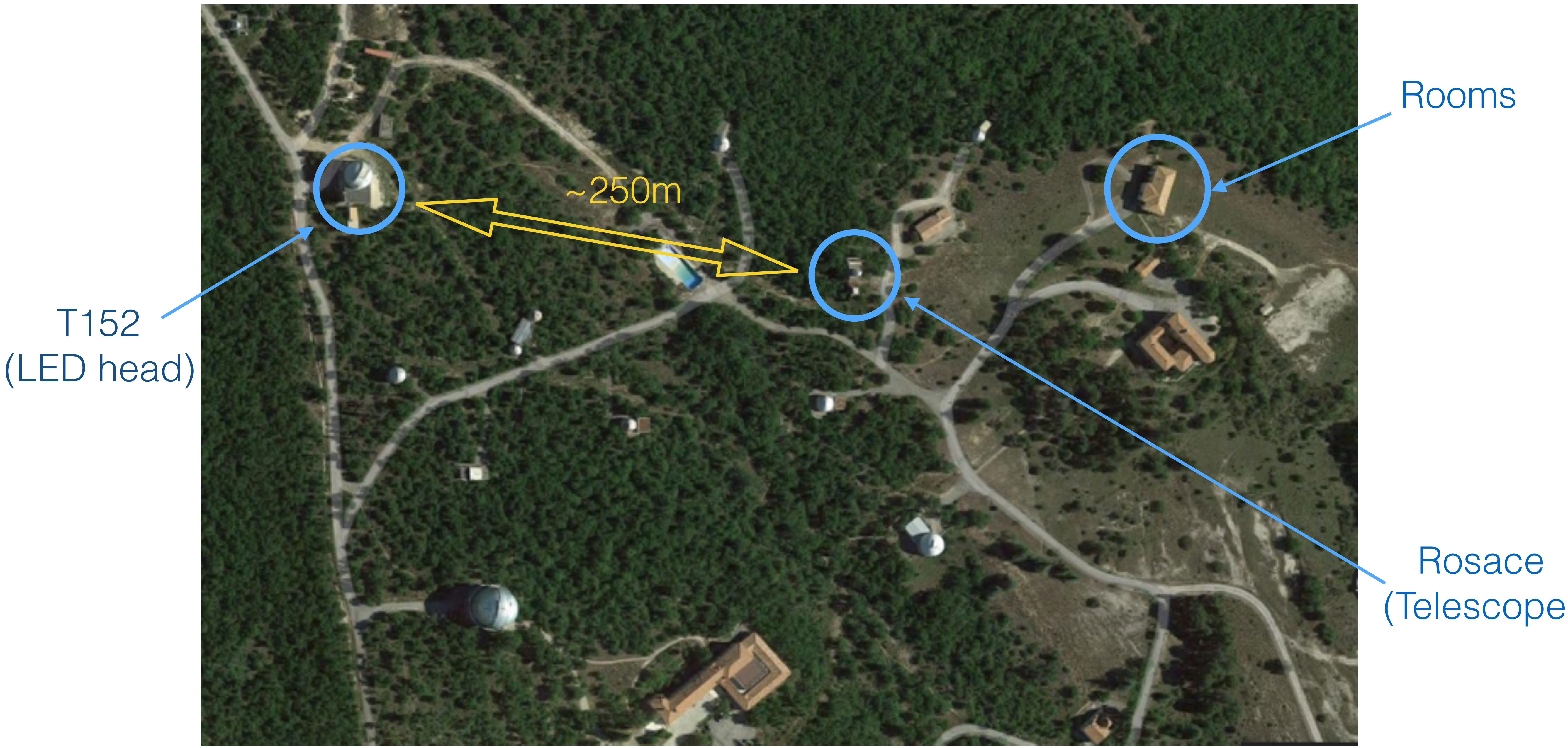


Relative transmissions of given filters computed with monochromator

Filter wheel = 5 slots : U B-i V-i R I

Testing campaign at Observatoire de Haute Provence

Director : Auguste Le Van Suu



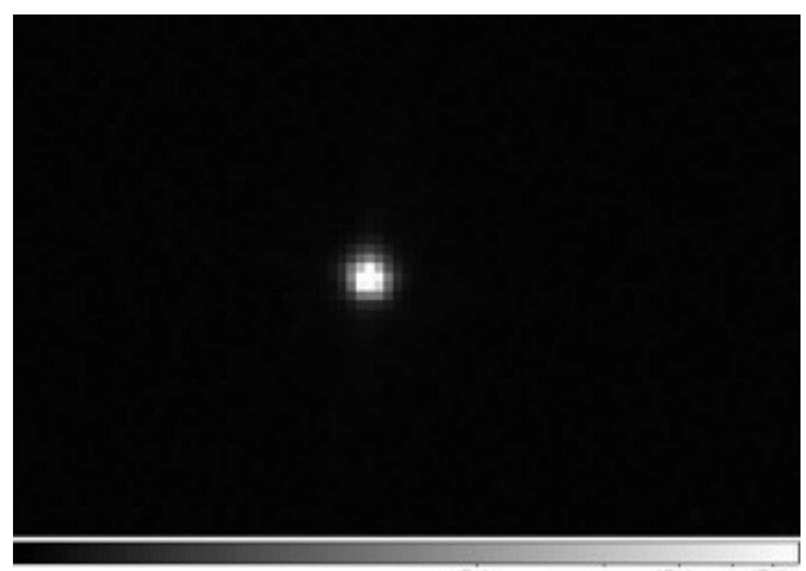
OHP site

Window for control devices wires

LED head pointing to the telescope

Beam width at 250m : ~9m

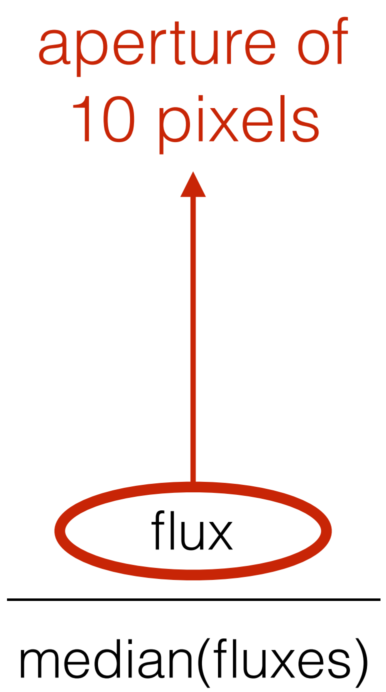
Easily to align

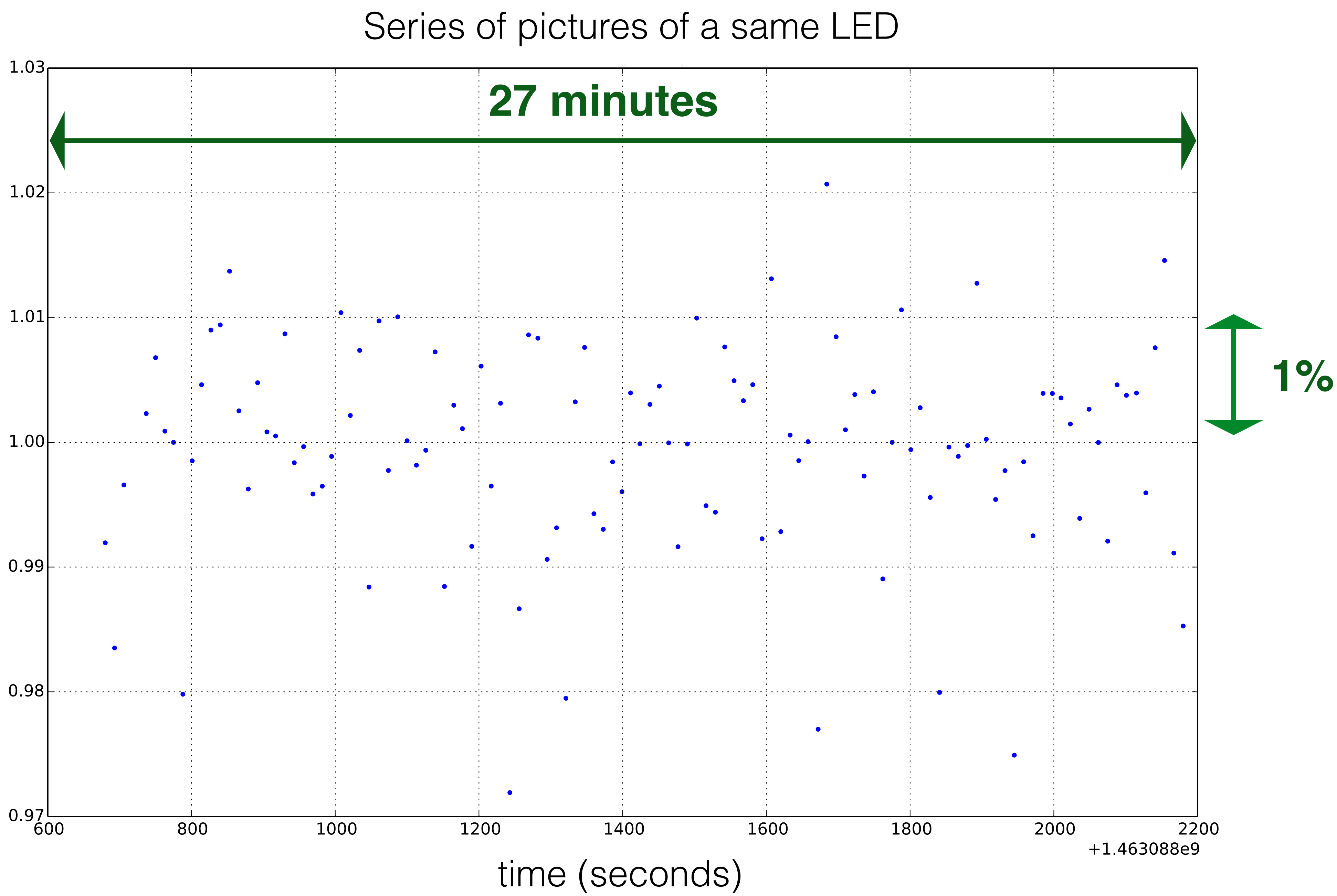


OHP first light from a LED

We took series of images of LEDs with different filters

Photometry





σ = 7‰ —> High repeatability

exposition time = 0.1 s
—> shutter noise

Our results

We stacked images of the same object with SWarp:

- removing those with mist, bad weather and the saturated ones.
- subtracting a dark taken just before each image
- recentering them to correct movements due to the wind

Stacked images:

LED #07 Filter #03 (Green)

LED #23 Filter #08 (Blue)

19 Ursa Minor, Filter #03 (Green)

Same type of object

Same filter

Comparisons

We compared LED #07 and 19 UMi in green filter

Very similar shapes

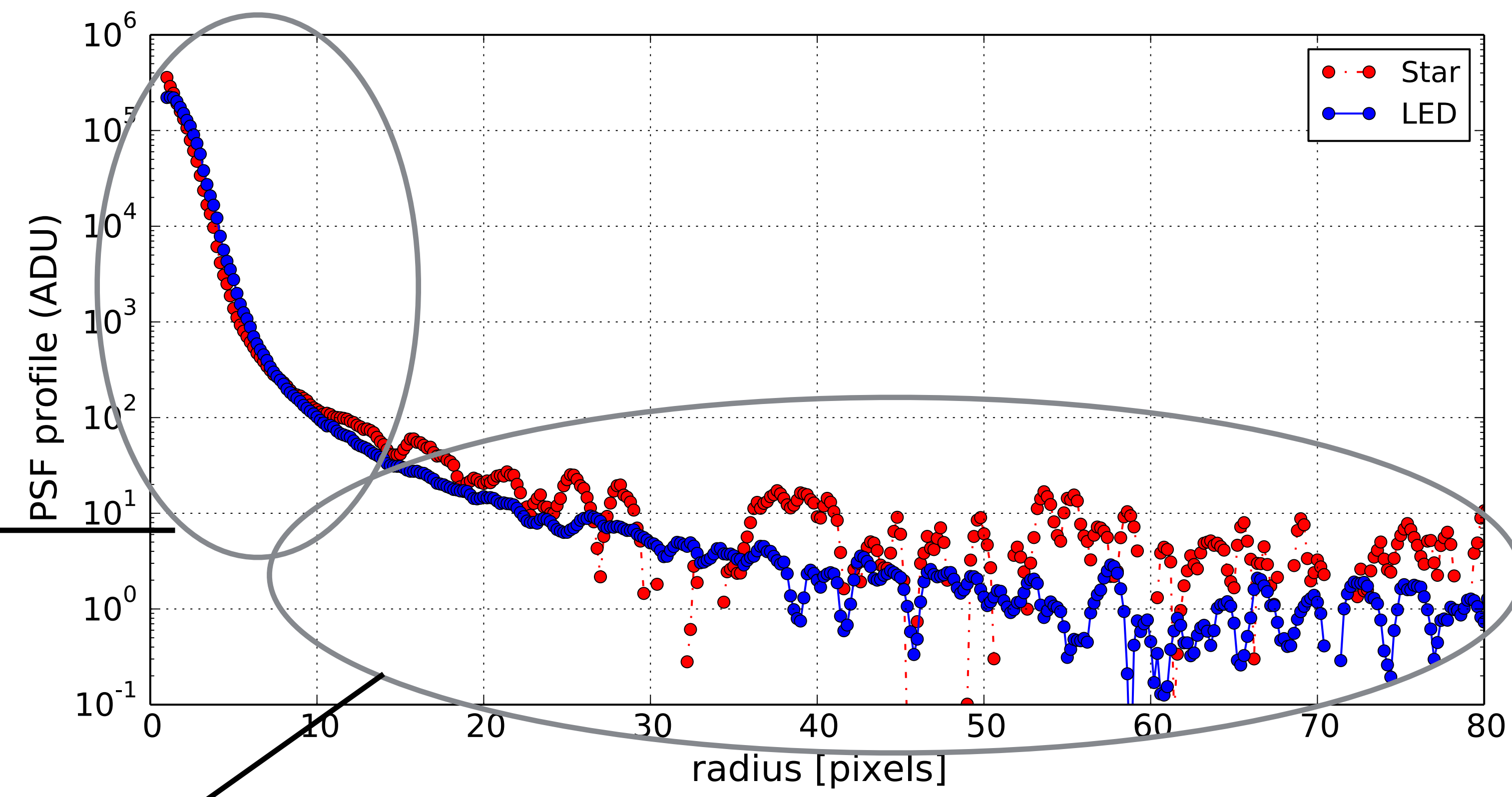
+

PSF over more than 4 orders of magnitude in flux beyond 15 pixels

We have an artificial star!

To be improved with a better reduction of the structured background

global factor for the LED for both LED and star have ~the same flux



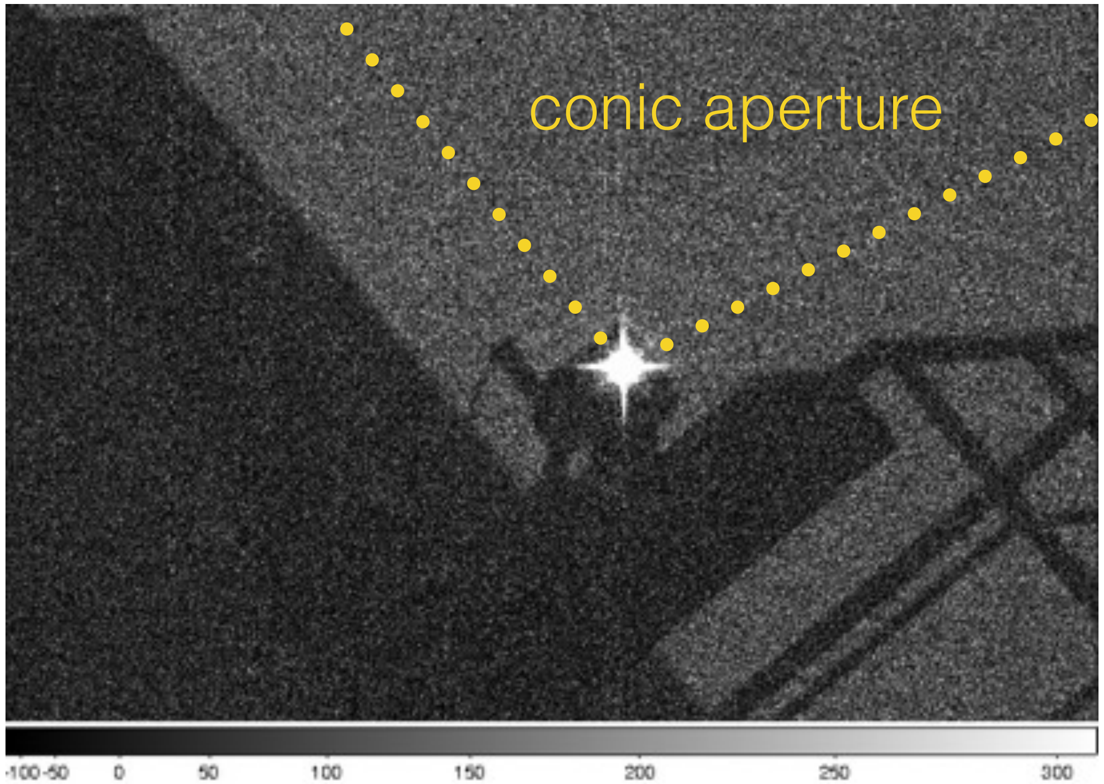


Image of the source convenient scale

Conclusion

- We found a good couple of sites
- We created an artificial star (point source with a PSF similar to a real star
- We checked that the photometry is stable
- We measured the PSF of our source over 5 orders of magnitude

Perspectives

- Measure the PSF at many wavelengths
- Build a source with lower fluxes
- Focus automation
- Telescope mount automation
- Build a shelter

Hope for better weather!