

The Sensors Unlimited GA1280J SWIR camera as a detector for the solar IR coronal polarimetry ?

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Available near IR detectors

- Xenics
- FLIR
- Teledyne
- Goodrich
- ...

Goodrich GA1280J camera

- UTC Aerospace Systems, Sensors Unlimited Products, 330 Carter Road, Suite 100, Princeton, NJ 08540, USA
- TOP10 of 2012 (*photonicsonline.com*)
- International Traffic In Arms Regulations (ITAR): “Export, re-export or transfer by any means to a foreign person or entity, whether in the US or abroad, without appropriate US State Department authorization, is prohibited and may result in substantial penalties.”
- email communication



Camera - public information

GA1280J-15

High Resolution, Mil-Rugged, High Sensitivity InGaAs SWIR Camera



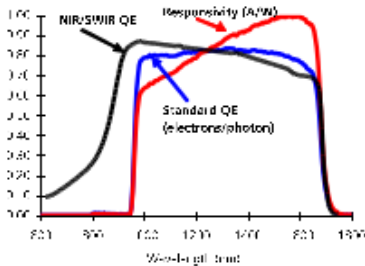
The compact **J-Series** is Goodrich's next generation SWIR digital video camera featuring a 1.3MP high-resolution, high-sensitivity InGaAs imager. It provides real-time daylight to low-light imaging in the Short Wave Infrared (SWIR) wavelength spectrum for persistent surveillance, laser detection, and penetration through fog, dust, and smoke. In addition, the camera employs on-board Automatic Gain Control (AGC) and built-in non-uniformity correction (NUCs), allowing it to address the challenges of high dynamic range urban night imaging without blooming. Camera Link® digital output provides for plug-and-play video with 12-bit images for digital image processing or transmission. The light weight and compact size enables easy integration into aerial, mobile and hand-held surveillance systems. Optional **NIR/SWIR technology** is available to extend the sensitivity of Goodrich cameras down to 0.7 μm , offering the advantage of both Near Infrared (NIR) and Short Wave Infrared wavelength response.

APPLICATIONS

- Low-light level imaging
- Cover surveillance with passive 24 hr/7 day operation
- Multi-laser spotting and tracking
- Imaging through atmospheric obscuration
- OEM version for easy integration into UASs, handheld, or robotic systems
- Direct Vision Enhancement (DVE)

FEATURES

- 1280 x 1024 pixel format, 15 μm pitch
- 30fps frame rate
- Highest sensitivity available in 0.9 to 1.7 μm spectrum: NIR/SWIR, from 0.7 to 1.7 μm
- Far-infrared to daylight imaging
- Compact, OEM module size $\approx 4.5"$
- All-weather InGaAs imager
- On-board, real-time non-uniformity correction
- Digital 12-bit base CameraLink® output
- Automatic Gain Control (AGC)
- Improved dynamic range enhancements (Local Area Processing)
- Tested to MIL-STD-883C for shock, vibration, altitude, humidity, and acceleration



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J Platform

MECHANICAL SPECIFICATIONS

Model	Formed	GHM
Module Dimensions	4.25 x 3.00 x 1.44 inches 50.8 x 76.2 x 36.1 mm (for PCB connectors, include connector)	1.15 x 1.00 x 1.10 inches 41.3 x 40.6 x 40.6 mm Resolves optional connector pitch = 20.0
Weight (no lens)	~235g	
Lens Mount	M42.1 mount	M42.1 mount (optional)
Included Lens	01A, 04mm, F/2.7, H07-wash, M42.1 mount	none
Camera Link Connector	RM-SWIR Connector	none
Field of View	Not applicable	none
Pixel Pitch	15 μm	
Total Pixel Array Format	1280 x 1024 pixels	
Active Area	18.2 mm x 13.4 mm x 2.8 mm diagonal	

ENVIRONMENTAL & POWER SPECIFICATIONS

Operating Case Temperature	-40 to 60°C
Storage Temperature	-54°C to 85°C
Humidity	90% relative humidity
Power requirements	
AC Adapter Supplied	100-240 VAC, 17-88 Hz
DC Voltage	48-10 V
Power	0.4W @ 0.1°C case temperature, @ 90% RH
Functional Shock, Random Vibration, Altitude, Humidity, Acceleration	MIL-STD-883C compliant
Conduction cooled End Users	CECC Part 15 MIL-STD-883C-102 and 102A

ELECTRICAL SPECIFICATIONS

Optical Fill Factor	100%
Spectral Response	Standard: 0.9 μm to 1.7 μm NIR/SWIR: 0.7 μm to 1.7 μm
Quantum Efficiency	Standard: 0.15 from 1.0 μm to 1.6 μm NIR/SWIR: 0.15 from 0.9 μm to 1.6 μm
Mean Dark Current, D [*]	1.4 x 10 ⁻⁷ amp/leak (aircraft)
Noise Equivalent Signal (NEP)	85 electrons/line/and
Dynamic Range	400:1 (high gain), 600:1 (low gain) (nominal)
Non-Uniformity Correction	20 precision equalized operational settings (0.7%)
Linearity	±0.9%
Exposure Times	42 ns to 4.2 ms
Image Correction	2-point offset and gain (per pixel), user re-loadable
Digital Output Format	12-bit, Base Camera Link®
Digital Output Frame Rate	30 fps
Scan Mode	Continuous or 4 externally triggered modes

A_{0.9} = 85 pA/line/cm², $\lambda = 0.9 \mu\text{m}$, highest available gain setting. D^* is the signal-to-noise ratio (SNR) at 0.1 electrons/cm². The number of pixels is measured electrically to be 1280×1024 .

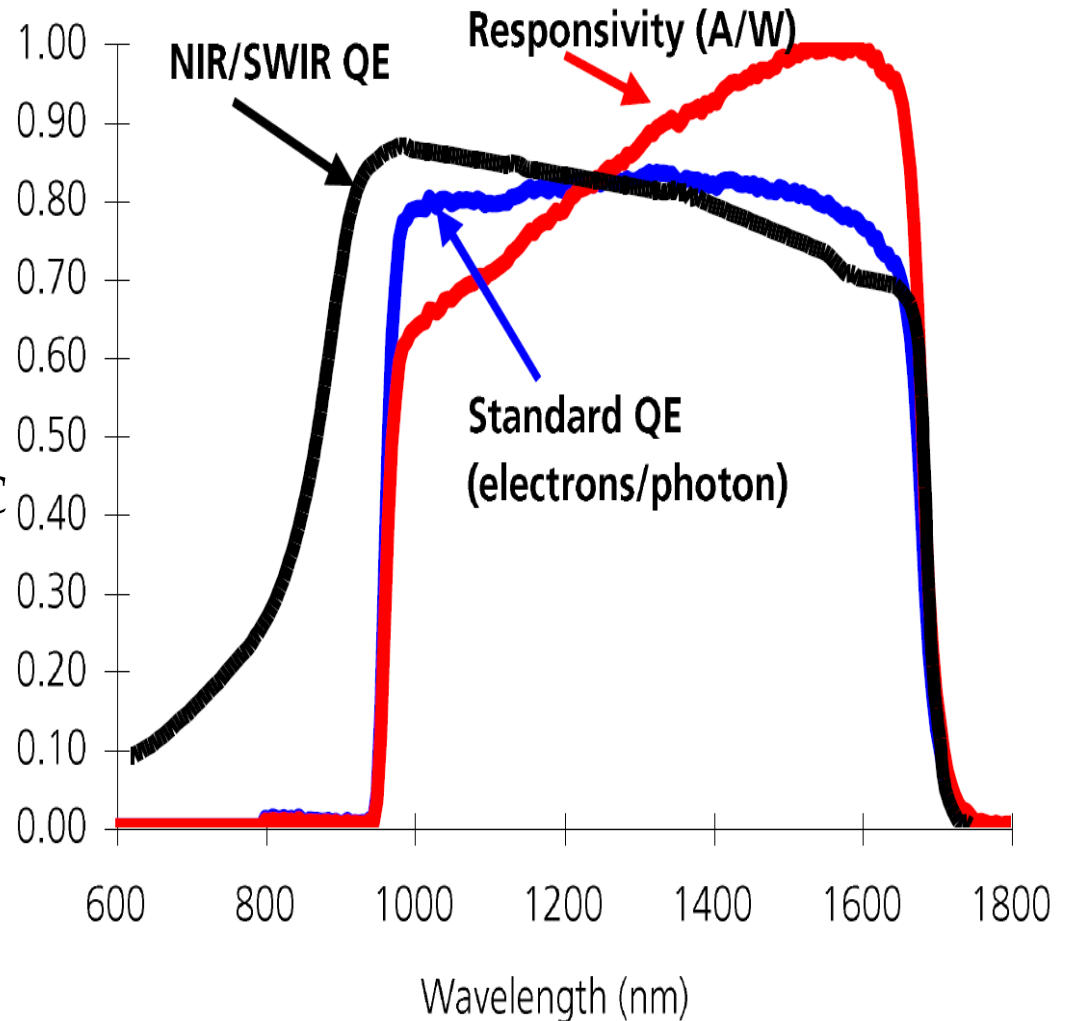


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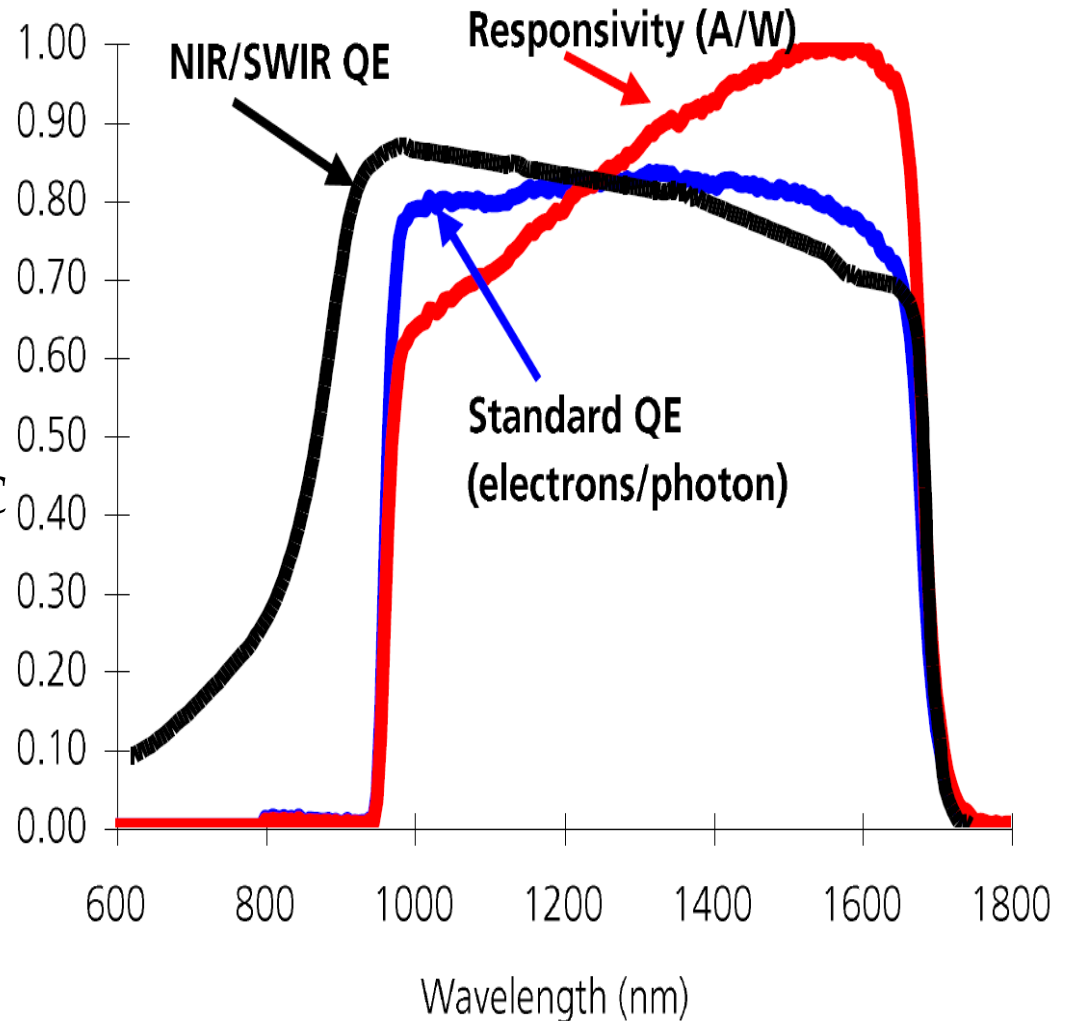
Camera - public information

- all solid-state InGaAs imager
- spectral response: 0.9-1.7 μm
- quantum efficiency: $> 65\%$
- 1280 x 1024 15 μm pixels
(19.2x15.4mm)
- 30 Hz full frame rate
- 51 x 51 x 63mm, 235g
- operating temperature: $-20^{\circ}\text{C} - +45^{\circ}\text{C}$
- power requirement: $< 8\text{ W}$
- digital 12/bit output
- noise: 85 electrons (maximum)
- dynamic range: 300:1 low gain,
900:1 high gain
- t_{exp} : 32 $\mu\text{s} - 33.2\text{ ms}$
- chip temperature: $+30^{\circ}\text{C}$
- frame adding possible in the camera



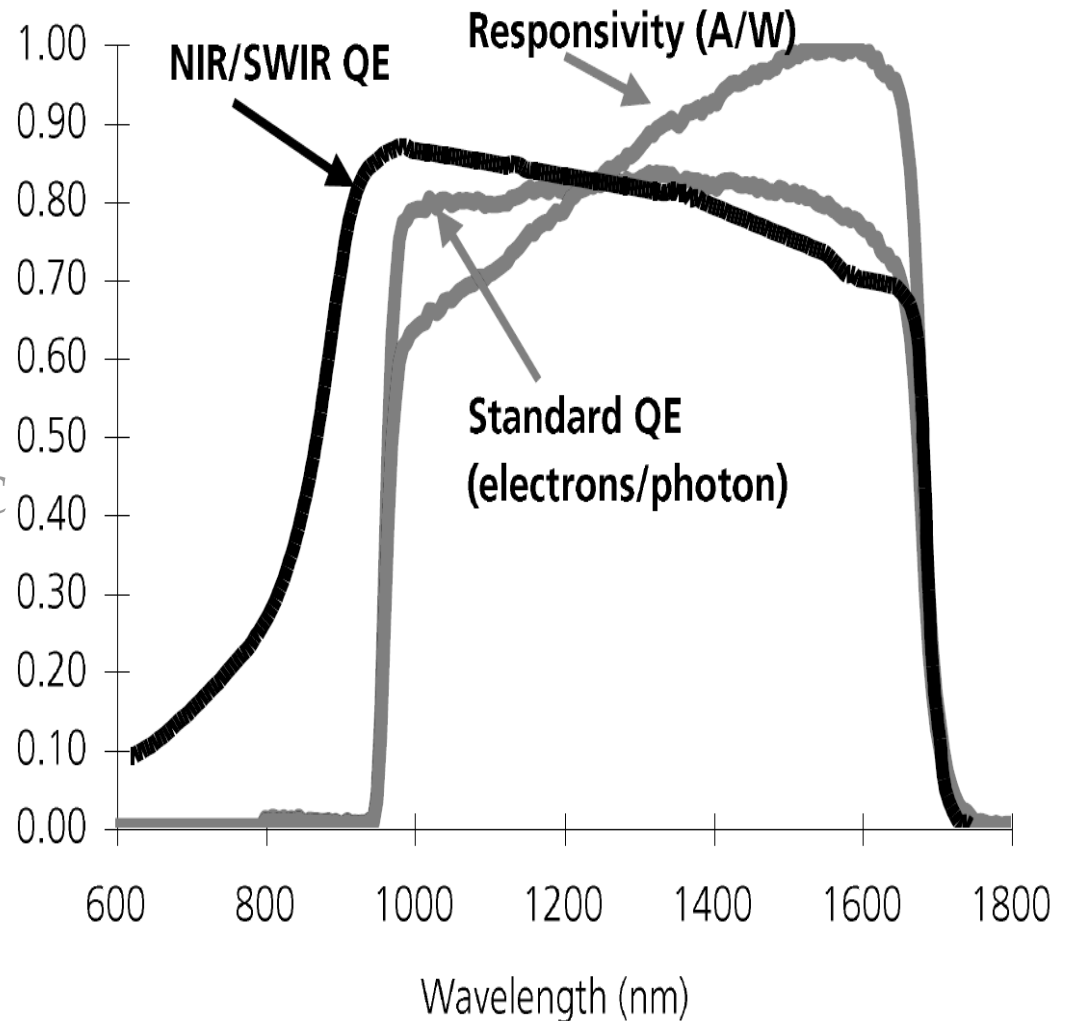
Camera – GREAT!

- all solid-state InGaAs imager
- spectral response: 0.9-1.7 μm
- quantum efficiency: $> 65\%$
- 1280 x 1024 15 μm pixels
(19.2x15.4mm)
- 30 Hz full frame rate
- 51 x 51 x 63mm, 235g
- operating temperature: $-20^{\circ}\text{C} - +45^{\circ}\text{C}$
- power requirement: $< 8\text{ W}$
- digital 12/bit output
- noise: 85 electrons (maximum)
- dynamic range: 300:1 low gain,
900:1 high gain
- t_{exp} : 32 $\mu\text{s} - 33.2\text{ ms}$
- chip temperature: $+30^{\circ}\text{C}$
- frame adding possible in the camera



Camera – BUT!

- all solid-state InGaAs imager
- spectral response: 0.9-1.7 μm
- quantum efficiency: > 65%
- 1280 x 1024 15 μm pixels (19.2x15.4mm)
- 30 Hz full frame rate
- 51 x 51 x 63mm, 235g
- operating temperature: -20°C - $+45^{\circ}\text{C}$
- power requirement: < 8 W
- digital 12/bit output
- noise: 85 electrons (maximum)
- dynamic range: 300:1 low gain, 900:1 high gain
- t_{exp} : 32 μs – 33.2 ms
- chip temperature: $+30^{\circ}\text{C}$
- frame adding possible in the camera

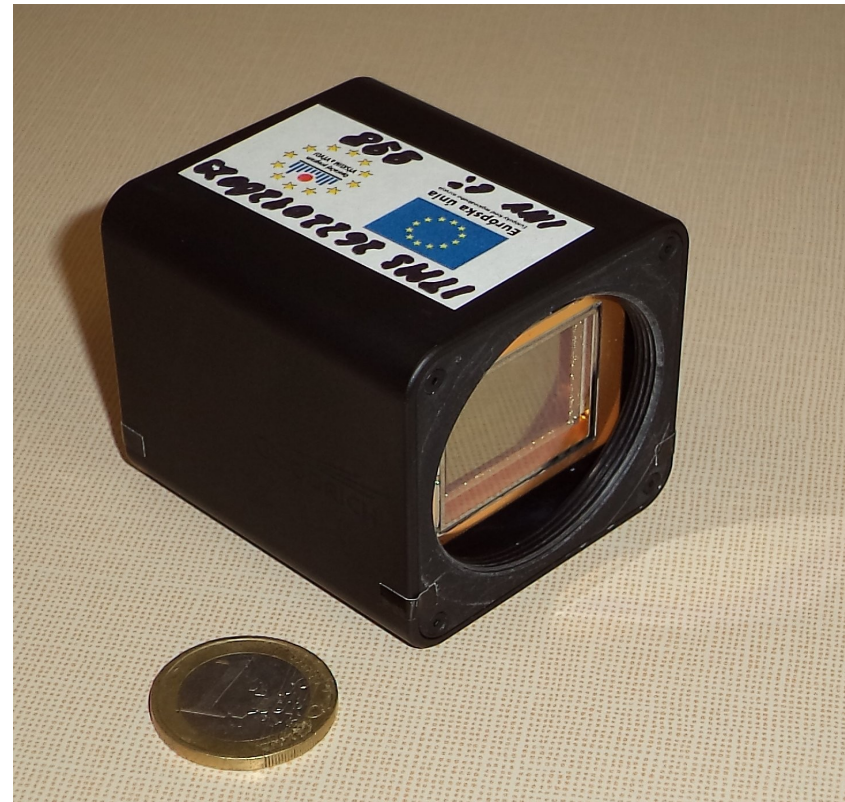


Information content

- Basic information on the camera
- Is it worth... ?
- Results on dark current (DC) and flat-field (FF) made so far at AISAS

Cameras at AISAS

- 2 cameras – parts of the extended camera module of the CoMP-S instrument produced by HAO/NCAR (S. Tomczyk, S. Sewell) for the LSO of AISAS (yes, after obtaining the ITAR agreement...)
- camera serial numbers: #1346S9850, #1305S9549



DC results format

- exposure time: 32 ms
- 3 adding modes on chip: 1, 10, or 100 acquired frames in a resulting image stored (i.e. total exposure times 32 ms, 320 ms, 3.2 s)
- series of 100 resulting images stored for each adding mode
- chip temperature: +30°C, processor temperature: +50°C

- DC images ->
 - mean of an image + standard deviation of an image
 - mean of a series of 100 images + standard deviation of a series of 100 images from the mean pixel by pixel
- correction of the adding mode exposure time to be able to compare results

- numerical results for both cameras and images for Camera #1 only

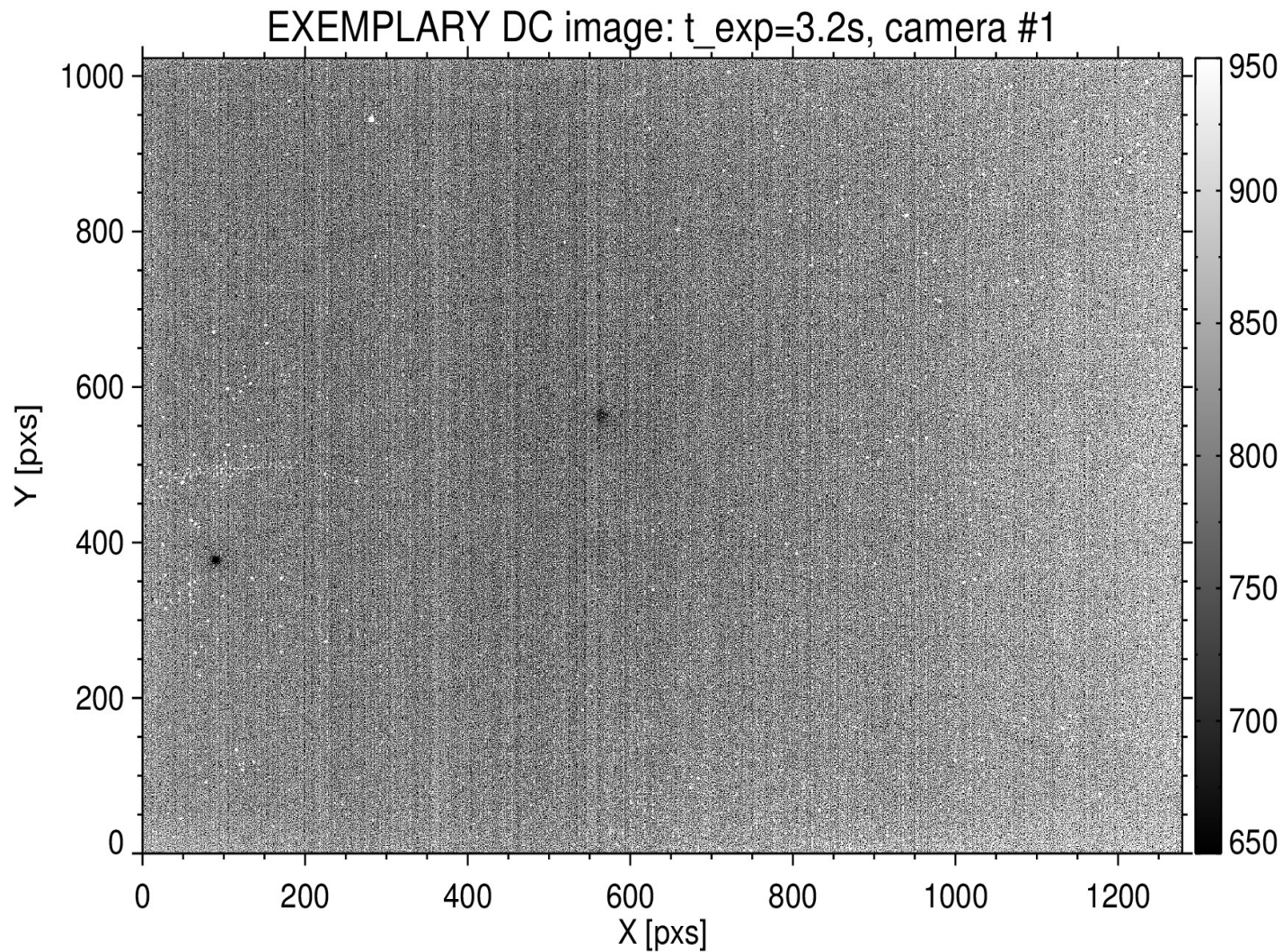
Single DC image example

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored

	Adding mode 100 t_exp = 3.2 s	Adding mode 10 t_exp = 320 ms	Adding mode 1 t_exp = 32 ms
Average DC value [counts]	#1 813.616 #2 515.162	#1 813.781 #2 515.082	#1 815.161 #2 514.978
Normalized standard deviation	#1 0.157193 #2 0.168209	#1 0.157283 #2 0.168896	#1 0.158321 #2 0.170208
Outlying pixels [%]	#1 0.748 #2 0.450	#1 0.746 #2 0.452	#1 0.733 #2 0.454

Single DC image example

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored



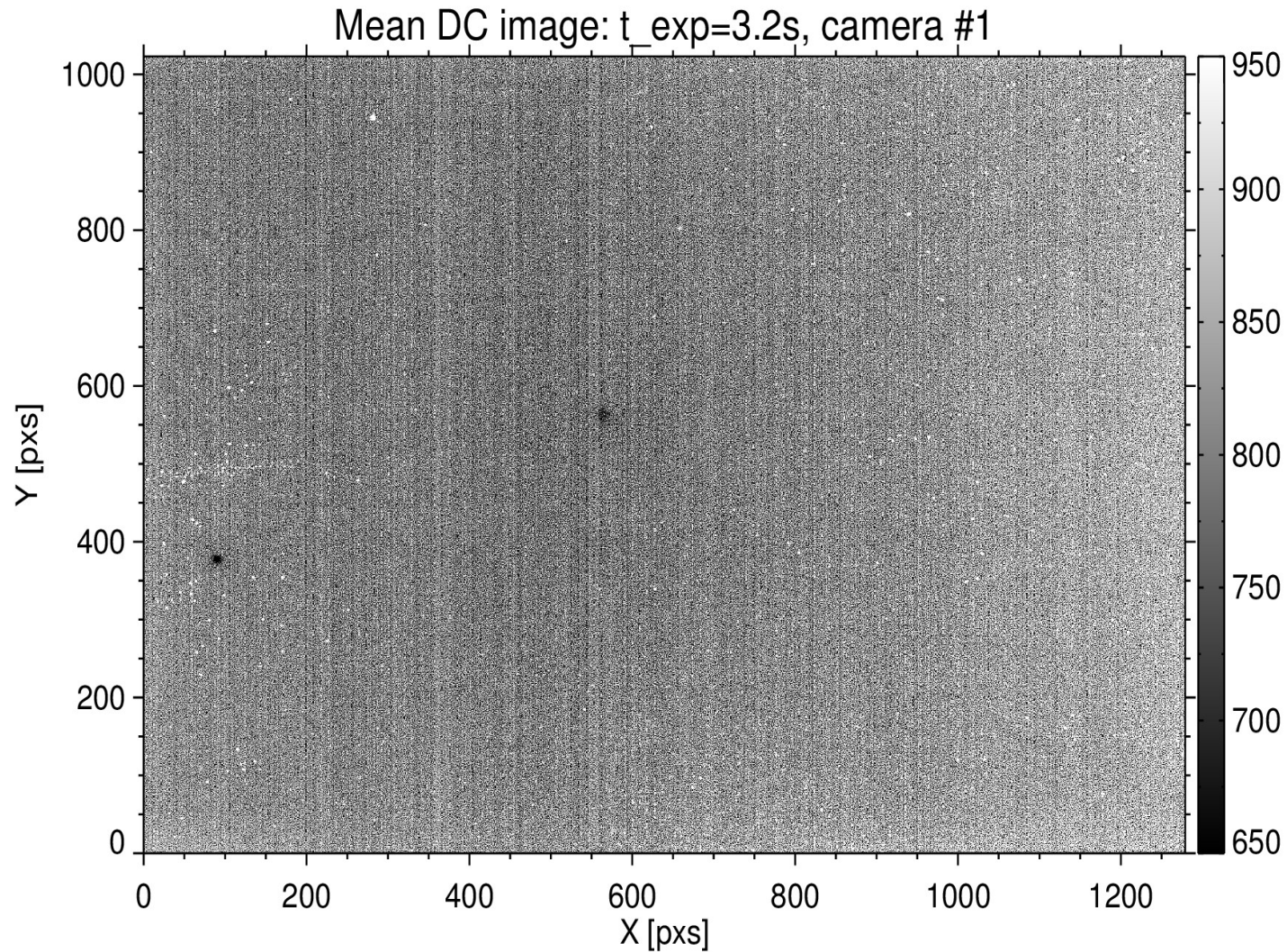
Mean DC image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
 - Mean of 100 individual images

	Adding mode 100 $t_{\text{exp}} = 3.2 \text{ s}$	Adding mode 10 $t_{\text{exp}} = 320 \text{ ms}$	Adding mode 1 $t_{\text{exp}} = 32 \text{ ms}$
Average DC value [counts]	#1 813.805 #2 514.740	#1 813.781 #2 514.413	#1 813.686 #2 514.192
Normalized standard deviation	#1 0.157094 #2 0.167920	#1 0.157162 #2 0.168504	#1 0.157141 #2 0.168415
Outlying pixels [%]	#1 0.749 #2 0.449	#1 0.748 #2 0.447	#1 0.749 #2 0.447

Mean DC image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
 - Mean of 100 individual images



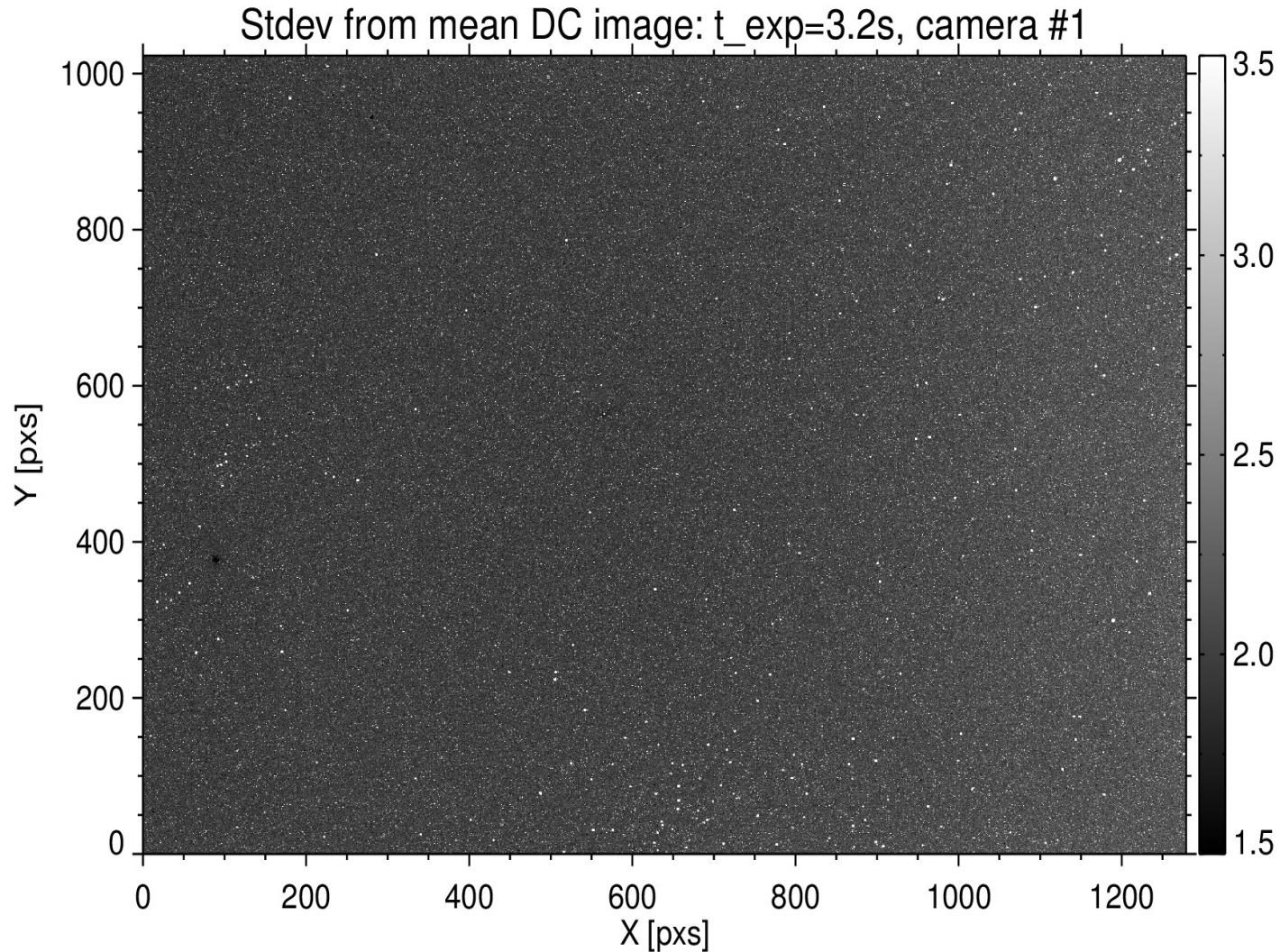
Stdev from mean DC image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
- Stdev from mean of 100 individual images on the pixel to pixel basis

	Adding mode 100 t_exp = 3.2 s	Adding mode 10 t_exp = 320 ms	Adding mode 1 t_exp = 32 ms
Average value [counts]	#1 2.08436 #2 1.37826	#1 5.67698 #2 4.30891	#1 17.6118 #2 14.3564
Normalized standard deviation	#1 0.509758 #2 0.392068	#1 0.152143 #2 0.219148	#1 0.0655122 #2 0.2364440
Outlying pixels [%]	#1 0.244 #2 0.399	#1 0.245 #2 0.634	#1 0.772 #2 0.784

Stdev from mean DC image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
- Stdev from mean of 100 individual images on the pixel to pixel basis



DC results summary

- Referring to: exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored

- Mean DARK CURRENT repetition quality estimated by

mean STRDEV / mean average LEVEL of the DARK images – pixel by pixel

cam #1 : $2.08 / 813.81 \Rightarrow 0.0026$

cam #2 : $1.37 / 514.74 \Rightarrow 0.0027$

< 0.30 % of the typical DC level

< 0.06 % of the full dynamic range

all at +30 degrees and 30 Hz frame cadence !

FF results format

- exposure time: 32 ms
- 3 adding modes on chip: 1, 10, or 100 acquired frames in a resulting image stored (i.e. total exposure times 32 ms, 320 ms, 3.2 s)
- series of 100 resulting images stored for each adding mode
- chip temperature: +30°C, processor temperature: +50°C
- illumination by a stable, very dim, but not ideally uniform, solar spectrum scattered light
- DC subtraction: none
- FF normalization: none

- FF images ->
 - mean of an image + standard deviation of an image
 - mean of a series of 100 images + standard deviation of a series of 100 images from the mean pixel by pixel
- correction of the adding mode exposure time to be able to compare results

- numerical results for both cameras and images for Camera #1 only

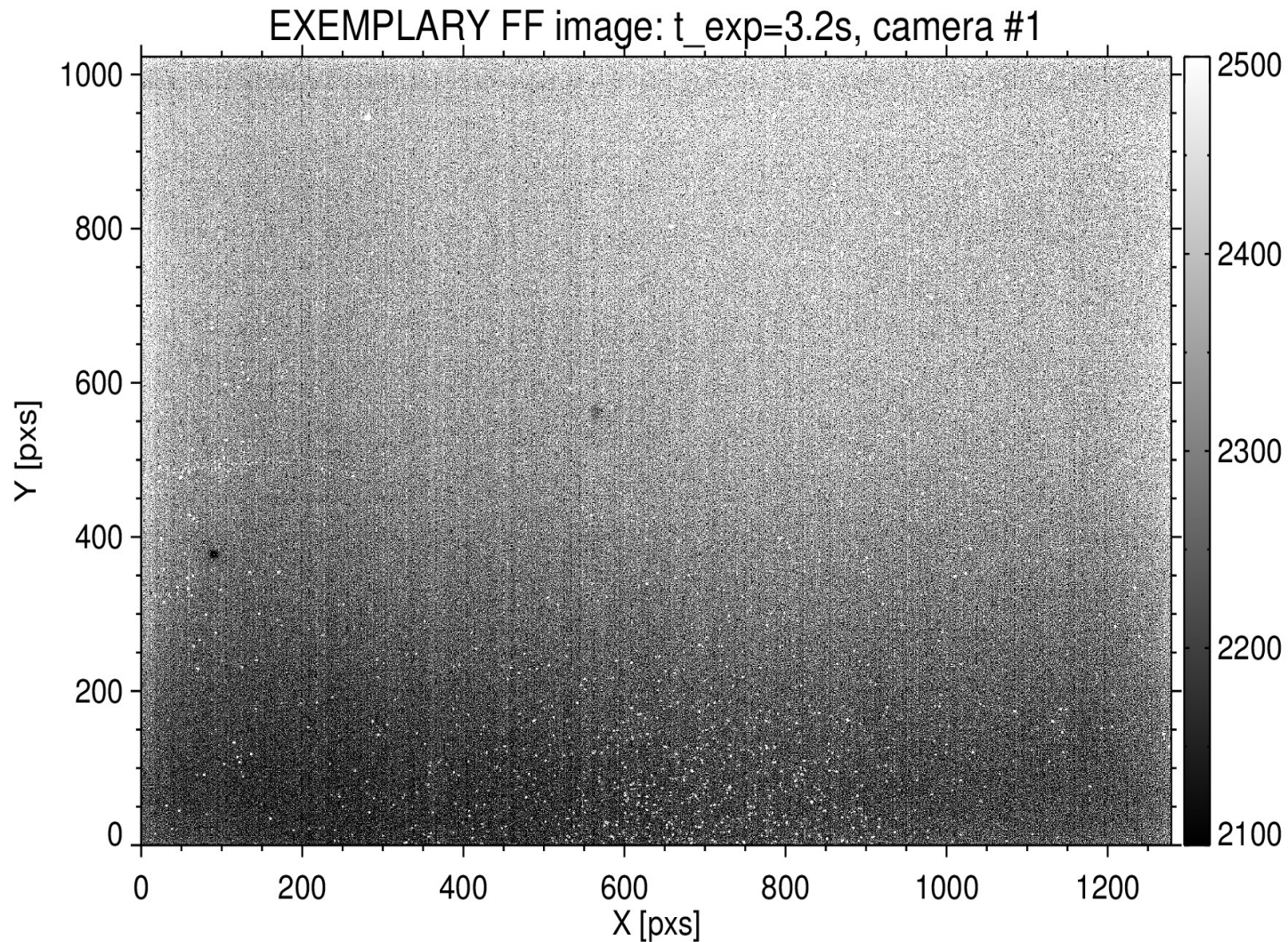
Single FF image example

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored

	Adding mode 100 t_exp = 3.2 s	Adding mode 10 t_exp = 320 ms	Adding mode 1 t_exp = 32 ms
Average DC value [counts]	#1 2331.76 #2 2731.92	#1 2801.11 #2 2694.38	#1 2668.94 #2
Normalized standard deviation	#1 0.0807491 #2 0.0524745	#1 0.0766638 #2 0.0528788	#1 0.0563370 #2
Outlying pixels [%]	#1 0.507 #2 0.545	#1 0.419 #2 0.545	#1 0.476 #2

Single FF image example

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored



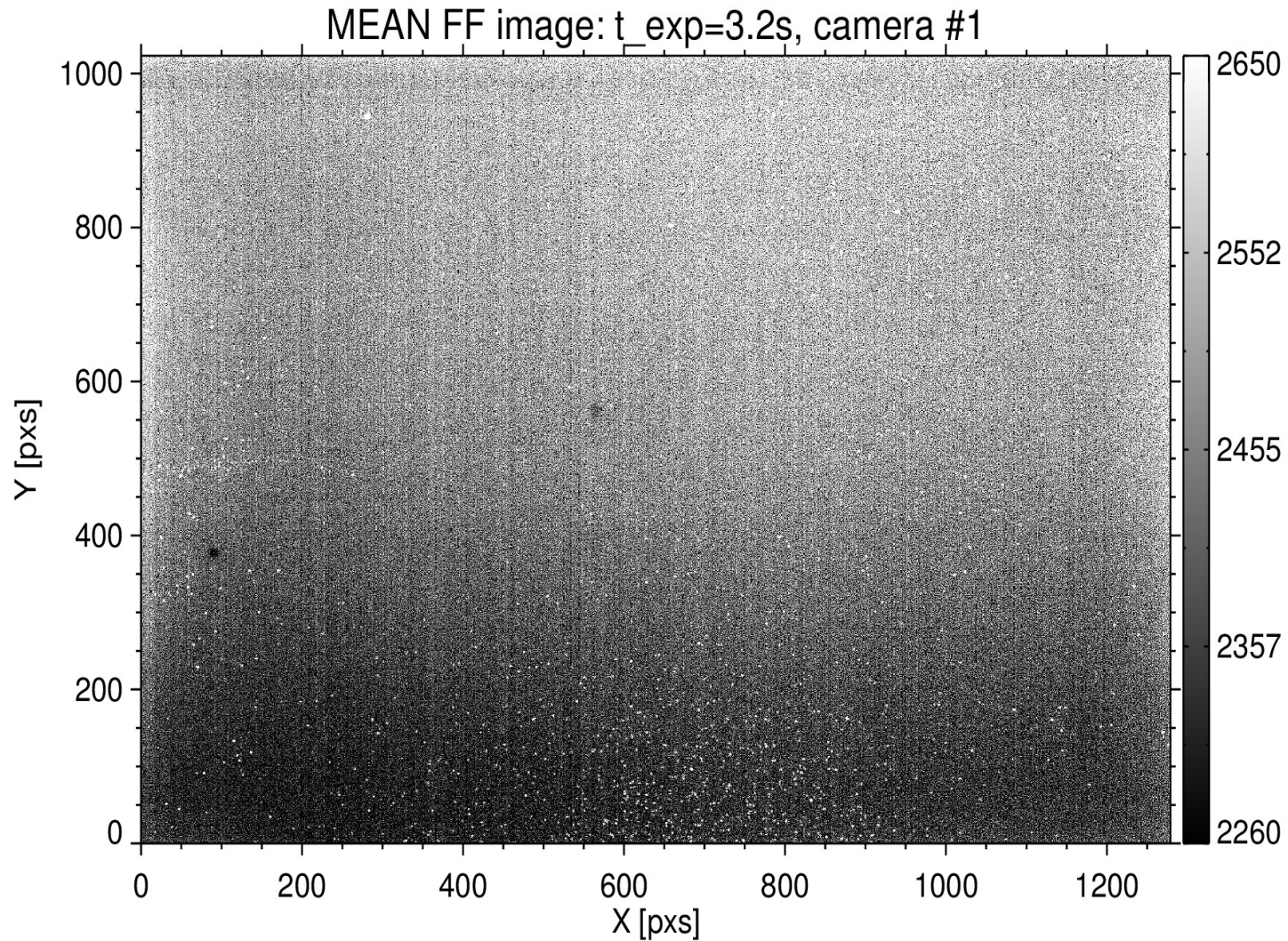
Mean FF image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
 - Mean of 100 individual images

	Adding mode 100 t_exp = 3.2 s	Adding mode 10 t_exp = 320 ms	Adding mode 1 t_exp = 32 ms
Average FF value [counts]	#1 2459.05 #2 2827.19	#1 2691.53 #2 2752.06	#1 2819.10 #2
Normalized standard deviation	#1 0.079 #2 0.063	#1 0.077 #2 0.052	#1 0.054 #2
Outlying pixels [%]	#1 0.484 #2 0.601	#1 0.439 #2 0.546	#1 0.472 #2

Mean FF image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
 - Mean of 100 individual images



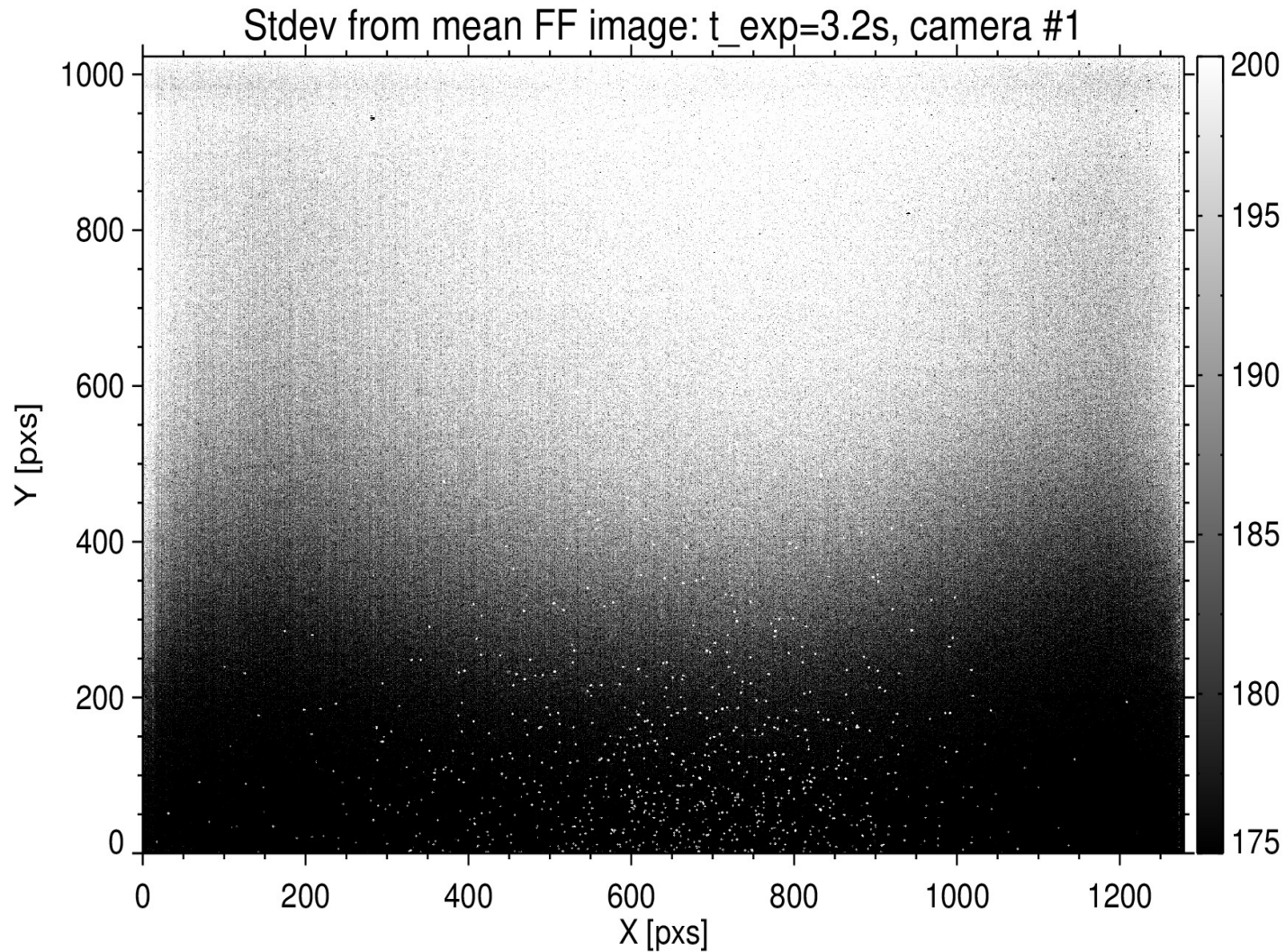
Stdev from mean FF image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
 - Mean of 100 individual images

	Adding mode 100 t_exp = 3.2 s	Adding mode 10 t_exp = 320 ms	Adding mode 1 t_exp = 32 ms
Average value [counts]	#1 188.356 #2 504.754	#1 33.5409 #2 47.4246	#1 235.529 #2
Normalized standard deviation	#1 0.076 #2 0.048	#1 0.084 #2 0.068	#1 0.057 #2
Outlying pixels [%]	#1 0.050 #2 0.229	#1 0.093 #2 0.191	#1 0.313 #2

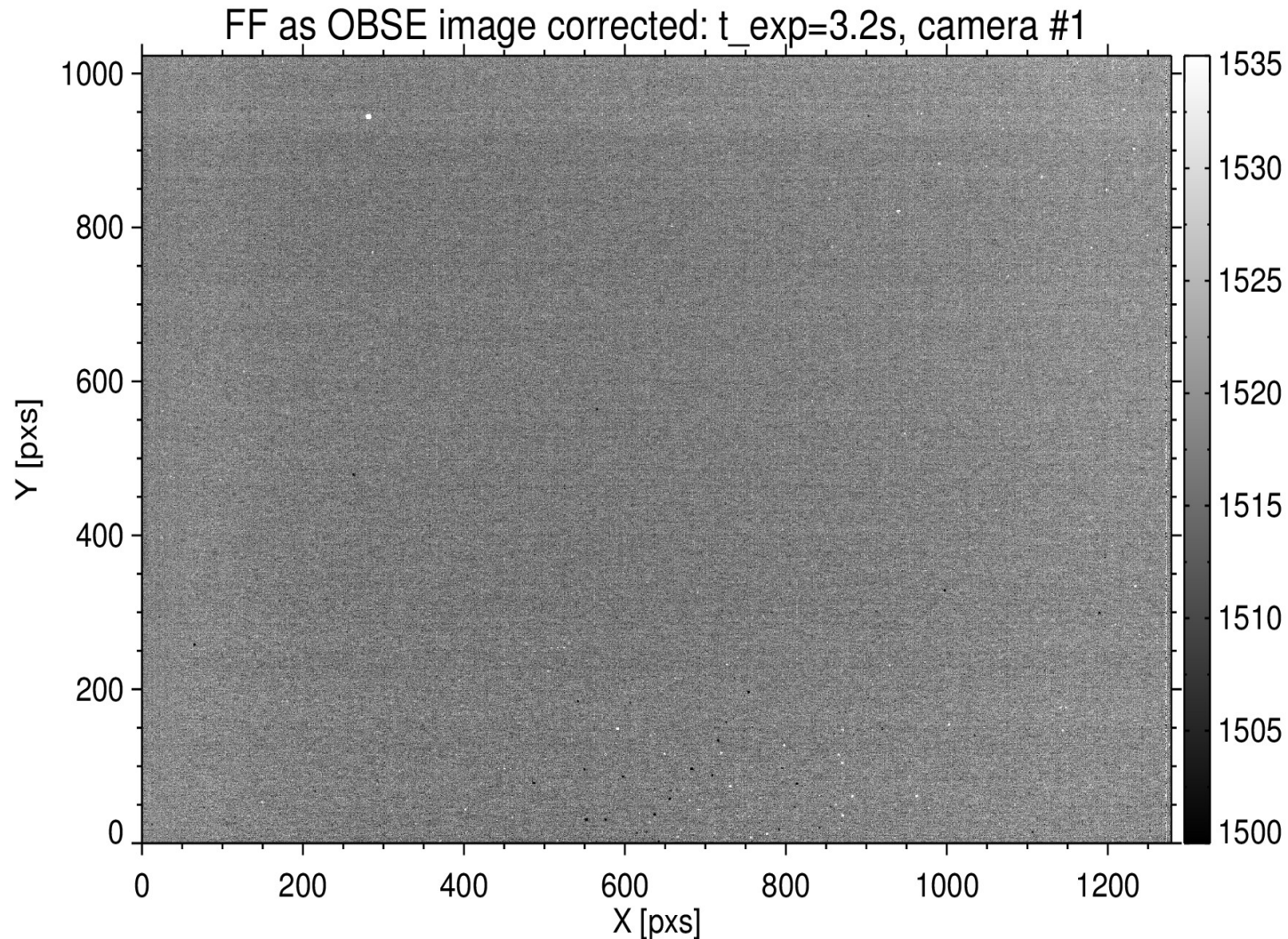
Stdev from mean FF image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
 - Mean of 100 individual images



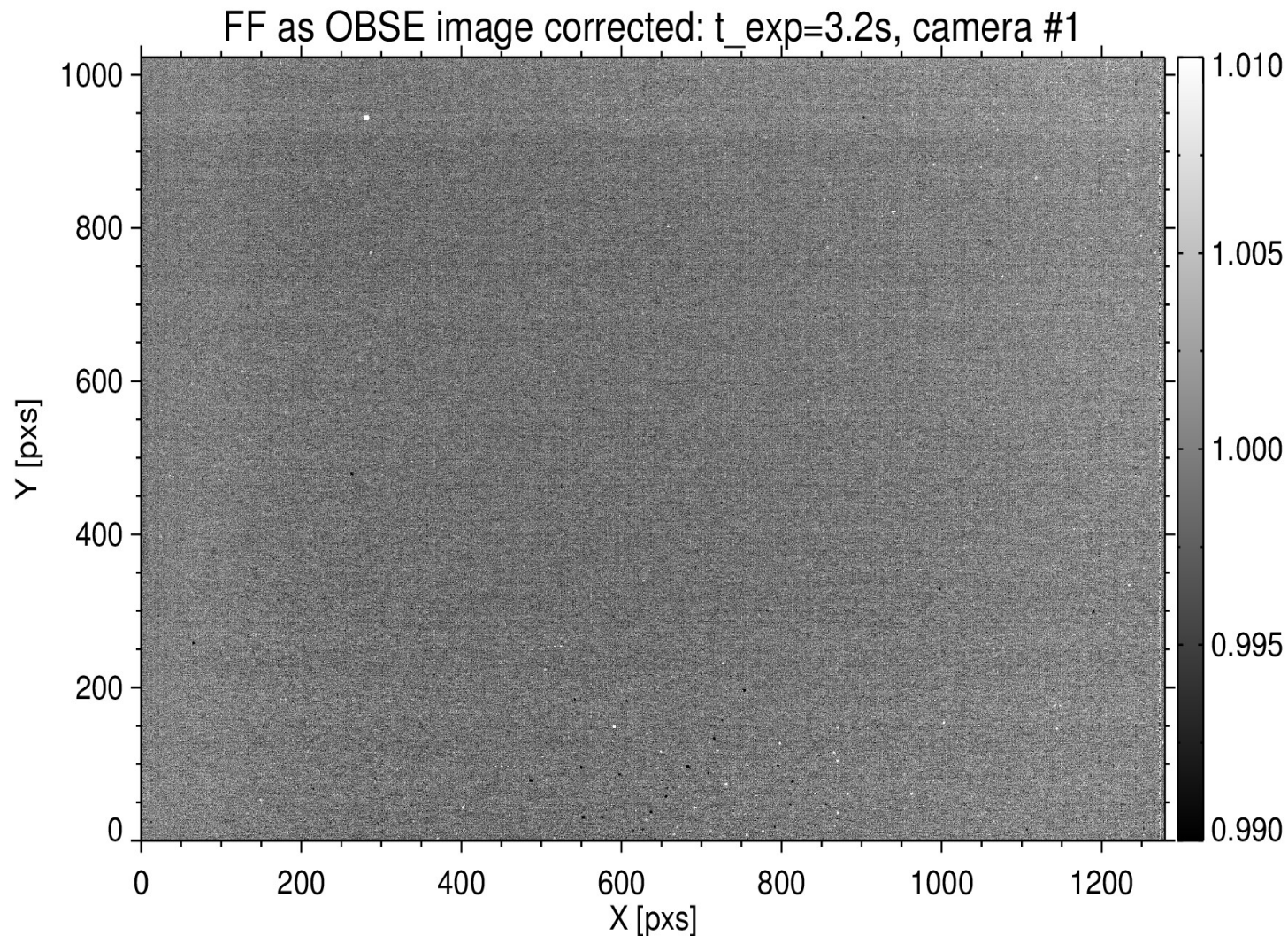
FF image as an OBSE image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
 - Exemplary FF image corrected for mean DC and mean FF images



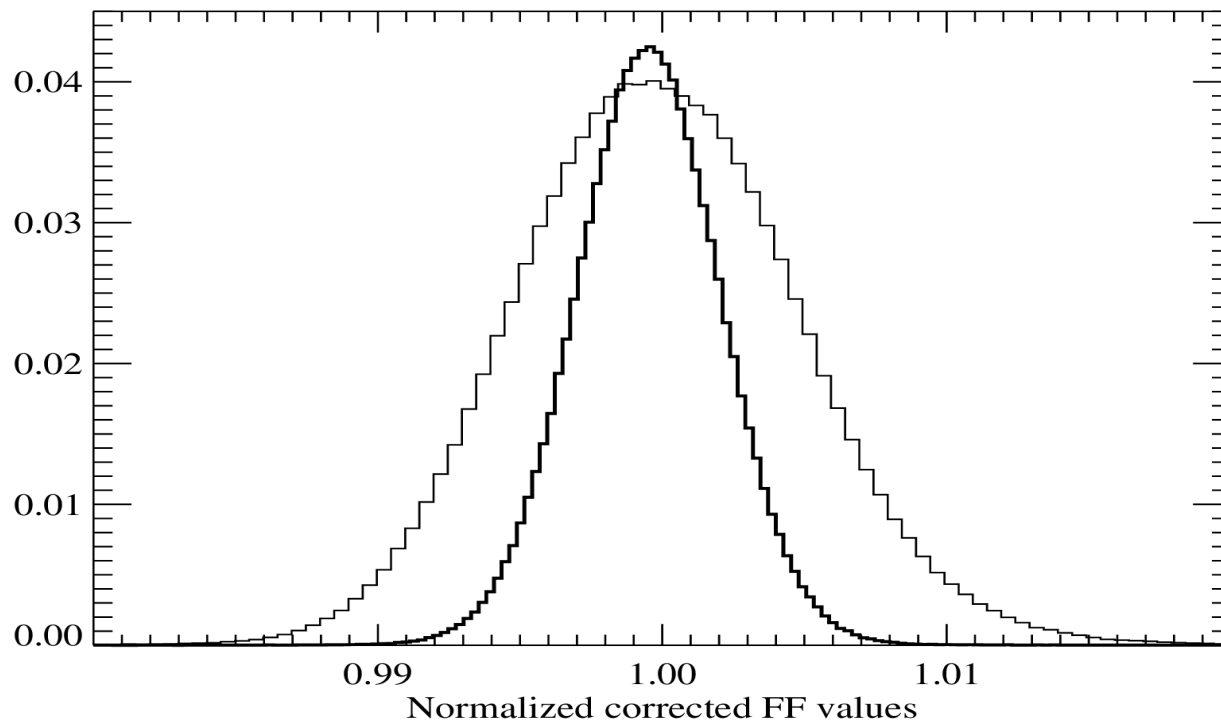
FF image as an OBSE image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
 - Exemplary FF image corrected for mean DC and mean FF images



FF image as an OBSE image

- Exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
 - Exemplary FF image corrected for mean DC and mean FF images
 - Cam #1: Average value = 1518.46 counts, Stdev = 3.962 counts
 - Cam #2: Average value = 2217.10 counts, Stdev = 11.0631 counts
 - Cam #1: Normalized values = 1.000 ± 0.0026 (1σ)
 - Cam #2: Normalized values = 1.000 ± 0.0050 (1σ)



FF results summary

- Referring to: exposure time: 3.2 s, i.e. adding mode 1: 100 frames in an image stored
- Mean FLAT FIELD and DARK CURRENT repetition quality estimated by mean STRDEV / mean average LEVEL of the OBSE image – pixel by pixel
- Cam #1 : 0.0026 (1σ) and 0.495% of outlayers (~ 6500 pxs $> 3\sigma$)
- Cam #2 : 0.0050 (1σ) and 0.558% of outlayers (~ 7500 pxs $> 3\sigma$)

i.e. 0.26% and 0.50 % of the typical signal level ($\sim 1/2$ of the full range)

all at +30 degrees and 30 Hz frame cadence !

Conclusions

- For the exposure time 3.2 s, i.e. adding of 100 32ms frames in an image stored: 0.26 and 0.50 % of the typical signal level
- Is 5×10^{-3} a lot ?
- Is it enough for linear/circular polarization signal we expect ?
- CoMP-S+PDSS@LSO: image scale $\sim 1,0''$ /px, theor. spatial resolution 1.4''
- Work should continue: real low-light level conditions, almost monochromatic illumination, sky background, sharp gradients
- New versions of the camera available!
- WAMIS proposal to NASA